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**NON-GOLD BASE DENTAL CASTING ALLOYS:
VOLUME II**

Porcelain-Fused-To-Metal Alloys

W. Patrick Naylor, Major, USAF, DC

August 1986

Final Report for Period October 1984 - October 1985

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**USAF SCHOOL OF AEROSPACE MEDICINE
Aerospace Medical Division (AFSC)
Brooks Air Force Base, TX 78235-5301**



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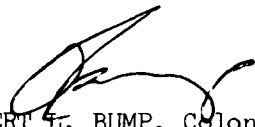
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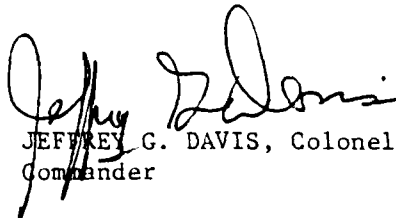
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<p>This test and evaluation program classified and examined several representative examples of non-gold base, porcelain-fused-to-metal alloys. The systems, or groups, included the following precious and non-precious alloys: high palladium-copper, high palladium-cobalt, palladium-silver, nickel-chromium-beryllium, nickel-chromium beryllium-free, and cobalt-chromium.</p> <p>General information on terminology, dental porcelain, porcelain-fused-to-metal alloys, investing, spruing, casting biocompatibility, laboratory safety, and cost comparisons was also included. In addition, detailed processing instructions for the representative alloys have been provided.</p>			
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P R E F A C E

Alternatives to Type III Gold, Volume I of the set on NON-GOLD BASE DENTAL CASTING ALLOYS, was written to introduce the terminology and technology of non-gold base dental casting alloy systems. Volume II, Porcelain-Fused-to-Metal Alloys, deals with those alloy systems possessing a capability to bond to dental porcelain.

Although the two volumes are independent of each other, the reader of one volume will profit from reading the other. For example, the reader of Volume II will benefit from reviewing the contents of Volume I; for some subject matter, common to the crown and bridge and the porcelain-fused-to-metal (PFM) alloys, is addressed in both texts. In most cases, those sections appearing in Volume II have been expanded to highlight the porcelain-bonding capability of these alloys. Whatever duplication is present has been necessary to permit each Report to serve as an independent text. This approach circumvents any requirement to read both volumes, if the reader is interested in only one particular subject.

Although Volume II includes illustrations, photographs, and references, the breadth of the subjects presented made impossible the mention of every important, or classical, article or text. This monograph is but a condensation of many complex subjects. Therefore, the reader is urged to become familiar with the literature that is referenced.

The casting alloys included in the study were evaluated for their handling characteristics and behavior in the production of single unit crowns. This pilot project was designed to provide familiarization with the processing of many of the non-gold base alternative alloys on the market today. Any recommendations and conclusions represent the author's personal opinions. The reader is advised not to regard this publication as an official endorsement, of any specific alloys or alloy systems, by the Dental Investigation Service, the United States Air Force Dental Corps, or the Department of Defense. This Report is provided solely for general knowledge.

Comments or suggestions regarding this publication, or future releases, should be submitted to the: Dental Investigation Service, USAF School of Aerospace Medicine, Aerospace Medical Division, AFSC, Brooks Air Force Base, Texas 78235-5301.

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SECTION 1:

INTRODUCTION TO PORCELAIN-FUSED-TO-METAL TECHNOLOGY

1-1. GENERAL INFORMATION

The processing of crown and bridge alloys, such as those described in Volume I,¹ is limited to waxing, investing, casting, and polishing. However, the handling of alloys used for bonding to dental porcelain is more complex. From the design of the metal substructure to the glazing and final polishing, one must not only be acquainted with new terminology and techniques, but also appreciate the multitude of skills associated with the manipulation of dental porcelain. This publication is a programmed text in introductory porcelain-fused-to-metal (PFM) technology, designed to familiarize the reader with an array of subjects from general information to specific processing instructions for numerous casting alloys.

The material provides current information on many of the newer, non-gold base alloy systems. The technology employed to process high-gold content porcelain alloys is often different from that used for many of these "alternative" alloys. Therefore, some adjustments in laboratory technique are recommended and the rationale for these changes is presented. In light of the advances in dental technology, increasing demands are being placed upon both the dental officer and the dental laboratory technician to keep abreast of these changes.

The dental marketplace abounds with new alloys, dental porcelains, casting investments, and related equipment and supplies. Making sense of all the marketing and sales information is an almost insurmountable task. The dental literature, while helpful, does not always provide specific guidance, nor answer many of our questions. Volume II, therefore, is a compilation of information obtained from laboratory handling and actual clinical application of representative alloys from the various non-gold base alternative alloy systems. This publication incorporates additional findings obtained from the literature and from personal communication with the manufacturers and suppliers of the materials tested. Various subjects are included in support of the main theme of porcelain-fused-to-metal alloys, but all these areas are intimately linked to the design and production of the PFM restoration.

The reader is cautioned that some of the positions taken by the author represent his own opinions, which may differ from previous teachings. In such instances, it is hoped that the references, or explanations, provided are adequate to justify alternative views. Unfortunately, many of our best reference texts simply can not be revised quickly enough to incorporate all the developments associated with the non-gold base alternative alloy systems.

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As another example, even the language of dental technology has been affected. In addition to adding new words to our vocabulary, the meanings of some existing terms have been revised. Many older expressions have been discouraged or eliminated. A more comprehensive listing of dental terminology is included as a separate appendix at the end of this report (Appendix D). Yet, some key terms must be introduced now to ensure clear communication from the very beginning.

1-2. TERMINOLOGY

Alloy descriptions and the terms used to distinguish between the various alloy systems require the use of a specific technical vocabulary. The following partial list of defined terms is presented to explain the specific application of each term in the context of this publication. As may be the case throughout this report, instances will arise when differences in interpretation exist, when compared with other publications. However, an attempt has been made to point out such distinctions as they arise. The selected interpretation will then be used as consistently as is possible throughout Volume II. The reader is advised to weigh the merits of both explanations, and make a personal interpretation.

NOBLE (or the noun, nobility) - a term applied to metals which are corrosion- and oxidation-resistant because of their inherent chemical inertness. There are at least 7 metals which fulfill this description: gold; and the six members of the platinum-palladium group--ruthenium (Ru), rhodium (Rh), palladium (Pd), osmium (Os), iridium (Ir), and platinum (Pt).² Some authors include silver (Ag) as a noble metal despite its tendency to oxidize in certain environments.³ Apparently, there are variations of nobility, leaving the term somewhat difficult to define exactly.

NON-NOBLE - obviously, if noble metals will not oxidize, then non-noble metals will be expected to form oxides or sulfides. Silver is frequently listed as a non-noble metal because of its tendency to sulfidize (form a sulfide tarnish).

PRECIOUS - the term applied to metals which, by virtue of their scarcity, possess a high intrinsic commercial value based on supply and demand. Several examples most likely to be found in dental casting alloys include: gold, silver, the six members of the platinum-palladium group, plus beryllium, gallium, and indium.

SEMI-PRECIOUS - while one of the most frequently used terms, it is also one of the most inaccurate. The implication of the word "semi-" is that one-half the alloy is precious, while the other half is, presumably, non-precious. No alloys meet this particular definition, thus making the description valueless. Therefore, use of this term should be discouraged.

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NON-PRECIOUS - refers to those metals (or alloys) which are not scarce, and do not possess a high intrinsic value, such as nickel and chromium. The designation "non-precious" is regarded by many as less technically correct than the preferred term, "base metal." Despite this fact, non-precious is engrained in our technical vocabulary and enjoys widespread use the world over. In fact, "non-precious" is the term chosen for use in this text, to avoid any potential misinterpretations.

BASE METAL(S) - the more technically correct designation for non-precious metals. However, it has not gained sufficient popularity or use to warrant substitution in this publication. When used in the literature, base metal should be interpreted as a term synonymous with non-precious.

1-3. DENTAL ALLOY NOMENCLATURE

Some additional terminology also must be introduced at this time to ensure that no misunderstandings arise in their application within this text. These words may be employed frequently in the descriptions of the properties, behavior, or use of the many metals and alloys which will be discussed. There may be differing interpretations of these words in other reference material, so it is vital that their intended meaning be clear here.

(PORCELAIN) BONDING - is the term used to explain the mechanisms by which dental porcelain "attaches" to a metal substructure. (This subject is addressed separately in Section 5.)

CERAMO-METAL RESTORATION - one of several designations in use today to describe the porcelain-fused-to-metal restoration.

COPING - is the term that will be used to identify the metal substructure of single unit crowns designed for bonding to dental porcelain. The word "framework" will be applied to the substructure of a fixed partial denture.

DEGAS - this term is used to describe the process of heat-treating a cast metal substructure in a porcelain furnace as one of the preparatory steps for the application of an opaque porcelain. It has been generally believed that, by subjecting the prepared metal to elevated temperatures (1900 °F) in a reduced atmosphere (vacuum), organic surface impurities are burned off, and any entrapped gaseous contaminants are eliminated.³ A newer, and perhaps more appropriate term, "oxidizing," has emerged in the literature; and this latter designation will be used throughout the text. (See the term "OXIDATION".)

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EXTRANEOUS OXIDATION - this is a designation suggested by the author to describe oxidation on non-porcelain bearing areas; i.e., an oxide layer on a surface not directly involved in porcelain bonding.⁴ The extent of "extraneous oxidation" on lingual collars, interproximal struts, and facial collars may be minimized by polishing these metal surfaces with a rubber wheel prior to the oxidation step. These oxides then, if not removed, may accumulate during successive firing cycles and impede final polishing for some alloy systems.

METAL-CERAMIC RESTORATION - is one of many designations in common use today to describe the porcelain-fused-to-metal restoration.³

OXIDATION (or OXIDIZING) - is the process in which a metal substructure is heated in a porcelain furnace to cleanse the porcelain-bearing surfaces of contaminants and produce an oxide layer for porcelain bonding. The oxidizable elements in an alloy generate a layer of oxides on the surface of the alloy. These oxides are then available to bond chemically with the dental porcelain.

PASSIVITY - a metal may be considered "passive" if, through oxidation or other chemical reaction, it produces a protective coating on its surface. This coating then protects the metal from any further corrosion, unless the coating is broken by abrasive action during chewing or cleaning.

PFM CROWN - the literal meaning of this designation is "porcelain-fused-to-metal" crown. This term is preferred over other descriptions; for it applies to all types of metal substructures, both cast and non-cast, and accurately describes the veneering material as (dental) porcelain. The term "metal-ceramic" may promote the misconception that the veneer is, in fact, some form of ceramic material, which it is not. Within this single heading there will be a differentiation between a FULL PORCELAIN VENEER CROWN (porcelain that envelops the facial, occlusal, and lingual aspects), as opposed to a PARTIAL PORCELAIN VENEER CROWN (metal occlusal or lingual with facial porcelain).

PROCESSING - is used to describe the collective steps and procedures involved in the fabrication of a porcelain-fused-to-metal restoration, from wax-up to final polish. While most frequently used in removable prosthodontics, the term has gained increased popularity in the field of fixed prosthodontics.

--SECTION 1--

1-4. EVALUATION OF DENTAL MATERIALS AND DEVICES

In 1966, the American Dental Association (A.D.A.) established the Council on Dental Materials, Instruments and Equipment (CDMIE) to oversee two dental product standardization and evaluation programs: the Certification Program, and the Acceptance Program. The Council's primary function is to assist the dentist in selecting safe and effective dental materials as a service to all patients. The commercial products are evaluated upon the request of the manufacturer, or the distributor, or on the initiative of the Council itself. Products for which physical standards or specifications exist may be evaluated under the Certification Program. In those instances where no such standards or specifications have been established, the materials may be submitted for the Acceptance Program. Once the safety and efficacy of a particular material has been demonstrated, and/or it has been shown to comply with an established specification, the Council will award the appropriate classification. The findings of the Council are published in Accepted Dental Therapeutics and the Journal of the American Dental Association.⁵

a. The A.D.A. Certification Program

In order for a product to be considered for the Certification Program, there must be a specification for that particular product. Presently, there are 38 specifications, with an additional 23 new specifications under development.⁶ In this program the manufacturer, or distributor, certifies that a product is safe, effective, and complies with all the specifications approved by the A.D.A. In addition, all product labels and advertising must conform to the American Dental Association Advertising and Exhibiting Standards. The product is then tested by the Council's Division of Evaluation and Standards Development at American Dental Association Headquarters (211 East Chicago Avenue, Chicago, Illinois 60611). A material is judged to be either certified or uncertified. Products found to be in compliance with the specification are then placed on the "List of Certified Dental Materials, Instruments and Equipment" in the Journal of the American Dental Association. Once awarded certification, the manufacturer may display the A.D.A. Seal of Certification in promotional material and on product labels. Should there be a change in either the manufacturer or distributor of an ADA-certified product, the certification expires automatically.⁵ The new manufacturer or distributor must then resubmit the product for reevaluation.

There is also now a provisional certification designation for products which are safe and effective, but do not meet some feature of a particular specification.

b. The A.D.A. Acceptance Program

Not all dental products have a physical standard, or ADA specification, as is the case with porcelain-fused-to-metal alloys, whether they may be gold-base or non-gold base. In fact, approximately 30 generic areas of products

--SECTION 1--

are evaluated under the A.D.A. Acceptance Program. As with the Certification Program, the manufacturer or distributor may submit a product to the Council on Dental Materials, Instruments and Equipment. The company seeking acceptance must also provide evidence of the safety and usefulness of the particular product, established through biological, laboratory, or clinical evaluation. The manufacturer must conduct the testing and submit the results along with the product.

Unlike the Certification Program, the A.D.A. does not test the materials, but submits the results provided by the manufacturer to a special board of consultants to the Council. It is the role of the board to review the data submitted by the manufacturer and to make recommendations to the Council. The Council then reviews the recommendations of the board of consultants and places the product in one of the three classifications in the Acceptance Program: Acceptable, Provisionally Acceptable, or Unacceptable.⁵

The Council also examines all promotional material and product labels to ensure strict adherence to the American Dental Association Advertising and Exhibiting Standards. As in the Certification Program, any change in either manufacturer or distributor results in the automatic expiration of the acceptance. The product must then be resubmitted and reevaluated.

c. Product Classifications

1. Acceptable

This is the highest attainable classification within the Acceptance Program, and entitles the manufacturer to display the Seal of Acceptance on product packaging and advertising. A complete list of such products appears in the Dentists' Desk Reference-Material, Instruments and Equipment,⁴ and is published regularly in the Journal of the American Dental Association. The award of the "Acceptable" classification is for a three-year period, but acceptance is renewable.

2. Provisionally Acceptable

This designation is used when there is reasonable evidence of safety and usefulness, but insufficient data to support the award of full acceptance. The designation, "Provisionally Acceptable," may be used on product labels and promotional material during the period of the award. These materials are listed after the "acceptable" products in the publications mentioned previously. Since these materials have only "provisional" acceptance, they are reviewed annually, and the classification is not continued for any more than three years.

3. Unacceptable

This designation is reserved for products which may be considered dangerous, obsolete, inferior, or useless. Such materials do not meet the provisions of the Acceptance Program.

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The A.D.A. Certification and Acceptance Programs are the two main programs used to assess dental products. Other avenues are available to manufacturers of products not covered by either of the above.

1-5. COST OF THE A.D.A. ACCEPTANCE PROGRAM

One reason so few alloys in today's market have been submitted to the A.D.A. for the Acceptance Program is probably financial. Estimates of the cost of underwriting the laboratory and clinical testing and supporting documentation range between \$15,000 and \$30,000. For some smaller manufacturers, there may be greater concern for competitive pricing than for the seal of A.D.A. Acceptance. This marketing strategy is merely a reflection of the apparent demands of the alloy consumers--the dental laboratories. Should interest in the Acceptance Program suddenly rise, then manufacturers and distributors might feel more inclined to participate in such programs.

The cost of financing submission of an alloy to such a program would be recuperated by an adjustment in the price of alloys. That cost increase would probably be small and more feasible for the precious alloys, which offer some latitude in profit margins. Most non-precious alloys are so inexpensive that manufacturers require high volume sales to realize a profit. Yet, for fear of loss of business, the manufacturers must meet their customers' demands for both precious and non-precious alloys. If A.D.A. Acceptance is made a requirement in alloy selection, we will find we have few alloys from which to choose. More importantly, those few alloys may not necessarily be the best products on the market.

1-6. USE OF THE A.D.A. ACCEPTANCE PROGRAM

Although the PFM alloys can not be considered under the Certification Program for lack of specifications, these alloys are eligible for participation in the Acceptance Program. We recommend that you consider the use of materials which are deemed "Acceptable," since the seal ensures some measure of product testing and A.D.A. scrutiny. In addition, such programs will remain viable only if manufacturers are assured of their merit and value.

Consumer support of the A.D.A. Certification and Acceptance Programs is strongly encouraged as a demonstration of the profession's concern for safety and interest in quality dental products.

1-7. THE DENTAL INVESTIGATION SERVICE (DIS) TESTING PROGRAM

Hundreds of alloys are available today for the fabrication of porcelain-fused-to-metal restoration, yet only 42 alloys are either A.D.A. "Acceptable" or "Provisionally Acceptable."⁷ This list of products includes both the gold-base and the non-gold base alternative alloys. Although updated periodically, the revised listing appears annually in the November issue of the Journal of the American Dental Association, and is an excellent reference.

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However, specific information on the processing, or clinical performance, of these 42 (or any other) alloys must be obtained either from the dental literature or directly from the manufacturer. In some instance, little, if any, data are available to assess the relative merits of certain alloys. As an example, reports on the behavior and performance of the high palladium alloys, introduced in the early 1980's, are only now appearing in dental journals. At the same time, even the more established systems continue to be scrutinized, and are reported.

In an effort to assess the wide range of alternative alloy systems, a preliminary testing program was undertaken at Tinker Air Force Base in August 1982. The areas of interest in this initial investigation were the non-precious systems: nickel-chromium-beryllium, nickel-chromium beryllium-free, and cobalt-chromium alloys. In the fall of 1983, under the auspices of the Dental Investigation Service and in collaboration with several alloy manufacturers and distributors (Appendix B), a more comprehensive pilot testing program was begun. Designed to examine the non-gold base systems, the project was intended to gather general information on these new, alternative alloys through actual, "hands-on" laboratory and clinical evaluation.

Therefore, this report is a compilation of information and data gathered during the course of this 3-year period. Including the work from the early testing, more than 30 alloys have been processed to produce nearly 800 castings and over 1000 units, by using 10 different casting investments.

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SECTION 2:

DENTAL PORCELAIN

2-1. INTRODUCTION

There are two main components in the porcelain-fused-to-metal restoration: namely, a metal substructure and a dental porcelain veneer. Together they form one of the most widely used restorative systems in dentistry today. Therefore, a report on the subject of porcelain alloys should be prefaced by an overview of dental porcelain itself. An appreciation of the science of dental porcelain provides a strong foundation for clear communication of information related to the properties and the limitations of this restorative material. Not all dental porcelains are alike; however, they do possess features which make them similar to one another, despite individual differences.

To better understand the requirements and demands of the porcelain-fused-to-metal restoration, it is important to begin with an introduction to the chemistry of dental porcelains.

2-2. THE CHEMICAL COMPOSITION OF DENTAL PORCELAIN

Basically, materials which are referred to as "dental porcelains" are crystalline minerals, such as feldspar, silica, and alumina (aluminum oxide) in a glass matrix.¹ Natural tooth color and opacification are obtained by the addition of metallic oxides to the porcelain powders. This description is actually an oversimplification of an otherwise very complex subject. Therefore, a little more information is necessary in order to understand just what is present in the porcelain powders, how they were made, and how and why they should be handled (processed) within specific guidelines.

For example, the glass phase just mentioned is a non-crystalline, or amorphous, solid produced by melting high fusing crystalline materials which, at their melting point, form a very viscous liquid.² With a glass matrix composed chiefly of feldspar, some contend this material is more correctly referred to as a "feldspathic glass," or "dental porcelain," rather than a "ceramic."^{3,4,5} To avoid any confusion, the term "dental porcelain" will be used instead of "ceramic," and the corresponding casting alloys will be identified as porcelain-fused-to-metal alloys instead of ceramic alloys. Definitions for these terms will vary, depending on the particular reference source; but an acceptable designation will be chosen and used uniformly.

The complete porcelain manufacturing process entails a series of rather complex pyrochemical reactions.³ The crystalline minerals (such as feldspar, silica, and alumina) which make up dental porcelain are mixed with alkali metal carbonate and borax, and then fired to high temperatures to form a vitreous (glasslike) phase.³ While the material is still molten, the mass is quickly quenched in water to actually preserve this glass phase.³ The results of this entire operation are unique non-crystalline solids, called "frits," which differ from other solids because their atomic structure and properties are based not

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only on their composition, but also on their thermal history.⁴ More importantly, the glasses can be manipulated, in both the molten and solid state, to alter such properties as viscosity, melting temperature, chemical durability, thermal expansion, and even resistance to devitrification (crystallization).⁴ Thus, the term "fritting" is used to describe the process of melting, blending, and then quenching these various glass components to achieve a desired end.⁴

Once the frits are produced, they are ground to the specific particle size(s), established by the manufacturer for that particular porcelain. Before the frits are bottled in the containers we receive, opacifying oxides and colored oxides are added to the powders to impart a multitude of optical qualities for very specific roles. Different designations are given to each group of powders, based on their functional role, or color contribution. Normally, they are classified as opaque, dentin (or body), and enamel (or incisal) porcelain powders with numerous color concentrates, such as opaque and dentin color modifiers and external colorants (or stains).⁶ These are the basic components of a dental porcelain system, but there are actually several different types of porcelain.

In fact, three dental porcelains are generally recognized, and each is classified according to its respective maturing or fusion temperature¹:

HIGH-FUSING	2350-2500° F (1288-1371° C)
MEDIUM-FUSING	2000-2300° F (1093-1260° C)
LOW-FUSING	1600-1950° F (871-1066° C)

Since these powders are principally glass, with very little free crystalline phase, McLean prefers to refer to them as "felspathic" porcelain, as opposed to dental porcelain enriched with alumina; i.e., aluminous porcelain.⁴

Each of these dental porcelains has its unique properties. The high- and medium-fusing porcelains are similar in composition and microstructure.⁶ Denture teeth are usually made from the high-fusing porcelains, while the medium-fusing porcelains are used to fabricate pontics (i.e., trupontic).⁶ The low-fusing dental porcelains are those which are fused to a metal substructure to produce the porcelain-fused-to-metal restoration.⁶ They differ from both the high- and medium-fusing porcelains in terms of composition and microstructure.⁶ Alumina is usually added, and little or no kaolin is found in modern low-fusing porcelains.⁷ Despite these obvious differences, they are all regarded as dental porcelains and contain various percentages of some, or all, of the following ingredients: quartz, feldspar, kaolin, and/or alumina.

a. Quartz

Quartz has a high fusion temperature, and acts as the framework around which the other ingredients can flow.⁷ Quartz helps prevent the porcelain on the metal substructure from slumping in the porcelain furnace when the material is in the liquid phase of the firing cycle.⁷ In addition, quartz serves as a strengthener to the porcelain.¹

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b. Feldspar

Feldspar is the main component of dental porcelains.⁷ It has been used for a number of years, because this material lends itself so well to the fritting and coloring processes.⁴ By simply varying the balance of oxides (glass modifiers), low or medium fusion dental porcelain can be created.⁴ More importantly, the ratio of feldspar to the other ingredients in the mixture separates dental porcelain from the industrial porcelains.⁷ Actually, there are two types of feldspar from which to choose: potash feldspar, and sodium feldspar.^{1,6} However, since natural feldspar is never pure, the ratio of potash to soda could vary.¹ The characteristics which each imparts to the porcelain are different and need to be controlled.

- 1). Potash Feldspar - This type of feldspar is found in the majority of dental porcelains, because of the translucent qualities it adds to the porcelain.⁷ When melted between 2280-2730° F (1250-1500° C), this feldspar fuses with kaolin and quartz to become a glass.⁶ However, the potash form of feldspar increases the viscosity of the molten glass,¹ thus helping to control the pyroplastic flow (slumping) of porcelain, during the firing process, to preserve the form of the restoration.
- 2). Sodium Feldspar - The sodium form of feldspar will actually lower the fusion temperature of the porcelain, thereby making it more susceptible to pyroplastic flow (slumping),¹ but does not contribute the optical quality of translucency seen with the potash form.⁷ By and large, sodium feldspar is a less attractive substitute for potash feldspar.

During processing, the feldspar fuses, decomposes, and produces a new substance, an alkali alumino-silicate, called **leucite**.⁷ As the firing cycle progresses the leucite is dissolved, if the rate of climb for the porcelain is that prescribed by the manufacturer.⁷ Changes in the firing cycle may prevent dissolution of the leucite, and thus prevent a weakened restoration and a decrease in translucency which reportedly can result.⁷ **Leucite** formation is an important process of which to be aware for another reason. When high expansion dental porcelains are overfired, they can undergo a phenomenon known as devitrification.⁴ This is a reversal of vitrification, or the formation of a liquid phase, and the return to a crystalline form by the porcelain.⁴ The devitrification process is more common to the high expansion dental porcelain, because alkali (such as soda (Na_2O) and potash (K_2O), is added to increase the expansion of the porcelain.⁴ Overfiring these porcelains, in the presence of alkali-like potash, can produce more **leucite** and lead to devitrification.⁴ Fired porcelain which has undergone this devitrification process will be structurally weaker, and more opaque (appear cloudy).⁴ However, fired dental porcelain powders always have a distinct amount of the crystal phase **leucite** present.⁸ These **leucite** crystals are important because they provide stability to the dental porcelain during fusion.⁸ Some contend that the devitrification (crystallizing) process is more of an academic issue than an occurrence likely to be observed in dental laboratories today

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c. Kaolin

This third major component is a clay, formed from igneous rock containing alumina.⁷ Its major role is that of a binder, added to increase the moldability of the unfired porcelain.⁷ This characteristic gives the porcelain mass, and enables it to be carved. However, since kaolin is also opaque, it is added in very small quantities--or not at all^{1,5}--thus precluding its incorporation into the enamel porcelains; for its presence would reduce the amount of incisal translucency.⁷

d. Alumina

Alumina is considered the hardest, and perhaps, the strongest oxide.⁴ Its coefficient of thermal expansion is quite similar to that of low-fusing porcelains, thus making the two materials structurally compatible.⁶ Alumina, which is only slightly soluble in low-fusing porcelain, improves overall strength.⁶ Alumina is also added to increase the viscosity of the melt, without opacifying the porcelain.⁴ McLean developed a fourth variety of dental porcelain by adding alumina, between 40 and 50% by weight, to low-fusing porcelain to form the core porcelain; and, by adding between 5 and 10% free alumina, to create the dentin porcelains.⁹ The resulting aluminous porcelain is used today in the fabrication of porcelain jacket crowns, but is not suitable for the fabrication of the porcelain-fused-to-metal restoration.¹⁰

2-3. THE VARIETIES OF LOW-FUSING PORCELAINS

Today, numerous manufacturers offer low-fusing dental porcelains which frequently differ in terms of particle-size distribution, handling characteristics, shrinkage, esthetic value, and cost. Generally, each kit contains a series of opaques, with corresponding dentin and enamel porcelains, as well as color modifiers for both the opaques and body porcelains. Corresponding surface stain kits are also available which are compatible with the body porcelains. Porcelain systems are generally available in shades matched to either the VITA or the BIOFORM shade guides. One porcelain is available to match the new IVOCLAR* shade guide, which differs entirely from both the VITA and BIOFORM shades. A new porcelain system has been introduced recently which does not rely on dentin porcelain color, because shade matching is reportedly initiated by the opaque, and finalized by the application of surface shading porcelains.**

The newest additions to the porcelain family have been the development of the opacous dentins (Vita porcelain***) and the shoulder porcelains (Vita***, Crystar****, and the Will-Ceram* porcelain systems--Fig. 2-1). However, none of these materials were examined as a part of this particular project.

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- * Will-Ceram Porcelain, Williams Gold Refining Co., Buffalo, NY.
 - ** Shademate Porcelain, Dentsply International, Inc, York, PA.
 - *** Vita Porcelain, Vita Zahnfabrik, Bad Sackingen, West Germany.
 - **** Crystar Porcelain, Vident, Baldwin Park, CA.



Figure 2-1. The porcelain-fused-to-metal crowns on the maxillary left central and lateral incisors were fabricated with porcelain labial margins by using Crystar Shoulder Porcelains (Unitek)* and Olympia metal (Jelenko).**

a. Opaque Porcelains

As their name alone would indicate, these porcelains are opaque in nature by virtue of the addition of insoluble oxides, such as titanium oxide (TiO_2), zirconium oxide (ZrO_2), tin oxide (SnO_2), cerium oxide (CeO_2), and zircon (ZrO_2-SiO_2). Other oxides include rubidium oxide, barium oxide, and/or zinc oxide.^{1,4,5,6,7,11,12,13} These oxides have high refractive indices, so they scatter light, rather than permit it to pass.¹¹ Generally, the oxides appear in opaque porcelains in amounts between 8 and 15%, and may be ground to a very fine particle size (less than $5\ \mu m$).^{4,13} Woosley et al. have suggested that small differences in particle size might dramatically affect the ability of opaque porcelains to mask the color of a metal substructure.¹⁴ Equally as important is the nature of the oxide layer produced by the metal substructure itself. The masking power of an opaque porcelain may be influenced both by the amount and the color of the oxide layer created by the oxidation (degassing) process.

When mixed with ceramic and glass stains, these porcelains can be colored to correspond with the basic body shade.¹¹ The high densities of the oxides require that they be finely ground to prevent physical separation from the base porcelain powders.¹¹ Other additives are introduced to simulate natural fluorescence in the opaque layer.¹¹ This opaque layer serves two main functions: first, it wets the metal surface and establishes a metal-porcelain bond; and second, it attempts to mask the dark color of the metal oxides.

The opaque powders are mixed either with a special liquid or distilled water, and generally are applied directly to the porcelain-bearing areas after the metal has been oxidized (degassed). For some alloys, the opaque may be applied directly to the oxide layer: with others, the metal should

* Unitek Corporation, Monrovia, CA.

** J. F. Jelenko & Co., Armonk, NY.

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first be air-abraded to remove the initial oxide film. With a few of the new high palladium alloys, no oxidation is performed; so the opaque porcelain may be applied directly to the finished casting immediately after air-abrading and cleaning. Regardless of the particular post-oxidation treatment, apply a thin layer of opaque liquid (or distilled water) to the porcelain-bearing area prior to the application of the opaque. The liquid will fill the tiny pores on the metal surface and wet the metal surface. As a result, no liquid is drawn from the wet opaque, a process which would dry out the mix and inhibit even coverage. The liquid will not only draw the opaque to the metal surface and promote more complete coverage, but will help to prevent opaque bubbling. The metal substrate, with dried opaque, is then vacuum-fired in a porcelain furnace, according to the porcelain manufacturer's instructions, to a predetermined maximum temperature (1725-1850 °F) at a specified rate of rise (90°F/min or greater). This high temperature setting is generally slightly above the maturing temperature of the body porcelains, to reduce the likelihood of opaque dispersion into the body layers.⁶

Many now recommend a two-stage opaquing process, rather than attempting to mask the metal with one thick layer. The first application of opaque is simply a thin layer to initiate the bond with the metal oxides and permit the diffusion of gases, or other possible contaminants.⁹ The second application of opaque should cover thin spots and mask any remaining gray areas.⁹

In general, opaque dental porcelains have two major weaknesses. First, they can not be glazed, so any exposed opaque should be covered with a body porcelain and refired. Second, they tend to be very bright (high value) and if insufficient body porcelain covers them, they will make the restoration stand out. The high value is responsible for what is often referred to as the "lemon drop," or "halo" effect in an anterior crown when the body porcelain is thinned at the incisal one-third. Proper two-plane tooth reduction can eliminate this problem, however.

The exact thickness of opaque to mask the metal and the oxides will not only vary between dental porcelain systems, but will vary for different shades of the same porcelain.^{14,15} Barghi and Lorenzana reported an opaque film thickness between 0.2 and 0.3 mm to be appropriate in one comparative study of Vita VMK 68* and Ceramco** porcelains.¹⁵ They also noted that the necessary thickness of opaque (0.3 mm) required body porcelain thicknesses between 0.5 and 1.0 mm to match the shade guide.¹⁵ Woosley et al. examined the opaques from five dental porcelains (Vita-VMK-68*, Ceramco "B"**, Biobond***, Neydium "B"****, and Will-Ceram*****), and noted substantial differences in masking power. Ceramco "B" had the highest relative masking power in four of the five shades tested, and was second highest for the fifth shade. Neydium "B" was second in three of the five tests, and third in the remaining two. Biobond was first in one test,

* Vita Zahnfabrik, Bad Sackingen, W. Germany.
** Ceramco, Inc., Johnson & Johnson, Inc., E. Windsor, N.J.
*** Dentsply International, Inc., York, PA.
**** J. M. Ney Company, Bloomfield, CT.
***** Williams Gold Refining Co., Buffalo, NY.

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second in another, and third for the remaining three shades. Vita VMK-68 was fourth for four shades and last for the fifth test. Will-Ceram had the lowest relative masking power in four of the five shades, and was fourth for the fifth shade. Statistically speaking, Ceramco "B" was significantly higher than the remaining opaques for only one shade (65). In the remaining four test shades, the differences were relative values and not great enough to be statistically significant.

Avila et al. subjected the opaques of the three dental porcelains (Vita-VMK-68, Ceramco, and Biobond) to varied opaque firing cycles.¹⁶ They reported that color changes did result with alterations to the recommended firing schedules. In fact, most color changes occurred when the opaques were fired less than 40° C below the recommended firing temperatures.¹⁶ In addition, no noticeable color changes could be detected by their ten observers when the opaque porcelains were overfired by 60° C.¹⁶ More importantly, this study substantiated the finding that opaque masking power varies among dental porcelains. The color of Biobond porcelain was less affected by firings at varied temperatures than either Ceramco or Vita-VMK-68. Avila et al. and Barghi used a high-gold content porcelain alloy (Jelenko "O"*) for the metal substructure.^{15,16}

In a recent report, Laceyfield et al. noted color changes in dental porcelain as a result of repeated firings using palladium-base alloys, rather than gold-base metals.¹⁷ In this study, 0.1 mm of opaque and 0.75 mm of body porcelain were placed on disks of a high-palladium-copper, a high-palladium-cobalt, a palladium-silver, and a gold-palladium alloy. Four specimens of each type were fired and glazed using conventional techniques. Each disk was cut in half, and one half was subjected to 5 additional firings at 1725 °F. The other half served as the control group and was not refired. Chromascan measurements were taken, along with visual examinations by 4 clinicians. Significant decreases in "value" were detected in those specimens subjected to repeated firings. In the visual inspection, the examiners were able to observe a significant color difference between the specimens for the high-palladium-copper and the high-palladium-cobalt alloys. Some of the minor alloying elements were found to have actually diffused into the porcelain as far as 50 µm, or more, as in the case of gallium. The authors concluded that the presence of high concentrations of certain metals in the porcelain may have accounted for the lowering of the shade value. The five additional firings may have been responsible for the diffusion of these metals.¹⁷ The dental porcelain used was not identified, nor were the results for the palladium-silver or gold-palladium specimens included. A point of interest in this study is the thickness of opaque used for each of the specimens (0.1 mm). A dimension of 0.1 mm is one-third to one-half the recommended thickness for the opaque layer; and this fact leads one to wonder if the results might have differed if 0.2 or 0.3 mm of opaque had been used?

In a related study, Jacovides et al. tested the masking power of several opaques on 3 palladium-base alloys (high-palladium-copper, high-palladium-cobalt, and palladium-silver) as well as on a gold-palladium alloy.¹⁸ Using

* J. F. Jelenko & Co., Armonk, NY.

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a 0.1-mm opaque layer and both the Chromascan and visual observation, Jacovides et al. noted that certain high-palladium alloys were more difficult to mask than others. Only the high-palladium-copper specimen with Ceramco II* was specifically named as manifesting a decrease in value, chroma, and a change in hue. In addition, no significant differences in color could be identified between alloy groups when Biobond** opaque porcelain was used. The authors also concluded that with certain high-palladium alloys (unnamed), a thicker opaque layer will be required with certain porcelains (not specified in this abstract).¹⁸ As emphasized previously, an opaque layer between 0.2 and 0.3 mm is generally recommended, especially for the high-palladium alloys.

Our general observation is that color changes may occur in dental porcelain as a function of the inherent oxidation behavior of the particular alloy system or group. Even under optimal conditions (an opaque thickness of 0.2 to 0.3 mm), undesirable color transformations may occur. For example, alloys in the high-palladium-copper group produce a gray-to-brown oxide which may be responsible for a lowering of the value, and a "graying" of the dental porcelain. The blue-gray oxide layer of the high-palladium-cobalt alloys may result in a "bluing" of the dental porcelain.

b. Body Porcelains

There are actually 3 traditional types of porcelain powders which are collectively referred to as "body porcelains:" **dentin** (or gingival) shades; **enamel** (or incisal) shades; and **modifiers**.⁶ They are all low-fusing porcelain powders, but are distinguished by the amount of oxide colorants in the case of dentin and modifiers, and the virtual absence of color in enamels.⁶ The designations, **dentin** and **enamel**, are preferred by the author because they better represent the intended roles of these particular porcelains. As an example, **dentin** porcelain may be placed in the incisal, or occlusal, one-third to support the incisal edge, or a cusp, and is not limited to placement in the gingival one-third of the tooth. At the same time, **enamel** porcelains can be applied from the incisal one-third, through the middle one-third, and be subtly blended into the **dentin** porcelain.

All three porcelains have the same chemical and physical properties, so they may be intermixed freely for custom shading.⁶ The **modifiers** are color intense, and the **dentin** porcelains are color predominant, while the **enamel** porcelains are color reduced. What makes all three the same material, yet with a different appearance, is the intensity--or lack thereof--of metallic oxide pigments.⁴

Listed next are several of the pigments which might be used to obtain some basic color effects:

* Ceramco, Inc., Johnson & Johnson, East Windsor, NJ.
** Dentsply International Inc., York, PA.

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- YELLOW - One of the predominant colors in most teeth is derived from either indium or praeosodymium (lemon), both of which are stable pigments. Vanadium-zirconium or tin oxide, diluted with chromium, are also used but are less stable.
- GREEN - Is developed from chromium oxide but, having the characteristic color of glass, is avoided in dental porcelain.
- PINK - Comes from either chromium-tin, or chrome-alumina, and helps eliminate the greenish hue in the glass, thereby creating a warm tone to the porcelain. Although these pigments are stable only to a temperature of 1350 °C, they are useful in low-fusing porcelain.
- WHITE - Is achieved through the use of opacifiers such as cerium oxide, titanium oxide, and zirconium oxide (zirconia), with zirconium oxide being the most popular.
- BLACK - Is produced by iron oxide.
- GRAY - Is derived from platinum gray, or by diluting iron oxide.
- BLUE - Is obtained from cobalt salts and used for enamel shading.

Body porcelain powders are normally color-coded with organic dyes so that the **dentin** powders are pink and **enamel** powders are blue. The body **modifiers** take on the particular color of the inherent pigments. Some brands of dental porcelain are not color-coded for identification, but liquid colorants (color tags*) are provided in both red and blue. These liquids are color intense; and the technician must color-code each mixture, since both the dentin and the enamel powders are white. Some technicians prefer to use various color tags to highlight modifiers and areas of custom shading and characterization during the build-up procedure.

Through custom color tags, mixtures of A-3 and A-3.5 on the same glass mixing slab, can be transformed into two distinct variations of pink. Without such differentiation, the two mixes of standard color-tagged porcelain would appear the same color. The technician would have to identify the various shades, either by location or marking the mixing pad. Once the porcelain mix is color identified, the technician establishes the proper consistency simply by adding distilled water or a special modelling liquid. The special liquids do not dry out as rapidly as distilled water, and are most helpful for the build-up of multiple single units or for fixed partial dentures. Tap water should NEVER be used with dental porcelain; for it is generally impure, and these impurities could contaminate the dental porcelain and adversely effect the fired restoration.

The properly mixed combination of body porcelain powder (and modifiers--if desired) and distilled water (or special liquid) is placed on all the

* Artis-Tech Porcelain, Rx Jeneric Gold Company, Wallingford, CT.

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porcelain-bearing areas of the metal substrate; dried; and then vacuum-fired to a predetermined temperature. Maximum temperatures range from 1724 °F to 1800 °F. The body porcelains actually will fuse over the opaque porcelain with a generally predictable amount of volumetric shrinkage, assuming proper condensation (water elimination) has been achieved. The required thickness of body porcelain, for acceptable color, will vary among porcelain systems, as well as between shades within the same system.¹⁵ Barghi and Lorenzana reported that thickness values may range from 0.5 to 1.0 mm, with a 0.3-mm thickness of opaque porcelain.¹⁵

As previously mentioned, one exception to this general description is the new Shademate* porcelain system in which a relatively achromatic, high value, build-up porcelain is used to build the restoration to full contour.¹⁹ There are no dentin or enamel porcelains to add and cut back. In view of the wide range of PFM alloys on the market, two build-up porcelains are available: one for low to medium thermal expansion alloys (Low); and one for medium to high thermal expansion metals (Regular). Special surface shading porcelains are used to achieve color matching. This elimination of the cut-back procedure and the application of internal color (aside from the opaque) can reduce the amount of time the technician must spend on the build-up procedure. However, one disadvantage is the great reliance on surface color and characterization, as opposed to the development of color depth by layering (internal characterization), as with the more conventional dental porcelains. Nonetheless, the Shademate* porcelain system may be acceptable for posterior restorations, and of particular value to high production dental laboratories.

c. Stains and Glazes

Unlike the opaque and body porcelains, **stain** powders contain less silica or alumina and more sodium and potassium oxide, plus special colorant oxides.⁶ **Stains** also differ from color (body) **modifiers** in their high concentration of color.⁴ The higher oxide content gives both **stains** and **glazes** a greater fluidity at temperatures above 1600° F.⁶ **Stains** are mixed with lower fusion point glasses, not to dilute the intensity of color, but to ensure their fusion below the maturing temperature of the **dentin** and **enamel** porcelains.⁴ These **stains** allow the development of surface characterization and color modification for custom shading matching or harmonizing. Body **modifiers**, on the other hand, are added to and fired with the body porcelain.

Stains are balanced to correspond with the coefficient of thermal expansion of the **body** and **opaque** porcelains. Nonetheless, these materials should NOT be routinely intermixed, since the **stains** have a higher fluidity. It is better to alter **dentin** and **enamel** porcelain color with body or enamel **modifiers** than to use surface stains internally.

Glazes are generally colorless porcelain powders with considerable fluidity at high temperature. **Glazes** are employed to ensure that the external porcelain surface portrays a sheen or glassy appearance much like a natural tooth. To the highly skilled ceramist, color development begins with the **opaque** layer,

* Dentsply International, Inc., York, PA.

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is enhanced by the **body** porcelains, and is highlighted by a natural (or self) glaze. Surface **stains** and **glazes** do not quite provide the finite optical qualities of a matured dental porcelain's natural glaze. They are surface characterizations and, as such, refract light differently than internal color modifications veneered by either **dentin** or **enamel** porcelain. Despite these limitations, **stains** are often a salvation; for they enable the technician or clinician to achieve some measure of color correction and compensate for some shade discrepancy. Generally, a porcelain restoration that has a high **value** (brightness) can be more easily adjusted than one with a **low** value. In other words, if the particular shade is unsatisfactory, porcelain may be darkened more readily than it can be lightened.

Although stain and glazes are useful in the establishment of harmony of color with adjacent teeth or restorations, glazing can potentially have an adverse effect on occlusal contour and occlusion. A vertical dimensional change in cusp and fossa height reportedly will occur during the glazing process.²⁰ Hobbins suggested the use of opaque cones to support cuspal porcelain, adjustment of occlusion after an initial glaze, and reglazing to minimize the amount of distortion.²⁰

2-4. OXIDATION (Degassing) OF THE METAL SUBSTRUCTURE

The process of heat-treating a metal substructure, in either atmosphere or vacuum, to cleanse the porcelain-bearing surface and/or to develop an oxide layer for porcelain bonding is termed "oxidizing" (or degassing). The subjects of metal preparation, oxidation, and porcelain bonding are discussed in much greater detail in Sections 3 and 4.

2-5. METHODS OF PORCELAIN CONDENSATION

After the porcelain powders have been mixed with the appropriate liquid to a proper consistency, they must be applied to the metal substructure, condensed, and fired (sintered). Although the process may sound simple, it is not always performed correctly, and can result in a weak, unesthetic restoration. The condensation procedure is simply an effort to pack the porcelain particles together by eliminating the liquid medium and air from the build-up (stacked porcelain). Any air bubbles present in the unfired state become voids in the fired porcelain, and can leave the restoration structurally weak. These voids also occupy space which is intended for porcelain particles, and thus can adversely affect the color, as well as the optical qualities, of the restoration by increasing its opacity.

Hence, the better the condensation, the less water and air will remain in the packed powder before firing. The greater the compaction of particles, the stronger the fired porcelain, and the more likely the final restoration will approach the anticipated esthetic expectations. Success in porcelain condensation is affected by several factors: (a) the size and shape of the porcelain particles (grains);⁷ (b) the amount of liquid in the mixed porcelain; (c) the actual technique of porcelain condensation;⁷ (d) the amount of build-up liquid eliminated during condensation;⁷ and (e) the use of vacuum firing.

a. Particle Size

The strongest dental porcelain will be the one with the greatest amount of condensation, and the least amount of air space. The commercial porcelains on the market today are frequently described as coarse-grained, mixed-grained, or fine-grained. The coarse-grained variety is often considered the easiest to manipulate; it also has the greatest amount of firing shrinkage, but may not offer the best esthetic qualities. The large particle size makes build-up and carving easier. Porcelain systems of this type are most attractive to high volume dental laboratories, where production must be rapid and efficient to maintain a competitive edge in the marketplace.

On the other hand, the fine-grained porcelains have been described by some as technique sensitive and more difficult to manipulate. However, they do not shrink as much as a coarse-grained porcelain, and produce some of the best esthetic results. Handling a fine-grained porcelain may not be easy for a technician accustomed to coarse-grained systems. The wet build-up may appear to slump easily, particularly if condensation is not approached slowly. However, learning the requirements of any porcelain system and how to properly manipulate a particular material is often a matter of training and experience. An individual initially trained in the use of fine-grained porcelains might consider a coarse-grained variety as technique sensitive by comparison. Therefore, it may be better to identify the various dental porcelains as possessing their unique handling characteristics. As such, they are not necessarily "technique sensitive," they are simply different from one another.

The mixed-grained porcelains occupy a position somewhere in between the fine- and coarse-grained systems. They reportedly possess (due to the varied particle sizes) the "feel" and the handling characteristics of a coarse-grained porcelain, plus esthetic properties approximating those of a fine-grained system.

McLean contends that packing density is also affected by the shape of the porcelain particles.⁴ Particles which are rounded from a dry grinding process tend to pack better than a wet ground powder.⁴ He believes that wet grinding produces angular grains which can create interferences and actually inhibit the porcelain particles from settling into position.⁴ Whether or not such an explanation is sufficient to explain variations in packing density is unclear. Regardless of the processing method, wet or dry, the procedure itself involves fracturing large particles into smaller ones. It is difficult to conceive of obtaining round-edge particles with a fracturing technique simply by virtue of the process itself.

b. The Wetness Of The Porcelain Mix

The development of a properly condensed restoration does not begin when the wet porcelain is applied to the metal substrate, but starts with the mixing of the dry porcelain powders with the build-up liquid. If the proper balance between powder and liquid is not established, poor condensation is more likely to follow. Therefore, if the porcelain instructions do not contain specific guidance on the ideal appearance of a properly prepared mix, contact the manufacturer, or ask a visiting technical representative for guidance.

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Mixing of the body porcelains with any liquid medium should be performed with a glass rod, rather than a metal instrument. This step will avoid the possibility of porcelain contamination by metal particles. It is difficult to describe the appearance of a properly prepared mix, especially since some manufacturers recommend a different consistency for **dentin** and **enamel** porcelains. One suggested test for the **dentin** mixture is to form the mass in the general shape of a rectangle. Pass a blade through the middle longitudinally and liquid should fill the center, if the porcelain is the correct consistency. Too wet a mixture can result in running of the porcelain during the build-up and condensation steps, "steam tears," and greater firing shrinkage. On the other hand, if the mix is too dry, it will appear thick and be more difficult to handle. A dry porcelain mix may also inhibit the intimate contact with either the alloy or previous porcelain layer, and result in postfiring checks and cracks, and a poor bond.

The **enamel** porcelains should be brought to a slightly wetter consistency than the **dentin** mixture to avoid layering or incomplete coverage. If the **dentin** build-up has dried out, rewet it slightly before adding the **enamel** layer to complete the contouring process. This step will saturate the **dentin** porcelain and prevent it from absorbing the liquid of the enamel addition.

c. Condensation Techniques

The numerous different recommended techniques to condense dental porcelain are: (1) capillary action; (2) vibration; (3) spatulation; (4) whipping; and (5) dry powder addition (or the Brush Application Method).^{3,4} Each approach has its particular strengths and weaknesses, yet selection of an appropriate method should take into account the skill level of the technician. Individual variability among technicians and clinicians, as well as personal preferences, must be considered when adopting a technique. Regardless of the method or methods chosen, the body porcelains should not be permitted to dessicate (dry out) during the condensation process.

1. Capillary Action - The technique of blotting a wet build-up with absorbent paper (facial tissue) employs capillary action (surface tension) to withdraw the liquid and pack the particles together.^{1,2} Ordinarily, this step is done in conjunction with one or more of the other condensation methods. Capillary action or surface tension, alone, does not remove all the available liquid. The cyclic action of vibration, or whipping, followed by blotting is repeated until free liquid can no longer be forced to the surface of the porcelain. A delicate touch is all that is necessary to initiate this mechanism. An overly aggressive technique could dislodge the porcelain build-up from the underlying metal, and shift the stacked porcelain from its intended position. One exception is opaque porcelain, which should not be blotted because the opaque could be lifted from the metal surface.

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2. Vibration - The easiest and simplest form of vibration is created by passing a serrated instrument over the neck of a hemostat in which the porcelain build-up is held,⁷ or merely tapping the hemostat neck. Those who prefer to accomplish the build-up directly on the master die simply vibrate the entire cast. Once the excess water is brought to the surface, the capillary action created by blotting pulls the liquid out and forces the porcelain particles closer together. There are several devices on the market designed to provide mechanical vibration, such as the vibrating brushes, spatulas, and ultrasonic condensers. They are geared toward maximum efficiency and minimal effort. The ultrasonic equipment is often limited to final condensation, reserving preliminary condensation for some other method. Without some initial condensation, the delicate wet porcelain build-up will undoubtedly slump or run. Such equipment is helpful, since the ultrasonic mechanism has a low amplitude (little agitation) with a high frequency of vibrations.⁷

Once the porcelain build-up has been dried and well condensed, any further agitation could disrupt the delicate position of the porcelain on the metal substructure.

3. Spatulation - With this form of condensation, a spatula or porcelain carver is used to apply, then rub (or pat) the porcelain to draw the liquid to the surface.^{1,7} This particular technique brings with it a greater likelihood of porcelain dislodgement, particularly if too much pressure is used, especially with the initial build-up. An undetected dislodgement could then result in porcelain cracks.⁷
4. Whipping - This method may actually be nothing more than a variation of the vibration technique. As the porcelain is built up, a No. 10 sable hairbrush is used with a gentle whipping motion over the porcelain surface. A slight vibration is produced which then brings the liquid to the outside surface for blotting. Whipping has been recommended as especially useful for the fine-grained porcelain.^{1,7} A hazard is that excessive manipulation might increase the loss of fine particles when blotting.
5. Dry Powder Addition - McLean refers to this technique as the "Dry Powder Application Method," in which dry porcelain powder is applied to a small area of wet porcelain surface.⁴ The reasoning behind this method is to use the existing liquid to moisten the applied dry powder and to remove the liquid by blotting. The difficulty is determining the correct amount of powder and placing the powder in the correct positions. This is, perhaps, the least favored and most difficult of the available techniques. It is certainly more time-consuming. Dry powder addition increases the possibility of the porcelain being cut, prematurely or nonuniformly, and interfering with the condensation process.

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2-6. FIRING OF DENTAL PORCELAIN

After the dental porcelain has been mixed properly, placed on the metal substructure (stacked), and properly condensed, the next step in the fabrication of a porcelain-fused-to-metal restoration is firing the dental porcelain. The exact method of processing each porcelain is outlined in the instructions which accompany each porcelain kit. Although there are a few general rules which appear to be common to all the systems we examined, the specific limits for the firing process do vary from system to system, thus further illustrating the individuality of the products, and the distinct absence of standardized handling. The processing instructions for one porcelain may not be successfully applied to another similar appearing product. Therefore, it is important to follow the directions provided by the respective manufacturer.

Despite the need to adhere to the specific procedures recommended by each manufacturer, several basic principles apply to the processing of dental porcelain. This general information on firing porcelain is presented here, and is followed by a brief description of the products used.

a. Drying

Regardless of whether the material to be fired is an opaque or a body porcelain, it must be thoroughly dried before the firing program is initiated. After a restoration has been properly condensed, common procedure is to place the "green" (unfired) porcelain at the muffle entrance for a specified period of time. The actual length of the drying period may range from 3-10 minutes. A thorough drying of the restoration ensures the elimination of any liquid, remaining in the porcelain build-up, which was not removed through condensation alone. The important feature of this process is the slow drying of the work. Sudden exposure to high temperatures by placing units directly in the furnace, or by beginning the predrying at too high a temperature, could be harmful to the restoration. The intense heat might result in steam formation which could blow the unfired porcelain off the metal substructure or produce multiple microcracks. Regardless of the particular result, the outcome is one to be avoided. The basic guideline is to start the predrying step at a relatively low temperature (1000-1292 °F or 540-700 °C) and to allow ample time (5-6 min) at the muffle entrance. The drying becomes more critical as the mass of unfired porcelain increases; i.e., more risk for the first body bake than for the first or second opaque firings.

Some of the new programmable porcelain furnaces divide the predrying procedure into a "drying" and a "preheating" step.* Each phase of drying can be set at a time most appropriate to the particular porcelain and specific firing step. The preheating setting provides an opportunity to thoroughly heat a build-up after it has already been dried. Many porcelain furnaces offer only one prolonged drying cycle without a specific preheating step.

* Multimat MC, Dentsply International, Inc., York, PA.

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One other function of the drying process which is often neglected is the elimination of the organic additives in the porcelain; namely, the color-coded dyes. During the initial drying stage, the water is removed and the organics are carbonized (changed into carbon), during which process the free carbon turns the porcelain a gray shade. Three factors are responsible for the complete elimination of the free carbon: temperature, atmosphere, and time. To remove all the carbon, the predrying must be performed at a temperature of 800 °F with oxygen present (air firing), and for a sufficient period of time. If all the carbon is not burned off, it will act as a pigment in the porcelain and cause discoloration.

b. Vacuum Firing

All the processing (firing) of the opaques and body porcelains is accomplished under full vacuum. Only the self, or external, glazing is done without vacuum (air fired). The vacuum is initiated and brought to its maximum level (28-30 mm Hg) BEFORE the work is fired to the maximum temperature. If a manual oven is used, do not raise the temperature and then draw the vacuum. To do so would mean the first few minutes of firing were done in atmosphere rather than in vacuum.

Under vacuum, the air or atmosphere is removed from spaces between the powder particles to permit the porcelain to shrink to a denser mass.⁴ Any entrapped air would not only be unesthetic (increased opacity), but would weaken the material structurally. Vacuum firing increases the density, strengthens the porcelain, and improves the esthetic quality of the fired restoration (decreases opacity).⁴ Some porcelains require the vacuum to be released at a particular temperature, and followed by air-firing for a short additional period. Other porcelains must be held at a maximum temperature for a specified time to permit proper maturing.

c. Temperature Settings

Each brand of dental porcelain has a low- and a high-temperature setting for every stage of firing. Generally, the low, set point temperature is constant; and only the maximum, or high temperature has to be varied for each individual procedure. The low settings may range from 1000 °F (540 °C) to 1292 °F (700 °C). The high settings vary between 1725 °F (940 °C) and 1860 °F (1015 °C) for the two opaque firings and first body bake. It is not uncommon to reduce the maximum temperature setting 10 °F degrees, or more for a second and third body bake, if they are required.

These settings are general guidelines which must be adjusted to compensate for the performance of individual porcelain furnaces. It is important to calibrate furnaces periodically to ensure consistent performance and predictable firing behavior. In addition, vertical loading porcelain furnaces may fire 50-75 °F higher than horizontal (front) loading ovens. Therefore, an adjustment in technique should be made for the particular equipment in use.

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d. Cooling The Fired Restoration

When the firing cycle has ended, bring the work (units) to the muffle entrance to begin the cool down. This procedure is important, since dental porcelain conducts heat about 1,000 times more slowly than the metal sub-structure.²¹ Therefore, do not immediately expose the restorations to the cooler outside environment (air); the thermal shock may cause the porcelain to crack. After several minutes, move the sagger tray from the muffle entrance to a protected area adjacent to the furnace. Do not attempt to touch the porcelain until it has cooled to room temperature. The metal and the porcelain retain heat differently, and thus will cool at different rates. Rushing the case at this point could possibly result in the generation of cracks, both visible and invisible. Any rapid exposure to a cool environment (thermal shocking) could result in either immediate or delayed porcelain fracture.

Cracking of the porcelain during the cooling phase may be indicative of a porcelain-metal incompatibility. Check with the alloy manufacturer if this problem persists despite appropriate cooling technique.

2-7. THE DIFFERENT APPEARANCES OF DENTAL PORCELAINS

As mentioned previously, the majority of manufacturers color-code the respective body porcelains so the dentin powders appear pink or red, while the accompanying enamel powders are blue. These are the universal colors chosen for these two types of porcelain, regardless of the particular shade within either of these two categories. For example, the red dentin powder for A-1 (or 59) would look similar to that of a C-4 (or 82) dentin powder. This comparison would also hold true for the various enamel porcelain powders. Liquid color tags are commercially available for custom coloring of dentin, enamel, and modifier powders.

The actual appearance of a PFM restoration will vary during the different stages of production: stacked and carved; predried; bisque (low, medium, and high); and glazed (low, medium, and high).

a. Stacked and Carved Build-Up

During the initial stage of development, a restoration might ordinarily display a red dentinal porcelain color and a complimentary blue enamel layer. Any modifiers placed internally might be masked by the intense red and blue hues (colors) at this particular stage. Modifiers located on the external surface would probably be noticeable initially, but could lose their color identity during condensation and blotting procedures. Also, as the build-up liquid evaporates and the stacked porcelain begins to dry, the differentiated zones of color tend to disappear or, at least, become less distinct. This effect is particularly true if the restoration is adjacent to a heat source (lamp, porcelain furnace, etc.). Even before the actual predrying is begun, a carved build-up will begin to dry if left unattended for any extended

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period of time. When thoroughly dried, the carved build-up will take on a "chalky" appearance, and even a gentle touch of the restoration will bring out the dry, powdery nature of the porcelain. No major adjustments to the build-up should be attempted at this stage without first rewetting the porcelain.

A new porcelain build-up liquid (Color Tru Liquid Binder*) has been developed which can enhance this particular phase of dental technology.²² Described as an "**organic liquid binder**," Color Tru liquid can be matched to the refractive index of each brand of dental porcelain.²² Consequently, the wet porcelain powders appear almost as if they were fired porcelain, rather than nondescript masses of liquid pink or blue porcelain (Fig. 2-2). As a result, custom color and shade modifications can be visualized before the porcelain is actually fired. An unfired "wet" shade tab could be created chairside.

The uses for such a liquid are numerous and, in all likelihood, this material will prove instrumental in improving the porcelain skills of dental technicians.

Figure 2-2. "Color Tru" Liquid Binder, mixed with dentin porcelain rather than distilled water. This special liquid permits the color of each porcelain shade to be visualized in the unfired state.

b. Dried

Most manufacturers do not recommend firing a wet porcelain build-up because of the destructive effects resulting from the sudden production of steam. The standard technique recommended to avoid the possibility of rapid heating of the liquid medium is to employ a lengthy predrying period. In other words, the porcelain build-up is exposed to a low-temperature heat source, usually the furnace muffle, for a specified period of time--up to 10 min for some porcelains. As mentioned previously, organic colorants in the various body porcelains carbonize and initially gray the build-up. However, by the end of the drying time the entire porcelain build-up should appear chalky white, and no traces of moisture or organic colorants should be detectable. At this point, the restoration is still not ready to be fired. The porcelain build-up

* Forsyth Dental Center, Boston, MA.

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must be heated slowly and brought up to the temperature of the idling furnace. To best accomplish this purpose, the restoration is gradually introduced (or walked) into the porcelain furnace muffle if you are using a front-loading manual oven. This is a timed walk which should take at least 5 minutes. At the end of this period, the build-up should be positioned directly under the thermocouple, with the bulk of the porcelain facing towards the heating coils of the oven and away from the muffle entrance. The muffle door is closed, a full vacuum is drawn, and the restoration is fired to the recommended maximum temperature setting.

The automatic and programable porcelain furnaces have made it easy to perform the preheating procedure consistently and accurately for almost any porcelain systems. These furnaces have also eliminated the requirement to manually walk the work into the muffle and to place the restorations in the ovens correctly. Avoid porcelain furnaces which initiate the vacuum before the burning temperature of carbon is reached. The premature elimination of oxygen (vacuum) can lessen the likelihood of total carbon removal.

c. Bisque Stages

Maturing dental porcelain is dependent on both time and temperature. Each porcelain system has a prescribed set of established maximum temperatures for each stage in the fabrication process (opaque, body porcelain, and glaze). Vacuum-firing a predried build-up of body porcelains produces a restoration in the bisque stage. The appearance of the porcelain will vary with the level of maturity achieved as a function of time and temperature. Moreover, color and translucency are particularly dependent on the level of porcelain maturity.⁷

1. Low Bisque - This is the least mature stage of development in which the grains of porcelain have only begun to soften and fuse at their contact angles.^{1,4} Structurally, the porcelain is both weak and porous.⁴ A porous surface means the restoration is particularly susceptible to contamination until the maturation process is complete, and the outer surface is completely sealed.^{1,7} The porcelain may appear opaque, and not display good color and sheen.^{1,7}
2. Medium Bisque - In this next level of maturity, the porcelain grains have fused together more substantially, less air (or atmosphere) is present, and some measure of shrinkage has occurred.^{1,4} The porcelain is still slightly porous but certainly not as much as that in a low bisque.⁴ Air (or atmosphere) which remains internally, and is unable to escape during the sintering process, will remain in the porcelain as voids.⁴ With a medium bisque, a sheen is more apparent, but the porcelain still lacks full color and translucency.⁷
3. High Bisque - A high bisque is the desired stage of matured porcelain development in which the grains have fused, and the maximum amount of air (atmosphere) has been eliminated for the level of condensation and vacuum applied. The appearance of the external surface of the fired porcelain may range from an orange peel texture to a smooth

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sheen. The smooth finish indicates that the outer surface is completely sealed.^{1,4,7} With shrinkage complete and voids eliminated as much as possible, the surface still has a texture--but features are rounded, not sharp. At this stage the porcelain has a high level of strength, and the majority of the shrinkage has taken place to permit final adjustments prior to glazing.⁴ McLean contends that even glazing should not affect the accuracy of the occlusal surface (i.e., cusp-to-fossa relationship).⁴

4. Overfired - When heated for too long a period or to too high a temperature, a restoration may be overfired. In this instance, no further shrinkage occurs, and the porcelain is glassy smooth with little or no surface texture. Too much transparency occurs, thus giving the porcelain a gray appearance. Grinding and glazing may not remedy these changes, since overfiring is not a surface phenomenon.

d. Glaze Stages

The manipulation of time and temperature during the firing of dental porcelain can also be applied to the development of a final glaze. Teeth differ substantially in both texture and sheen, thus making one standard technique for glazing impractical. Since a properly fired restoration should be sealed externally (high bisque), the glazing cycle is helpful in creating the particular characterizations of a life-like restoration. External (surface) color modifications, or highlights, along with surface texture adjustments and the development of a final sheen, can all be developed through glazing. A natural (or self) glaze is generally preferred to an externally applied glaze and usually produces a more vital appearance. Unfortunately, shade discrepancies between restorations and adjacent teeth frequently require external color modifications or characterizations (glazing and/or staining) in order to approach a level of acceptability.

Repeated firings may diminish the quality of a self-glaze (autoglaze) due to a slight surface crystallization, a loss of porcelain fluxes, or a change in the composition of the porcelain (a reduction in the glassy matrix).²³

1. Low Glaze - This initial stage of glaze is just over the level of maturity for the porcelain.⁷ The restoration may appear smooth, or textured, yet lack any appearance of a high sheen. There are patients in whom this low glaze would appear acceptable for the glazed restoration to blend harmoniously with the surrounding natural teeth.
2. Medium Glaze - A medium glaze has a higher level of sheen and is probably suitable for most patients.⁷ It can be obtained from the low glaze by holding the restoration at temperature for a slightly longer period of time. The reverse is not necessarily true, however. If you want a low glaze but overfire the porcelain, thus producing a medium glaze, you may have to break the glaze and refire it at a lower temperature or for a shorter period of time. This procedure is necessary if you cannot dull the surface satisfactorily through mechanical means (polishing paste or rubber wheel).

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3. High Glaze - When a restoration is overfired because of too much time at temperature or too high a temperature, or both, a high glaze will result. This stage of glazing is to be avoided because the porcelain begins to coalesce, losing not only its form but its color, translucency, and strength.⁷ Overglazed crowns do not look like teeth, but take on a glassy appearance and look unnatural. They may also undergo "devitrification" and appear cloudy.⁴ Not only is the porcelain structurally weaker, but it also becomes more opaque as devitrification continues. If a loss of form is noted, the glaze should be removed to permit refiring with additional body porcelain before reglazing. However, grinding and refiring with additional porcelain is not always successful, because the added porcelain must carry the entire shade burden. The porcelain is still overfired, and becomes even more so with the firing of the added layer. Consequently, removing the porcelain and rebuilding the restoration may be what is actually necessary to resolve the problems of overfiring.

2-8. DISCOLORATION OF DENTAL PORCELAIN

No discussion of dental porcelain would be complete without some mention of the subject of porcelain discoloration. Aside from inadvertent porcelain contamination due to poor technique, the culprit for contamination to which most technicians will readily point is: silver. This topic, which is covered in greater detail in "Section 3," can at least be introduced at this point to clear up a few misconceptions.

First: Despite the presence of silver in an alloy, the dental porcelain will not always be contaminated, and subsequently "green." When present, the actual form of the discoloration may vary from green to yellow, to orange, or even brown, and it may only be noticeable in the very light shades of porcelain.¹² In the darker shade ranges, discoloration might not be detectable even if present. More importantly, silver does NOT discolor all dental porcelains. This particular point is not often emphasized; and few realize that there are two porcelain systems, available today, which are chemically compatible with silver-containing alloys and therefore resistant to "greening." The first and oldest system is Will-Ceram Porcelain,* and the second is the recently introduced Artis-Tech Porcelain.** We used both of these porcelains with the palladium-silver alloys, and no discoloration was observed during our testing period.

Second: The exact mechanism of the discoloration process is not fully understood, but silver vapors are believed to be at the heart of the problem. Preventing the vaporization of silver from the silver-containing alloys is impossible; however, some of the recommended techniques are presented in the discussion of palladium-silver alloys in "Section 3."

* Williams Gold Refining Company, Buffalo, NY.
** Rx. Jeneric Gold Company, Wallingford, CT.

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2-9. FAST FIRING OF DENTAL PORCELAIN

This is one of the more interesting concepts that is being promoted by some members of industry. Traditionally, dental porcelain has been fired (sintered) at a rate of 50-100 °F/min (32-55 °C/min) depending on the particular porcelain system involved. Suddenly, interest has arisen in accelerating this rate to levels up to 400 °F/min. The chief benefit to be derived from purchasing a porcelain furnace which can provide this capability is the saving of TIME. Yet, to mature dental porcelain, a balance must be maintained between **time** and **temperature**. If the rate of firing is increased, it would be expected that the porcelain firing cycle would have to be adjusted in terms of temperature to compensate for the decreased firing time. The maximum temperature setting could be increased, or the porcelain could be held at a prescribed temperature for a specified period of time.

If no adjustments are proposed to the firing schedule, then the belief in a traditional time and temperature relationship for porcelain maturity is to be questioned and challenged.

The benefit of fast firing at a rate of 400 °F/min (204 °C/min) over the course of a normal 7-8 min cycle would be a savings of approximately 5 min. Unfortunately, not all manufacturers support the concept of fast firing their porcelain products. If they do permit it, they stress the need to adjust the high temperature setting or extend the hold time, if one is normally recommended. These modifications do not completely restore the **time** and **temperature** recommendations, and can reduce any theoretical time "savings" attributed to the increased firing rate.

Undoubtedly, more information will become available if interest in this concept gains momentum. In the interim, the respective dental porcelain manufacturer should be consulted before making such a major modification to the recommended processing instructions.

2-10. CLASSIFICATION OF DENTAL PORCELAINS BY THERMAL EXPANSION

Technical manuals contain a great deal of discussion concerning the relationship between the coefficients of thermal expansion of the casting alloy and the dental porcelain. However, few manufacturers provide such technical data with their alloy or their porcelain. The following descriptions of the dental porcelains examined in this evaluation are provided solely for guidance:

High Expansion

Crystar

Medium Expansion

Jelenko
Shademat Reg
Will-Ceram

Low Expansion

Artis-Tech
Shademat Low
Vita

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The alloy manufacturers were also asked to provide the coefficient of thermal expansion for each alloy in the program. That information, when provided, is presented in the "Mechanical and Physical Properties" section of the respective alloy description.

Although it is now generally believed that the coefficient of thermal expansion of the alloy should be greater than that of the dental porcelain, manufacturers may be reluctant to provide these data for several reasons:

- a. Although people believe that the use of the coefficient of thermal expansion can predict compatibility, it can not. There are many factors which make up compatibility, and the coefficient of thermal expansion is but one.²⁴
- b. Coefficients are measured in a manner completely foreign to standard porcelain fabrication, so they are good only for quality control.²⁴
- c. Coefficients are generally measured in expansion, while contraction characteristics are the important parameters in actual use.²⁴
- d. Reproducibility of results is unreliable between instruments, as well as users of those instruments. If one manufacturer measures an alloy and another the dental porcelain, there is no credibility in comparing the two results.²⁴

2-11. INFORMATION AND PROCESSING INSTRUCTIONS FOR SIX DENTAL PORCELAINS

The following material contains general information about several of the dental porcelains on the market today, and possibly in use at U.S. Air Force facilities. Only those systems which we actually examined are included.

The firing schedules should be used as guides only, since the specific temperature settings and performance of each porcelain furnace will vary. Moreover, variations can also be anticipated between front loading and vertical loading ovens, as well as between manual and automatic or programmable furnaces.

- | | |
|--|--------------|
| a. Artis-Tech Porcelain (Jeneric) - | ATTACHMENT 1 |
| b. Crystar Porcelain (Unitek) - | ATTACHMENT 2 |
| c. Jelenko Porcelain (Jelenko) - | ATTACHMENT 3 |
| d. Shademate Porcelain (Dentsply) - | ATTACHMENT 4 |
| e. Vita VMK-68 Porcelain (Vident) - | ATTACHMENT 5 |
| f. Will-Ceram (Williams) - | ATTACHMENT 6 |
| g. Cost Comparisons of Various Dental Porcelains - | ATTACHMENT 7 |

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--SECTION 2: ATTACHMENT 1--

ARTIS-TECH PORCELAIN

GENERAL INFORMATION

GRAIN SIZE: Coarse-grained

THERMAL EXPANSION: Low Expansion

AVAILABLE SHADES: Vita-Lumin (A-1 thru D-4) and Bioform (59-82) Series.

DISTRIBUTOR:

Rx. Jeneric Gold Company
 Jeneric Industries, Inc.
 P.O. Box 724
 Wallingford, Connecticut 06492

TOLL-FREE PHONE NUMBER:
 1-(800) 243-3969, Ext. 212 or 310

COMMERCIAL PHONE NUMBER:
 1-(203) 265-7397 (in Connecticut
 and outside U.S., call collect)

TELEPHONE CONTACTS:

Laboratory: Mr. Grant Day
 Mr. Rick Tobey
 Research: Dr. Arun Prasad

REGIONAL SALES REPRESENTATIVES:

No

COST: The unit price for each type and size of porcelain is listed with the per gram(g) price in parentheses.

	1 oz. (per g)	4 oz. (per g)	8 oz. (per g)
opaque	\$ 7.95 (\$ 0.28)	\$ 31.80 (\$ 0.28)	\$ 63.60 (\$ 0.28)
"gingival"	\$ " "	\$ " "	\$ " "
"incisal"	\$ " "	\$ " "	\$ " "
modifiers	\$ " "	\$ " "	\$ " "
add-on porcelain	\$ " "	\$ " "	\$ " "
Clear Glaze	\$ 22.80 (\$ 0.80)	N/A	N/A
	<u>6.5 g</u>		<u>1 oz. 4 oz</u>
Pre-mixed (wet) stains	\$ 9.60 (\$ 1.48)	Color tags (red & blue)	\$ 3.60 \$ 8.00

ARTIS-TECH PORCELAIN FIRING SCHEDULE

PORCELAIN	DRYING TEMP. TIME	RATE OF RISE (° per min)	ENVIRONMENT	MAX. TEMP.	ENVIRONMENT	COOLING	APPEARANCE	DESIRED THICKNESS
<u>Opaque:</u>								
1st Layer	1200 °F (650 °C) 5 min	100 °F (55 °C)	Vacuum	1825-1860 °F (996-1015 °C)	Slowly break vacuum at max. temperature	Slow Cooling	Eggshell Glisten	Thin skim
2nd Layer	1200 °F (650 °C) 5 min	100 °F (55 °C)	Vacuum	1825-1860 °F (996-1015 °C)	"	Slow Cooling	Eggshell Glisten	0.2 mm
<u>Leath and Enamel:</u>								
1st Bake	1700 °F (920 °C) 5 min	100 °F (55 °C)	Vacuum	1725-1750 °F (940-954 °C)	"	Slow Cooling	Fused Granular (High Bisque)	1 mm
2nd Bake	1700 °F (920 °C) 5 min	100 °F (55 °C)	Vacuum	1715-1740 °F (935-949 °C) or maturing pt.	"	Slow Cooling	Orange Peel (High Bisque)	As needed
<u>Glaze:</u>								
	1600 °F (870 °C) 5 min	100 °F (55 °C)	Air	1675-1725 °F (913-940 °C)	H/A	Slow Cooling	Glossy	As needed
	1750 °F (950 °C) 5 min	100 °F (55 °C)	Air	1750-1775 °F (954-963 °C)	H/A	Slow Cooling	Maternal Luster	Thin layer

* The 1750 °F (950 °C) 5 min maturing point and the porcelain turns white.

--SECTION 2: ATTACHMENT 2--

CRYSTAR PORCELAIN

GENERAL INFORMATION

GRAIN SIZE: Fine-grained

THERMAL EXPANSION: High Expansion

AVAILABLE SHADES: Vita-Lumin (A-1 thru D-4) Series ONLY.

MANUFACTURER:

Unitek Corporation
2724 South Peck Road
Monrovia, California 91016

TOLL-FREE PHONE NUMBER:
1-(800) 423-4508

COMMERCIAL PHONE NUMBER:
1-(818) 445-7960

TELEPHONE CONTACTS:

Training Lab Manager
(Call person-to-person collect
on the commercial number)

REGIONAL SALES REPRESENTATIVES:

Yes

COST: The unit price for each type and size of porcelain is listed with the per gram(g) price in parentheses.

	<u>15 grams (per g)</u>	<u>50 grams (per g)</u>	<u>200 grams (per g)</u>
opaque	\$ 3.20 (\$ 0.55)	\$ 24.00 (\$ 0.48)	\$ 98.80 (\$ 0.49)
"body"	" "	" "	" "
"incisal"	" "	" "	" "
	<u>5 grams (per g)</u>	<u>10 grams (per g)</u>	
shoulder porcelains	N/A	\$ 11.16 (\$1.12)	
stains	\$ 3.00 (\$1.60)	N/A	

CRYSTAR PORCELAIN FIRING SCHEDULE

PORCELAIN	DRYING TEMP. TIME	RATE OF RISE (° per min.)	ENVIRONMENT	MAX. TEMP.	ENVIRONMENT	COOLING	APPEARANCE	DESIRED THICKNESS
<u>Opaque:</u>								
1st Layer	1200 °F 5 min (648 °C)	100 °F (55 °C)	Vacuum	1760 °F (960 °C)	Break vacuum at maximum temperature.	Remove Immed.	Mat Finish	Thin skin
2nd Layer	1200 °F 5 min (648 °C)	100 °F (55 °C)	Vacuum	1760 °F (960 °C)	"	Remove Immed.	Mat Finish	0.2 mm
<u>Dentin and Enamel</u> ¹								
1st Bake	1200 °F 5 min (648 °C)	100 °F (55 °C)	Vacuum	1725 °F (940 °C)	"	Remove Immed.	Mildly Glazed	1 mm
2nd Bake ²	1200 °F 5 min (648 °C)	100 °F (55 °C)	Vacuum	1700 °F (930 °C)	"	Remove Immed.	Mildly Glazed	As needed
<u>Add-Ons:</u> ^{1,2}								
	1200 °F 5 min (648 °C) (Use translucent powder for minor additions.)	100 °F (55 °C)	Vacuum	1700 °F (930 °C)	"	Remove Immed.	Mildly Glazed	As needed
<u>Glaze:</u> ³								
	1200 °F min (648 °C)	100 °F (55 °C)	Air	1688 °F (920 °C)	N/A	Remove Immed.	Natural Luster	Thin layer

1 Do not start the drying until the color tags have been burned off and the porcelain turns "white."
 2 For subsequent bakes or additions, lower maximum firing temperature 10-15°C.
 3 For translucent glazes, glazes recommended for Crystar Porcelain; but overglazes may be used.

--SECTION 2: ATTACHMENT 3--

JELENKO PORCELAIN

GENERAL INFORMATION

GRAIN SIZE: Fine-grained

THERMAL EXPANSION: Medium Expansion

AVAILABLE SHADES: Vita-Lumin (A-1 thru D-4), Bioform (59-82) Series, and Bioform Extended Range (51-56, 91-96) Series.

MANUFACTURER:

J. F. Jelenko & Co.
99 Business Park Drive
Armonk, New York 10504

TOLL-FREE PHONE NUMBER
1-(800) 431-1785

COMMERCIAL PHONE NUMBER:
1-(914) 273-8600

TELEPHONE CONTACTS:

Technical Services Dept.

REGIONAL SALES REPRESENTATIVES:

Yes

COST: The unit price for each type and size of porcelain is listed with the per gram(g) price in parentheses.

	<u>15 grams (per g)</u>	<u>25 grams (per g)</u>	<u>175 grams (per g)</u>
opaque	\$ 7.50 (\$ 0.50)	\$ 12.50 (\$ 0.50)	\$ 81.00 (\$ 0.46)
dentin	" "	" "	" "
enamel	" "	" "	" "
	<u>5 grams (per g)</u>		
stains	\$ 3.60 (\$ 0.72)		

JETENKO PORCELAIN FIRING SCHEDULE

PORCELAIN	DRYING TEMP.	DRYING TIME	RATE OF RISE (° per min.)	ENVIRONMENT	MAX. TEMP.	ENVIRONMENT	AIR FIRING	COOLING	DESIRED APPEARANCE	THICKNESS
<u>Opaque:</u>										
1st Layer	1100 OF (593 OC)	2-5 min	100 OF (56 OC)	Vacuum	1800 OF (980 OC)	Slowly break vacuum at max. temperature.	Air fire to 1825-1850 OF	Slow Cooling	Eggshell Glisten	Thin skim
2nd Layer	1100 OF (593 OC)	2-5 min	100 OF (56 OC)	Vacuum	1800 OF (980 OC)	"	Air fire to 1825-1850 OF	Slow Cooling	Eggshell Glisten	0.2 mm
<u>Dentin and Enamel*</u>										
1st Bake	1100 OF (593 OC)	5-10 min	100 OF (56 OC)	Vacuum	1725 OF (941 OC)	"	Air fire to 1800 OF (980OC)	Slow Cooling	Orange Peel (High Bisque)	1 mm
2nd Bake	1100 OF (593 OC)	5-10 min	100 OF (56 OC)	Vacuum	1725 OF (941 OC)	"	Air fire to 1800 OF (980OC)	Slow Cooling	Orange Peel (High Bisque)	As needed
<u>Add-Ons:*</u>										
	1100 OF (593 OC)	5-10 min	100 OF (56 OC)	Air	1725 OF (941 OC)	Air		Slow Cooling		As needed
<u>Glaze:*</u>										
	1100 OF (593 OC)	2-5 min	100 OF (56 OC)	Air	1775 OF (968 OC)	Air	As needed	Slow Cooling	Natural Luster	Thin Layer

* Do not start the drying until the color tags have been burned off and the porcelain turns "white".

--SECTION 2: ATTACHMENT 4--

SHADEMATE PORCELAIN

GENERAL INFORMATION

GRAIN SIZE: Coarse-grained

THERMAL EXPANSION: Low - Low to Medium Expansion
Reg - Medium to High Expansion

AVAILABLE SHADES: Shade matching is achieved by the application of external colorants only. In theory, any shade guide may be used which is within the range of the available shading porcelains and external stains.

MANUFACTURER:

Dentsply International Inc.
570 West College Avenue
P.O. Box 872
York, Pennsylvania 17405

TOLL FREE PHONE NUMBER:
1-(800) 233-9454

COMMERCIAL PHONE NUMBER:
1-(717) 845-7511

TELEPHONE CONTACTS:

Technical - Mr. John Appelbaum

REGIONAL SALES REPRESENTATIVES:

Yes

COST: The unit price for each type and size of porcelain is listed with the per gram(g) price in parentheses.

	<u>8 grams (per g)</u>	<u>1 ounce (per g)</u>	<u>4 ounces (per g)</u>	<u>8 ounces (per g)</u>
opaque	N/A	\$14.17 (\$0.50)	\$51.38 (\$0.45)	\$92.30 (\$0.41)
build-up porcelains (reg & low expansion)	N/A	N/A	N/A	\$68.02 (\$0.30)
shading porcelain (body & enamels)	\$11.36 (\$1.42)	N/A	N/A	N/A
	<u>3 grams (per g)</u>			
stains	\$ 6.16 (\$2.05)			

SHADEMATE PORCELAIN FIRING SCHEDULE
(FOR CONVENTIONAL PORCELAIN FURNACES)

PORCELAIN	DRYING TEMP. TIME	RATE OF RISE (° per min.)	ENVIRONMENT	MAX. TEMP.	ENVIRONMENT	HOLD TIME	APPEARANCE	DESIRED THICKNESS
<u>Opaque:</u>								
1st Layer	1100 OF 10 sec (593 °C)	to 400 OF (190 °C)	Vacuum	1850 OF (1010 °C)	Slowly break vacuum at max. temperature.	0	Glaze	Thin skim
2nd Layer	1100 OF 10 sec (593 °C)	to 400 OF (190 °C)	Vacuum	1825 OF (996 °C)	"	0	Glaze	0.2-0.3 mm
<u>Build-Up Porcelain*</u>								
1st Bake	1100 OF 3-6 min (593 °C)	to 400 OF (190 °C)	Vacuum	1750 OF (954 °C)	"	0-1 min	Slightly Glazed	1 mm
2nd Bake	1100 OF 3-6 min (593 °C)	to 400 OF (190 °C)	Vacuum	1750 OF (954 °C)	"	0-1 min	Slightly Glazed	As needed
<u>Add-Ons:*</u>								
	1300 OF 3-6 min (690 °C)	to 400 OF (190 °C)	Air	1676 OF (899 °C)	N/A	0-1 min	Slightly Glazed	As needed
<u>Overglaze:*</u>								
	With Shading Medium: 1300 OF 3-6 min (690 °C)	to 400 OF (190 °C)	Air	1650 OF (885 °C)	N/A	0-1 min	Natural Luster	Thin layer
	With Stain and Glaze Liquid: 1300 OF 3-6 min (690 °C)	to 400 OF (190 °C)	Air	1660 OF (835 °C)	N/A	0-1 min	Natural Luster	Thin layer

* Do not start the drying until the color tags have been burned off and the porcelain turns "white".

--SECTION 2: ATTACHMENT 5--

VITA VMK-68 PORCELAIN

GENERAL INFORMATION

GRAIN SIZE: Fine-grained

THERMAL EXPANSION: Low Expansion

AVAILABLE SHADES: Vita-Lumin (A-1 thru D-4) Series ONLY.

MANUFACTURER:

Vident
5130 Commerce Drive
Baldwin Park, California 91706

TOLL-FREE PHONE NUMBER:
1-(800) 828-3839

COMMERCIAL PHONE NUMBER:
1-(800) 960-7531

TELEPHONE CONTACTS:

Technical - Mr. Tony Torres

REGIONAL SALES REPRESENTATIVES:

Yes

COST: The unit price for each type and size of porcelain is listed with the per gram(g) price in parentheses.

	12 grams (per g)	50 grams (per g)	250 grams (per g)
opaques (VMK-68 Paint-On)	\$ 6.88 (\$ 0.57)	\$26.24 (\$ 0.53)	N/A
opaques (VMK-68 Standard)	\$ " "	" "	N/A
opaques (VMK-88 Paint-On)	\$ " "	" "	\$115.60 (\$ 0.46)
opaque modifiers	\$ " "	N/A	N/A
dentin	\$ " "	" "	\$115.60 (\$ 0.46)
colored modifiers	\$ " "	" "	N/A
enamel	\$ " "	" "	\$115.60 (\$ 0.46)
opacous dentine	\$ " "	" "	N/A
shoulder powders	\$ " "	N/A	N/A
	3 grams (per g)		
stains	\$ 9.60 (\$ 3.20)		

VITA VMK 65 PORCELAIN FIRING SCHEDULE

PORCELAIN	DRYING TEMP. TIME	RAVE OF RISE (° per min.)	ENVIRONMENT	MAX. TEMP.	ENVIRONMENT	HOLD TIME	COOLING	APPEARANCE	DESIRED THICKNESS
<u>Opaque (Paint-On 88 Opaques):</u>									
1st Layer	1112 OF 0 min (600 °C)	100 OF (55 °C)	Vacuum	1796 OF (980 °C)	Slowly break vacuum at max. temperature.	1 min	Slow Cooling	High Sheen	Thin skim
2nd Layer	1112 OF 0 min (600 °C)	100 OF (55 °C)	Vacuum	1796 OF (980 °C)	"	1 min	Slow Cooling	High Sheen	0.2 mm
<u>Dentin and Enamel*</u>									
1st Bake	1112 OF 6-10 min (600 °C)	100 OF (55 °C)	Vacuum	1760 OF (960 °C)	"	1 min	Slow Cooling	Glossy	1.0 mm
2nd Bake	1112 OF 6-10 min (600 °C)	100 OF (55 °C)	Vacuum	1742 OF (950 °C)	"	1 min	Slow Cooling	Glossy	As needed
<u>Add-Ons:</u>									
	1112 OF 6-10 min (600 °C)	100 OF (55 °C)	Vacuum	1706-1725 OF (930-940 °C)	"	0	Slow Cooling	Glossy	As needed
<u>Glaze:</u> *									
	1112 OF 6-10 min (600 °C)	100 OF (55 °C)	Air	1760 OF (960 °C)	N/A	As needed	Slow Cooling	Natural Luster	Thin layer

* Do not start the drying until the color tags have been burned off, and the porcelain turns "white".

--SECTION 2: ATTACHMENT 6--

WILL-CERAM PORCELAIN

GENERAL INFORMATION

GRAIN SIZE: Mixed-grained

THERMAL EXPANSION: Medium Expansion

AVAILABLE SHADES: Vita-Lumin (A-1 thru D-4); Bioform (59-82); Extended Bioform (51-56 and 91-96); and Ivoclar (D01 thru D6) Series.

MANUFACTURER:

Williams Gold Refining Company
2978 Main Street
Buffalo, New York 14214

TOLL-FREE PHONE NUMBER:
1-(800) 828-1003 HOTLINE
1-(800) 462-7688 (in New York State)
1-(800) 852-7066 (in California)
1-(800) 824-7925 (west of the
Rocky Mountains)

COMMERCIAL PHONE NUMBER:
1-(716) 837-1000

TELEPHONE CONTACTS:

Education Department
1-(800) 828-1538

REGIONAL SALES REPRESENTATIVES:

Yes

COST: The unit price for each type and size of porcelain is listed with the per gram(g) price in parentheses.

	<u>20 grams (per g)</u>	<u>80 grams (per g)</u>	<u>240 grams (per g)</u>
opaque	\$ 10.16 (\$ 0.51)	\$ 37.15 (\$.46)	-
dentin	" "	" "	\$ 140.16 (\$ 0.43)
enamel	" "	" "	" "
shoulder porcelains	\$ 13.40 (\$ 0.67)	N/A	N/A
	<u>3.5 grams (per g)</u>		
stains	\$ 7.01 (\$2.00)		

WILL-CERAM PORCELAIN FIRING SCHEDULE

PORCELAIN	DRYING TEMP. TIME	RATE OF RISE (° per min.)	ENVIRONMENT	MAX. TEMP.	ENVIRONMENT	HOLD TIME	COOLING	APPEARANCE	DESIRED THICKNESS
<u>Opaque:</u>					(Slowly break vacuum at max. temperature)				
1st Layer	1000 OF 6 min (538 OC)	90-100 OF (50-55 OC)	Vacuum	1830 OF (999 OC)	Air	30-60 sec	Slow Cooling	Eggshell Glisten	Thin skim
2nd Layer	1000 OF 6 min (538 OC)	90-100 OF (50-55 OC)	Vacuum	1830 OF (999 OC)	Air	30-60 sec	Slow Cooling	Eggshell Glisten	0.2 mm
<u>Dentin and Enamel*</u>									
1st Bake	1000 OF 6 min (538 OC)	90-100 OF (50-55 OC)	Vacuum	1760 OF (960 OC)	Air	30-60 sec	Slow Cooling	Orange Peel (High Bisque)	1 mm
2nd Bake	1000 OF 6 min (538 OC)	90-100 OF (50-55 OC)	Vacuum	1760 OF (960 OC) or maturing pt.	Air	0	Slow Cooling	Orange Peel (High Bisque)	As needed
<u>Add-Ons:*</u> (20-25% GLAZE powder added to body or incisal porcelain)									
	1000 OF 6 min (538 OC)	90-100 OF (50-55 OC)	Air	1760 OF (960 OC)	N/A	30-60 sec	Slow Cooling		As needed
<u>Glaze:*</u>									
	1000 OF 3-5 min (538 OC)	90-100 OF (50-55 OC)	Air	1760 OF (960 OC)	N/A	30-60 sec	Slow Cooling	Natural luster	Thin layer

* Do not start the drying until the color tags have been burned off and the porcelain turns "white."

--SECTION 2: ATTACHMENT 7--

COST COMPARISON OF VARIOUS DENTAL PORCELAINS (per gram)

BRAND	OPAQUES	DENTIN or ENAMEL	STAINS	SHOULDER POWDERS	OPACOUS DENTIN
Artis-Tech					
1,4 or 8 oz.	\$ 0.28	\$ 0.28	-	-	-
6.5 g	-	-	\$ 1.48	-	-
Crystar					
10 g	-	-	-	\$ 1.12	-
15 g	\$ 0.55	\$ 0.55	-	-	-
50 g	\$ 0.48	\$ 0.48	-	-	-
200g	\$ 0.49	\$ 0.49	-	-	-
5 g	-	-	\$ 1.60	-	-
Jelenko					
15 g	\$ 0.50	\$ 0.50	-	-	-
25 g	\$ 0.50	\$ 0.50	-	-	-
175 g	-	\$ 0.46	-	-	-
5 g	-	-	\$ 0.72	-	-
Shademate					
8 g	-	-	\$ 1.42*	-	-
1 oz	\$ 0.50	-	-	-	-
4 oz	\$ 0.45	-	-	-	-
8 oz	\$ 0.41	\$ 0.30	-	-	-
3 g	-	-	\$ 2.05	-	-
Vita					
12 g	\$ 0.57	\$ 0.57	-	\$ 0.57	\$ 0.57
50 g	\$ 0.53	\$ 0.57	-	-	\$ 0.53
250 g	\$ 0.46	\$ 0.46	-	-	-
3 g	-	-	\$ 3.20	-	-
Will-Ceram					
20 g	\$ 0.51	\$ 0.51	-	\$ 0.67	-
80 g	\$ 0.46	\$ 0.46	-	-	-
240 g	-	\$ 0.43	-	-	-
3.5 g	-	-	\$ 2.00	-	-

(-) = not available at this time

* = dentin and enamel shading porcelains

NOTE: All price quotations are for minimum orders. Many manufacturers offer additional discounts for volume purchases. Consult a company representative for current pricing.

SECTION 3:

ALLOYS FOR THE PORCELAIN-FUSED-TO-METAL RESTORATION

3-1. INTRODUCTION

Hundreds of the casting alloys on the market today reportedly possess the capability to bond to dental porcelain.^{1,2} What makes these porcelain alloys different from one another, and from the alloys used in crown and bridge, is their composition. An appreciation of the chemistry of dental casting alloys is helpful in understanding why an alloy system has been developed, and how it is intended to work. Each component (element) in an alloy plays a particular role by contributing specific properties and characteristics to the metal. These properties can be altered in the presence of other ingredients, yet the end result generally is an alloy carefully shaped by a skillful metallurgist.

This section begins with a brief review of the chemistry of alloys; presents the American Dental Association (A.D.A.) casting alloys classification system; discusses an alternative system of classification; provides an historical account of the evolution of the various porcelain-fused-to-metal (PFM) systems; introduces general descriptions of the "alternatives" to gold-base PFM alloys; and examines various topics related to PFM technology. In subsequent sections, various non-gold base PFM alloy alternatives are discussed individually and in greater detail, and processing instructions are included.

3-2. THE CHEMISTRY OF PORCELAIN-FUSED-TO-METAL ALLOYS

To appreciate the capabilities and limitations of any porcelain alloy, having at least a general familiarity with the process of alloy development is helpful. Today's metallurgist may first create a new alloy, not in the laboratory, through trial and error, but at a computer terminal using a computer-generated "model." Since the computer stores the properties of the constituents to be added, the percentage composition of each element can be manipulated to produce the desired properties for a new alloy. Although the process may appear simple, it is indeed complex, and requires laboratory testing and experimentation. Other factors--such as the purity of each ingredient (element), and the sequence in which each component is added--can also affect the quality of the final result. This is an important point; for it indicates that two alloys may not perform similarly, despite the fact that they appear to contain the same elements in the same percentages.

Competition is so keen in the alloys market that commercially successful products are often duplicated by competitors. These "copycat" alloys may lack a particular trace element or a unique processing step, since the exact manufacturing procedure is kept secret by the developer. The end result is varying performance among what appear to be comparable products. One of the best examples of this phenomenon is the interest in the high palladium alloys with 2% gold. Several variations on the basic formulation of 79% palladium and 2% gold have been offered to the consumer. What few people realize is

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that two distinct groups of alloys--a copper and a cobalt group have this same apparent composition. Each group has its own particular advantages and disadvantages, as will be discussed in subsequent sections. Although some clinicians and technicians might assume that all the products with this composition are the same, this assumption is not always valid.

To better understand the composition of PFM alloys and how these alloys differ, it is helpful to review some basic chemistry and to appreciate the properties of alloy constituents.

a. What Is A METAL?

As familiar as metals might appear, they are not easy to describe in one simple definition.³ Generally, in a normal environment, metals are crystalline solids--with the exception of mercury and possibly gallium, which are actually liquids (30 °C melting point), and hydrogen, which is a gas.³ Metals usually are harder, stronger, more dense than non-metals, and they have a luster to them. They are good conductors (thermal and electrical), and are more ductile and malleable than non-metals. There are also several different types of metals: noble, light, heavy, ductile, brittle, low melting, high melting, rare earth, and radioactive.³ Most of the metals are frequently described also as "white,"³ but are actually gray or "platinum" colored. Two exceptions to this generalization are gold and copper,³ which are colored yellow (orange) and red, respectively.

b. What Is An ALLOY?

One definition describes an alloy as "a metal that is a mixture of two or more metals."⁴ However, an alloy is actually a combination of two or more elements, with metallic elements comprising the majority of the mixture.⁵ Very few pure metals are used in dentistry, because the elements in the pure state do not possess properties required for dental applications, the one notable exception being gold direct filling materials (gold foils).

c. What is a PORCELAIN-FUSED-TO-METAL ALLOY?

Four major features distinguish a porcelain-fused-to-metal alloy from those alloys used to fabricate all metal crowns (e.g., Type III gold)--

First: A PFM alloy must be able to oxidize, or produce oxides, for chemical bonding with dental porcelains. As an example, the major elements in the non-precious alloys are non-noble. Therefore, they possess an inherent, or natural, tendency to undergo oxidation when subjected to the elevated temperatures of a porcelain furnace. The precious alloy, in particular the high noble metal systems, behave in just the opposite manner. The noble metal components will not oxidize when heat treated. In order to make these noble alloys suitable for the porcelain-fused-to-metal restoration, trace amounts

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of non-noble metals are added to the alloy formulation for oxidation to occur. Section 4 explores the subject of porcelain adherence to metal in much greater detail. Crown and bridge alloys also contain oxidizable elements, although they are not added for bonding purposes as in porcelain alloys.

Second: A PFM alloy must be formulated so its coefficient of thermal expansion is slightly greater than that of the dental porcelain to maintain the metal-porcelain bond. In other words, even though oxides form and the metal chemically bonds to the porcelain, fracture of the porcelain may occur, if the metal and the porcelain are not thermally compatible.^{6,7}

Third: The metallurgist must balance the first two requirements with the technician's demand for ease of handling. Processing should not be too technically demanding. Any alloy that is difficult to melt, cast, finish, and polish could lose favor, despite its excellent bond strength and thermal properties. A good example of this is the resistance by many to switch from precious alloys to less expensive, non-precious alternatives.

Fourth: A casting alloy should be biocompatible. The safety of the technician, the clinician, and the patient must NOT be at risk as a result of the use of a casting alloy, particularly if satisfactory alternatives are available. Such a requirement should be directed at both local (intraoral) and remote effects (systemic) of physical exposure and/or tissue contact with an alloy. The biocompatibility of non-gold dental casting alloys is addressed separately, and in greater detail, in Section 12.

d. The Role of Constituent Elements

The following is an alphabetical listing of many of the elements which might be included in a casting alloy.⁸ The exact role a particular element may play in any given alloy could vary from alloy system to alloy system.^{3,9} Yet, an appreciation of any system can only be gained through examination of the properties of the components of that system.

ALUMINUM (Al) - is added to lower the melting range of a nickel-base alloy. Al is a hardening agent and influences oxide formation. With the cobalt-chromium alloys used for porcelain-fused-to-metal restorations, it is mainly aluminum which is "etched" from the alloy's surface to create microretention for resin-bonded retainers (Maryland Bridges).

BERYLLIUM (Be) - like aluminum, lowers the melting range of nickel-base alloys, improves castability, is a hardener, and helps control oxide formation. Beryllium reportedly also improves the polishability of an alloy by acting as a lubricant for polishing agents, permitting them to work more effectively. The etching of nickel-chromium-beryllium alloys removes a Ni-Be phase to create the microretention so important to the etched metal resin-bonded retainer.

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- BORON (B) - is a deoxidizer. For nickel-base alloys, it is a hardening agent and an element which reduces the surface tension of the molten alloy, thereby improving castability.⁵ The nickel-chromium beryllium-free alloys which contain boron will pool on melting, as opposed to the Ni-Cr-Be alloys which do not. Boron also acts to reduce ductility and to increase hardness.
- CHROMIUM (Cr) - acts as a solid solution hardening agent, and contributes to corrosion resistance by its "passivating" nature in nickel, cobalt, and iron-base alloys.⁵
- COBALT (Co) - is an alternative to the nickel-base alloys, but the cobalt-base metals are more difficult to process (due to their hexagonal close-packed atomic structure). Cobalt is added to some high palladium base alloys to increase the coefficient of thermal expansion, and to serve as a strengthening agent.⁵
- COPPER (Cu) - serves as a hardening and strengthening agent; lowers the melting range; and interacts with platinum, palladium, silver, and gold to provide a heat-treating capability in gold-, silver-, and palladium-base alloys. In the high palladium-copper alloys, copper helps form an oxide for porcelain bonding, lowers the density slightly, and can enhance passivity.
- GALLIUM (Ga) - is added to silver-free ceramic alloys to compensate for the decreased coefficient of thermal expansion created by the removal of silver. (Concerns over silver's potential to discolor dental porcelain have greatly limited its use in systems other than palladium-silver.)
- GOLD (Au) - provides a high level of resistance to corrosion and tarnish (no associated passivity); and slightly increases the melting range of an alloy while improving workability and burnishability. Gold can impart a very esthetically pleasing yellow hue to the alloy if present in sufficient quantity. However, this yellow color is readily offset by the addition of gray metals, such as palladium and silver. Gold raises the density and the cost of an alloy as well. Gold is both a **NOBLE** and a **PRECIOUS** metal.
- INDIUM (In) - serves many functions in gold-base alloys: it is a less volatile scavenging agent; lowers the alloy's melting range and density; improves fluidity; and has a strengthening effect. Indium is added to non-gold-base alloy systems to form an oxide layer for bonding to dental porcelain. For alloys with a high silver content, indium contributes to the tarnish resistance.
- IRIDIUM (Ir) - serves as a grain refiner for gold- and palladium-base alloys to improve the mechanical properties and the tarnish resistance as compared to non-grain refined dental alloys. Ir is a member of the platinum-palladium group (often referred to as simply the "platinum group"), and is both a **NOBLE** and a **PRECIOUS** metal.

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- IRON (Fe) - is added to some gold-base ceramic systems to harden the alloy and aid in the production of an oxide layer for porcelain bonding. Iron is also included in a few non-precious alloys, and at least one iron base porcelain-fused-to-metal alloy is available.⁵
- MANGANESE (Mn) - is a hardening agent in nickel, cobalt, and iron base alloys, but its primary function is to act as an oxide scavenger. In this capacity, Mn helps prevent the oxidation of other elements when the alloy is being melted.
- MOLYBDENUM (Mo) - can be helpful in adjusting the coefficient of thermal expansion of nickel-base alloys. Molybdenum also improves corrosion resistance, and influences the oxides produced for porcelain bonding.
- NICKEL (Ni) - has been selected as a base for porcelain alloys because its coefficient of thermal expansion approximates that of gold, and because it provides a resistance to corrosion. The face-centered cubic atomic structure of Ni makes it easier to process than the cobalt-chromium non-precious alloys. Unfortunately, nickel is a sensitizer, and approximately 10% of the female and less than 1% of the male population may be allergic to it.
- PALLADIUM (Pd) - is added to increase the strength, hardness (with copper), corrosion and tarnish resistance of gold-base alloys. Pd will also elevate an alloy's melting range and improve sag-resistance. It has a very strong whitening effect in an alloy, so even an alloy with 90% gold and 10% palladium will appear white (platinum). Palladium possesses a high affinity for hydrogen, oxygen, carbon.⁵ and lowers the density of the gold-base alloys slightly, but has little effect on silver-base metals in this regard.⁵ Palladium, a member of the platinum group, is both a **NOBLE** and a **PRECIOUS** metal.
- PLATINUM (Pt) - increases the strength, melting range, and hardness of gold-base alloys, while improving their corrosion, tarnish, and sag resistance. Platinum is one of the gray metals which whitens an alloy, and increases the density of non-gold-base alloys due to its high density. Platinum is a member of the platinum group, and is both a **NOBLE** and a **PRECIOUS** metal.
- RUTHENIUM (Ru) - acts as a grain refiner for gold- and palladium-base alloys to improve the mechanical properties and the tarnish resistance (like iridium). Ruthenium is a member of the platinum group, and is both a **NOBLE** and a **PRECIOUS** metal.
- SILICON (Si) - serves primarily as an oxide scavenger to prevent the oxidation of other elements during the melt. Like manganese, Si also acts as a hardening agent.

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SILVER (Ag) - imparts a moderate increase to the strength and hardness of gold-base alloys (with copper), while lowering their density. In gold-base and palladium-base PFM alloys, silver lowers the melting range by counteracting the influence of palladium. In gold and gold-palladium alloys, silver improves fluidity and helps control the coefficient of thermal expansion.⁵ Silver-containing porcelain alloys have been known to produce a greenish discoloration (green or brown) with some porcelains. Silver possesses a rather high affinity for oxygen absorption which can lead to casting porosity and/or gassing. However, small amounts of zinc or indium, in gold- and silver-base alloys, can help control silver's absorption of oxygen. Silver will also corrode and tarnish in the presence of sulfur. Although silver is a **PRECIOUS** metal, it is not universally regarded as a **NOBLE** metal.

TIN (Sn) - serves as a hardening agent, and tends to decrease the melting range of an alloy. Sn also assists in the production of an oxide layer for porcelain bonding in gold- and palladium-base alloys. Tin is one of the key trace elements for oxidation with the palladium-silver alloys.

TITANIUM (Ti) - like aluminum and beryllium, is added to lower the melting range and to improve castability. Titanium also acts as a hardener and influences oxide formation at high temperatures.

ZINC (Zn) - helps lower the melting range of an alloy, acts as a deoxidizer or scavenger to combine with other oxides present. Zinc improves the castability of an alloy and, when combined with palladium, contributes to hardness. Zinc is also commonly included in gold alloy solders.

3-3. CLASSIFICATION OF DENTAL CASTING ALLOYS

The next step is to group or classify metals in some logical order or arrangement. Several accepted methods for classifying alloys are generally accepted, but no single system has yet to become an established standard. In fact, many different descriptions of alloys can be found in both the dental literature and in marketing information supplied by a manufacturer. As a result, it is quite a challenge to keep track of all the "new" and "improved" alloys that enter the marketplace. Moreover, it is extremely difficult to group similar materials for comparative purposes, if we do not know either an alloy's composition or how to best classify a particular metal.

The aim of each classification method may vary in itself. One system may be based on function, while others may be established for reasons of cost, use, or alloy composition. One of the oldest and simplest classification methods is the traditional reference to **function**.^{1,4} Five categories are used, with the first four describing crown and bridge alloys and only the fifth depicting the porcelain-fused-to-metal alloys. Each crown and bridge alloy classification, or type, is associated with its level of hardness.

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a. Alloy Classification Based on Function

- Type I (soft) - for small **inlays**, because the metal is easily burnished and only capable of withstanding very slight stress.³ Vickers hardness range is 50-90 (quenched).³
- Type II (medium) - for larger **inlays**, some 3/4 crowns, retainers, pontics and full crowns, if subject to moderate stress.³ Vickers hardness range is 90-120 (quenched).³
- Type III (hard) - for thin 3/4 crowns, retainers, pontics, **full crowns**, short-span **fixed partial dentures**, and inlays able to withstand high stress. Type III alloys can be heat treated for age hardening.³ Vickers hardness range is 120-150 (quenched).³
- Type IV (extra hard) - for inlays subjected to very high stress, full crowns, long-span fixed partial dentures, and **removable partial denture frameworks**. These alloys can also be age hardened.³ Vickers hardness is 150+ (quenched).³
- Metal-Ceramic (hard and extra hard) - compatible with dental porcelain. The hard type are used for copings, thin-walled crowns and short fixed partial dentures, while the extra hard type may be used for long-span fixed partial dentures.³

This method of classification was most helpful before the introduction of PFM alloys, when the alloys in question (Type I-IV) were all gold-base and used exclusively for crown and bridge.⁵ With the development and introduction of the silver-, palladium-, nickel-, cobalt-, iron-, and mixed-base PFM alloys, comparisons based on hardness are no longer valid because alloys with the same hardness value, but from a different alloy base (silver, palladium, etc.), generally do not possess the same strength characteristics.⁵

b. Alloy Classification Based on Color or Composition.

A second method of classification is to describe the alloys according to their **color** and the **principal element** (or elements).^{3,10,11} The number of subcategories varies in different sources from four to eleven.³

Yellow golds - yellow color, with greater than 60% gold content.³

White golds - white color, but with more than 50% gold content.³

Low (or economy) golds - usually yellow colored, with less than 60% gold (usually 42-55%).

Palladium - white colored, with palladium the major component.⁴ May contain small quantities of gold (2%) and a limited amount of either copper or cobalt.³

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Silver-palladium - white colored, predominantly silver (55-71%) with substantial amounts of palladium (25-27%) to provide nobility and to help control tarnish. May or may not contain small amounts of copper or gold.^{3,9}

Palladium-silver - white colored, with palladium the major component, plus a substantial quantity of silver (up to approximately 40%).

c. The A.D.A. Classification System for Cast Alloys

The Council on Dental Materials, Instruments and Equipment of the American Dental Association prepared a new classification system for cast alloys based on **noble metal content**. The system was devised for identification in dental procedure codes only, where the value of the metal may influence the amount of reimbursement from insurance carriers. It was not meant to indicate performance levels. The classification system was published in the Journal of the American Dental Association and is repeated in Fig. 3-1¹²:

<u>Classification</u>	<u>Requirement</u>
HIGH NOBLE - - - - -	Noble Metal Content \geq 60% (Gold, Platinum, Palladium) and Gold \geq 40%
NOBLE - - - - -	Noble Metal Content \geq 25%* (Gold, Platinum, Palladium)
PREDOMINANTLY BASE - - - - -	Noble Metal Content $<$ 25% (Gold, Platinum, Palladium)

* There is no upper limit. This is to accommodate high noble metal content alloys with less than 40% gold.

Figure 3-1. This is the American Dental Association classification system for gold and non-gold base dental casting alloys.¹²

d. A Classification System for Non-Gold Base Dental Casting Alloys⁹

The recently developed A.D.A. classification system is perhaps most helpful when completing insurance forms, as it permits some measure or comparison of the relative cost of dental casting alloys. This information can be interpreted by dental insurance carriers in their review of claims for reimbursement. Apparently, this is all this classification system was intended to accomplish. It does not group, order, or otherwise arrange the multitude of alloys which have flooded the dental market. Nor does it help identify any subcategories within each of the three major divisions.

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For example, non-gold base alloys for the PFM restoration (Fig. 3-2)¹² are not readily identifiable from the A.D.A. system of classifications (Fig. 3-1):¹²

1. THE HIGH PALLADIUM ALLOYS
 - a. Copper Group
 - b. Cobalt Group
2. THE PALLADIUM-SILVER ALLOYS
3. THE NON-PRECIOUS ALLOYS
 - a. Nickel-Chromium-Beryllium Group
 - b. Nickel-Chromium-Beryllium-Free Group
 - c. Cobalt-Chromium

Figure 3-2. These are the non-gold base "alternative" alloys which may be used to produce porcelain-fused-to-metal restorations.

In an effort to address this particular problem, an alternative system of classification was developed and presented in Non-Gold Base Dental Casting Alloys, Volume I: Alternatives to Type III Gold.⁹ Figure 3-3 depicts this alternative classification system. Note that all metals are first separated into one of two major types, precious or non-precious, and then arranged by system; each system is further broken down into its constituent groups, if present. Alloys are classified according to their composition, with the name of the major component listed first and the second largest element in the alloy listed next. Key trace, or minor alloying elements which distinguish the performance or the properties of alloys in the same system are used to identify such subcategories as groups.

This classification method is simple and easy to learn. Since it requires the identification of an alloy's composition for placement in the system, the method makes the use of the A.D.A. classification that much easier. More importantly, this system, and the general descriptions of the various alloy systems and groups, are useful in classifying alloys according to function.

e. Levels of Content

Gold-base alloys containing less than 70% gold are often referred to as "low" gold content metals, despite the fact that this single constituent may actually account for the majority of the alloy's composition (>50%). Therefore, use of the designation "low" may be confusing when alloys with 10% and 69% of any one element are placed in the same classification, although they differ markedly in actual composition.

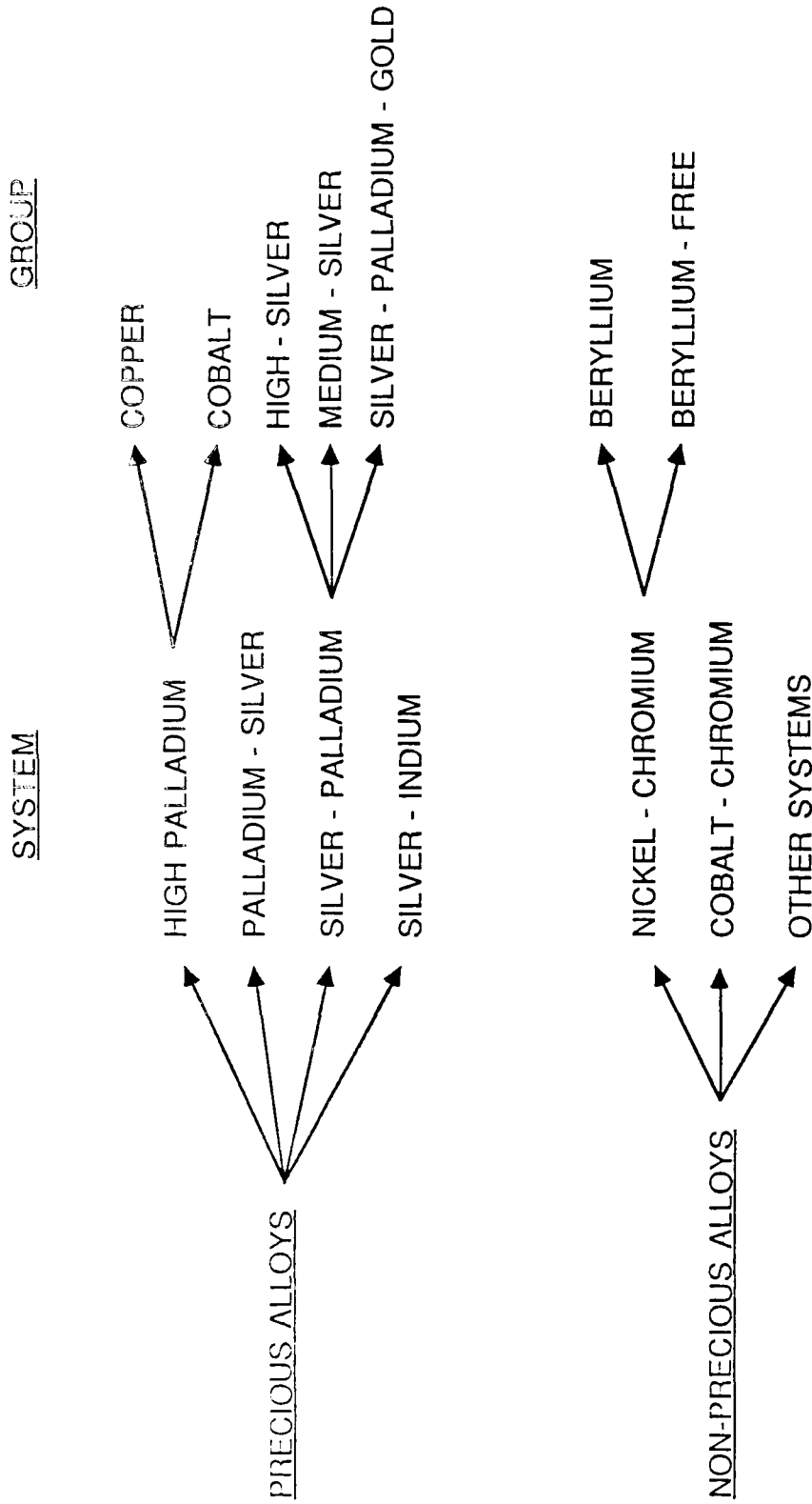


Figure 3-3. A classification system for non-gold base dental casting alloys.

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In an attempt to avoid potential misinterpretations, the designations "low," "medium," and "high" are assigned the following values for their use in this classification system and text:

a) LOW = 0-33%; b) MEDIUM = 34-66%; and c) HIGH = 67-100%

This simple division of the total composition of an alloy into thirds permits classification of an alloy in a more recognizable and understandable format. This division also encourages the use of more meaningful terminology, and discourages the use of vague identifiers such as "palladium-rich." At the same time, it must be understood that the desired physical, mechanical, and thermal properties of a particular alloy are influenced not only by the constituent metals used to produce the alloy, but also by the purity of the ingredients as well as the sequence in which the elements are added during the melt. In addition, variations in minor alloying elements have produced numerous alloys which differ in properties and features, yet outwardly appear quite similar in composition.

It may prove helpful here to understand the historical background which led to the development of these alternative alloys.

3-4. AN HISTORICAL VIEW OF CASTING ALLOY DEVELOPMENT¹³

Although the practice of dentistry can be regarded as hundreds of years old, the PFM restoration is a relatively recent addition to dentistry. Despite its brief history, the progress of the PFM restoration has been rather rapid, and often influenced by rather dramatic events.

The 1940's

A dental porcelain-metal system was reportedly developed by Coleman in the 1940's.⁵ Unfortunately, a copper oxide-dental porcelain reaction produced an unacceptable discoloration.⁵

The 1950's

Dr. Abraham Weinstein is often credited as being the first individual to devise a system whereby dental porcelain could be fused to metal.¹³ In the 1950's, Dr. Weinstein developed an alloy which contained 84% gold, 10% platinum, 2% palladium, 3% silver, 0.5% indium, and 0.4% tin. At that time, gold was relatively inexpensive, and could readily serve as the base for an alloy. In today's economy, however, gold is far more costly; and the predominant alloy systems in use these days are the non-gold base types.

Unfortunately, this gold-platinum-palladium system was not without its weaknesses. The alloy's high melting point (2130 °F) made it nearly impossible to melt with conventional gas-air, and difficult to melt with gas-oxygen.

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This melting temperature also was well beyond the recommended limits for the gypsum-bonded investments which were in common use for crown and bridge alloys. Once cast, the alloy's yield strength (16,500 psi) and hardness (90) were quite low, and equivalent to a Type II crown and bridge alloy. This finding made the gold-platinum-palladium alloy only marginally acceptable for single unit crowns, and highly questionable for fixed partial dentures.

The 1960's (prior to 1968)

Many of the initial problems of gold-platinum-palladium alloys were overcome by the addition of 0.5% iron to increase the hardness; by refining the grain structure from coarse to fine, to improve strength; and by developing phosphatebonded casting investments.¹³ However, the modulus of elasticity still remained too low for the demands of long-span fixed partial dentures. In addition, the thermal stability of the alloys was poor and needed improvement.

Prior to 1968, the chief direction of alloy research and development focused on refining the gold-platinum-palladium system. Many of the lingering problems with that system were found to be resolved by reducing the gold content slightly and by adding more palladium. The major drawback to this apparent simple alteration in the alloy formulation was the whitening of the metal. The increased palladium content changed the alloy from a yellow color to a white or platinum hue.

The Year 1968

In 1968, for the first time in history, the government removed price restrictions on gold and allowed it to float on the open market. In other words, the previously fixed price of \$35.00 per oz was removed, and gold was permitted to sell according to the dictates of supply and demand. This particular event was one of the more significant factors to influence the development of alternative systems.

Aside from these economic considerations, work was also underway to improve the high temperature strength of the gold-base alloys to increase sag resistance.⁵ Researchers elected to lower the gold content, to remove platinum altogether, and to add silver. Thus was born the gold-palladium-silver system. An alloy from this system would usually contain: 50-60% gold; 20-30% palladium; 10-15% silver; and the balance, indium and tin, for oxide formation.^{5,13} The higher palladium content resulted in a 100 °F elevation in the melting range of the alloy, thus further separating the fusion temperature of the dental porcelain from the melting range of the alloy. The net result was greater thermal stability. As with all the preceding systems, there were problems with these alloys. The high silver content was found to be responsible for discoloration of the dental porcelain. During the porcelain firing process, silver vaporized from the exposed metal surface, and tended to "green" at the porcelain-metal junction. The silver vapors often collected in cool areas of the porcelain furnace where they would later re-vaporize, and even contaminate, subsequent non-silver-containing restorations.

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Special metal conditioners were then developed in an effort to control the greening problem, but they were not always 100% successful. More importantly, they added one more step and also required more time to complete the processing.

One other major system was also introduced in 1968: the nickel-chromium-beryllium alloys. Since the price of gold at that time was approximately \$38.00 per ounce, there was no real incentive to adopt a system that was much more difficult to process. By 1976, however, gold had risen to \$130.00 per oz; and 25% of the alloy market had been taken over by the nickel-chromium-beryllium alloys. (In 1980, the price of gold rocketed to \$800.00 oz; and the nickel-chromium-beryllium alloys captured approximately 50% of the market.)

The Year 1974

Despite the apparent successes of the gold-palladium-silver alloys, research continued to develop less expensive porcelain-fused-to-metal alloy systems. Then, in 1974, the palladium-silver system was introduced. This was quite a departure from the systems which preceded it, because it represented a precious alloy system based on palladium, rather than gold. The formulation had to be rather precise and well balanced, since silver lowers an alloy's melting range while increasing its coefficient of thermal expansion. The general formula for the palladium-silver system was: 55-60% palladium, 25-30% silver, plus 10-20% indium and tin.

These alloys appeared to offer handling characteristics similar to those of the gold-palladium-silver metals, but at only a fraction of their cost. Like every other system to date, the palladium-silver alloys have their weaknesses. First, silver has the potential to discolor some dental porcelains and contaminate porcelain furnaces. Second, these alloys have a rather high coefficient of thermal expansion to accommodate U.S. porcelains, rather than porcelains manufactured abroad. The first problem was addressed by the development of metal conditioners to create a physical barrier and prevent silver contact and contamination of the porcelain. However, measures of this type were found to be more time consuming, and did not always ensure success. Moreover, proper furnace decontamination procedures may not have been followed. Mismatches of coefficients of thermal expansion were not alterable. This problem further limited the system to the higher expansion dental porcelains (at least, for the average technician).

The palladium-silver PFM alloys evaluated in this project differed in composition from the general formula of the initial examples. A typical alloy might contain 53.5-58% palladium, and 31-39% silver, with approximately 10% indium and tin or tin without indium. More importantly, two dental porcelains are available today which reportedly are resistant to greening when used with the silver-containing alloys, Will-Ceram* and Artis-Tech**.

The availability of non-greening dental porcelains is apparently not a well-known fact, even to this day. Certainly, in the 1970's, the fear of

* Williams Gold Refining Company, Buffalo, NY.

** Rx Jeneric Gold Company, Wallingford, CT.

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porcelain "greening" simply overshadowed any potential savings accompanying the palladium-silver system. However, many of the criticisms of the palladium-silver system are either unwarranted or no longer hold true for one reason or another. (Clarification of these points will be addressed in this section, as well as in Section 8.) Nonetheless, the search for an even more acceptable system continued.

The Year 1977

In 1977, gold-palladium alloys appeared on the market. Unlike the preceding alloys which were introduced as lower cost alternatives, this particular system was more expensive. These alloys have a composition ranging from 45-55% gold, 35-40% palladium, and 8-12% indium and tin, with 1-2% gallium. However, a general description of a gold-palladium alloy such as Olympia* would be approximately 52% gold, 38% palladium, 8.5% indium, and 1.5% gallium with NO silver. The elimination of silver and the increase in palladium and gold translated into greater cost. Nonetheless, this system succeeded in taking over a tremendous share of the market because of its excellent properties and ease of handling. In addition, with the elimination of silver, these alloys could be used with European dental porcelains. The removal silver also resulted in a lowering of the coefficient of thermal expansion. However, in some cases the coefficient of thermal expansion of these alloys was too low for the higher expansion domestic porcelains. Thus, the weakness of this system centers on its incompatibility with certain dental porcelains. Despite the limitations imposed by silver, some gold-palladium alloys containing 5-6% silver were introduced. This low silver content was sufficient to raise the coefficient of thermal expansion and enhance the alloy's fluidity, without running the risk of discoloration to the dental porcelain (greening).

Despite its cost, the gold-palladium system (without silver) remains extremely popular among consumers of precious PFM alloys.

The 1980's

It was actually about 1979 that the cost of gold started to make its historic rise. Dental alloy consumers had rather difficult decisions to make: continue with gold-base alloys and pay unprecedented prices; switch to palladium-silver alloys, and learn to overcome their special handling requirements; or venture into the realm of non-precious alloys. These choices did not appeal to everyone, and the search for alternatives continued.

Despite the added technical demands, non-precious alloys were viewed as an economic salvation by many. The predominant choice was the older nickel-chromium-beryllium alloys. Yet, rising concerns for the potential health threat posed by beryllium led to the development of the nickel-chromium-beryllium-free alloys. This alternative group does not appear to be used as

* J. F. Jelenko & Co, Armonk, NY.

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widely as the nickel-base metals containing beryllium. More importantly, beryllium-free alloys still contain nickel and require the same precautions for patients and technicians as the nickel-chromium-beryllium alloys.

The only major departure from tradition in the non-precious arena was, and continues to be, the promotion of the non-nickel, non-beryllium non-precious alloys from the cobalt-chromium system. For years these cobalt-base alloys had been used for removable partial denture framework construction. With all the unresolved concerns for the biocompatibility of nickel and beryllium, why not introduce cobalt-base metal porcelain alloys? Thus, these removable partial dental alloys were reformulated for bonding to dental porcelain. The marketing for these particular alloys has been much better than their performance. The major weaknesses of these alloys over the nickel-base groups are excessive oxidation, bond failure, and difficulty in pre-soldering.

The early 1980's also brought us yet another system, the high palladium alloys. Some of the initial alloys appeared on the market with 79% palladium, 2% gold, and undisclosed quantities of cobalt, copper, tin, gallium, or other trace elements for oxide formation. In some instances, the 2% gold content has been modified to 1% gold and 1% platinum, or completely eliminated with a palladium content between 74% and 88%. These variations on the basic theme of 79/2 have been and continue to be quite numerous. The addition of 2% gold has more commercial value than metallurgical benefit, since it is too small a percentage to affect the alloy structurally. With only 1-2% gold, these metals should not be referred to as palladium-gold or gold-palladium, but identified simply as high palladium alloys and categorized as either a member of the copper- or the cobalt-group. The designation, gold-palladium or palladium-gold, might convey a meaning which is not truly reflected by the composition of the alloy.

The excitement these high palladium alloys first generated has now been dimmed to some degree, as the system's weaknesses gradually have surfaced. Some of the problems with this system, to mention just a few, include: porcelain discoloration by oxides (graying and bluing); the opening of margins following the application of porcelain (thermal creep); lower sag resistance for fixed partial dentures; reduced polishability; and difficulty pre-soldering.

Despite these limitations, high palladium alloys have become considerably popular, particularly with individuals who remain reluctant to switch to non-precious metals. These alloys have also drawn the attention of non-precious users concerned about the potential health risks associated with continued nickel and beryllium exposure.

And the search for the perfect alloy continues

3-5. ALTERNATIVES TO GOLD-BASE ALLOYS

The classification system for non-gold base casting alloys presented in Fig. 3-3 depicts those alloy systems proposed for both crown and bridge and PFM restorations. It is hoped that the brief review of alloy chemistry, existing classification systems, and the history of PFM alloy development have introduced the subject of PFM alloys sufficiently to facilitate explanation of this proposed classification system.

The concept for this classification method has been kept simple to permit the insertion of new alloy systems by those who wish to adopt it. However, the format is intended to permit rapid identification of an alloy, even if it is unfamiliar to the reader. Placement of an alloy in the classification system should be of value in appreciating generally accepted beliefs about a selected alloy system.

Nonetheless, the performance of any specific product within a particular category can not be derived from generalizations of this kind. Variations in minor alloying elements and contaminating elements have resulted in alloys with different properties, features, and clinical performance.¹⁴

To make this introduction to non-gold base alloys less confusing, only general descriptions of the PFM alloy systems will be provided here. More detailed information and technical instructions for the processing of representative alloys appear in the individual sections devoted to each major system or group (Sections 6-11).

a. Precious Alloys

Each alloy must first be assigned to one, and only one, of two major categories for any alloy: precious or non-precious (base metal). If an alloy contains members of the platinum group, gold, and/or silver, for example, then it may be considered **precious**. However, if these elements are absent, or present in a very small quantity, then the alloy is presumably **non-precious**.

Let us first assume that an alloy is indeed **precious**, and proceed under that basic premise. At present, there are four recognized systems which are non-gold base, or do not contain substantial quantities of gold. Two of those systems contain 2 or 3 subcategories, which we have termed "groups." In addition, only 2 of the systems are for porcelain-fused-to-metal alloys, the remaining 2 are limited exclusively to crown and bridge use (i.e., full metal castings).

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PRECIOUS ALLOYS

High Palladium System - The general description of these PFM alloys would include a composition range of palladium from 74-88%, with or without trace amounts (1-2%) of noble metals (gold and/or platinum). There appear to be two major groups of high palladium alloys--those which contain copper, and those which contain cobalt. More alloys are available from the copper group than from the cobalt group.

Palladium-Silver System - A classic generalization of this PFM alloy system is that it contains 60% palladium, with the balance being silver with additions of indium and tin.⁶ However, the exact formulation will vary among manufacturers, and some companies may even market two separate palladium-silver alloys. One alloy may have a palladium level near 60%, with silver just below 30%, and contain both indium and tin. Another may have approximately 54% palladium, as much as 39% silver, and contain tin but no indium. The indium and tin are added for oxide formation and porcelain bonding.

Silver-Palladium System - These are economical, non-gold base crown and bridge alloys developed as alternatives to Type III gold. Historically, they have been classified as though they were one; but there are at least three groups of these silver-palladium alloys: the high-silver group; the medium silver group (contains copper); and the silver-palladium-gold group. These alloys were discussed in detail in Non-Gold Base Dental Casting Alloys: Volume I--Alternatives to Type III Gold.⁹

Silver-Indium System - These crown and bridge alloys contain approximately 25% indium with silver, accounting for the majority of the remaining 75%.¹⁵ They are more expensive than the silver-palladium alloys, and reportedly do not offer any advantages over them.¹⁷ More importantly, no long-term data are available on the corrosion resistance of the silver-indium alloys. Since this is a relatively unknown and untested minor system, it was not included in this project.

b. Non-Precious Alloys

Two generally recognized non-precious (or base metal) systems are in use today: one has a nickel base; and the other a cobalt base. Both of these systems contain chromium as the second largest constituent. (The other non-precious alloys are undoubtedly minor systems and should be approached with caution.)

NON-PRECIOUS ALLOYS

Nickel-Chromium-System - These are PFM alloys which offer such economy that they are additionally used for crown and bridge purposes. The major constituents are nickel (44-52%) and chromium (12-22%), with a wide variety of minor alloying elements. There are two major groups: those which

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contain **beryllium** (1.6-2.0%), and those which are **beryllium-free**. Of the two, the nickel-chromium-beryllium alloys are generally recognized as having the better working characteristics.¹³ It is important to understand that many of the alloys in this system were introduced in the late 1970's. The nickel-base alloys which were introduced in 1968 were the forerunners of this system. The conclusions of the research on alloys more than a decade ago are not always relevant to the products in today's market. However, as will be brought out later, this system continues to be plagued by problems. Nonetheless, nickel-chromium alloys are in widespread use and dominate a portion of the industry.¹⁶

Cobalt-Chromium - Like the nickel-base system, the cobalt-base alloys have been marketed as PFM alloys with the added capability for use in the fabrication of all metal crowns and fixed partial dentures. The cobalt content may range between 53 and 68%, with 25-34% chromium, along with minor alloying elements. There has been some reference to a possible subdivision of the cobalt-base system into two groups--those which contain **ruthenium**, and those which are **ruthenium-free**.¹³ Whether sufficient differences exist to warrant such a division of the cobalt-chromium system remains to be seen. Such a proposal is new, and it is beyond the scope of this project to assess its merits. Although the cobalt-chromium alloys are being promoted as porcelain alloys, they are not regarded with the same favor and level of success as the nickel-chromium system, in particular, the nickel-chromium-beryllium alloys.

Other Systems - This category was established to include those minor systems which are not generally recognized by major manufacturers, but which might appear on the market. These systems would include aluminum-bronze (80-85% copper, 8-10% aluminum, 1-3% nickel, plus iron); beta-brass (60% copper and 40% zinc), and other lesser known entities. The advertising concerning such alloys may appear rather impressive, but usually omits one major feature, the percentage composition. Research on the clinical performance of these systems is scant, because they are not in general use. Caution is urged should these products be recommended for the PFM restoration. (No alloys from this category were included in the project.)

3-6. OTHER IMPORTANT FEATURES OF PORCELAIN-FUSED-TO-METAL ALLOYS

Aside from a basic understanding of the composition and classification of PFM alloys, there are several other items related to these metals which warranted specific discussion.

a. Alloy Packaging and Contents Disclosure

Not all manufacturers provide enough product information on alloy packages to permit easy identification. In fact, some packages list everything but the content. It is important that consumers be completely informed on the materials they use. In order for this recommendation to be put into practice, the alloy

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manufacturers should be encouraged to provide routinely the following information on the package and/or with the technical instructions which accompany an alloy:

1. List all alloying elements.
2. Provide percentage composition for all elements listed.
3. List important properties: density, hardness (Vickers); percentage elongation; yield strength, bond strength (if possible); and coefficient of thermal expansion (state whether it is a high or a low expansion metal to facilitate pairing with a dental porcelain).
4. Identify compatible dental porcelains.
5. Identify incompatible dental porcelains.

Since there is no standardized testing format for porcelain compatibility or bond strength, some manufacturers may be reluctant or unable to provide this information. Other manufacturers may make these data available on request.

If an alloy has been thoroughly tested and evaluated prior to marketing, then such information should be at hand. If these data are not available, it might be an indication of limited, or no, test marketing. The consumer then becomes the tester.

b. Ingot Identification

Precious alloys generally have some form of ingot identification with either the alloy's or manufacturer's name. However, this statement can not be uniformly applied to the non-precious alloy (Figs. 3-4 & 3-5). Several of the alloys tested had neither identifiable markings nor readily recognizable shape which would permit identification of the alloy type or manufacturer.

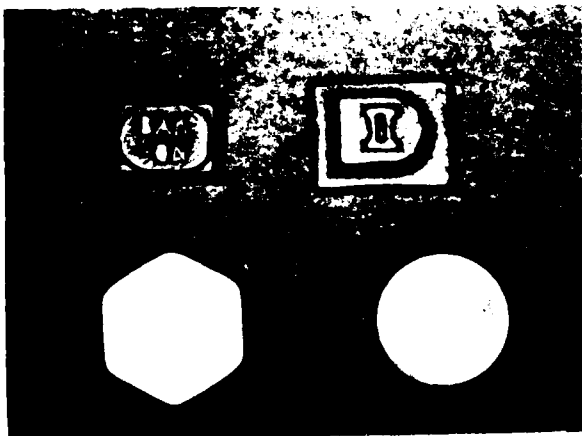


Figure 3-4. Many non-precious alloys do not have any identification on the individual ingots.

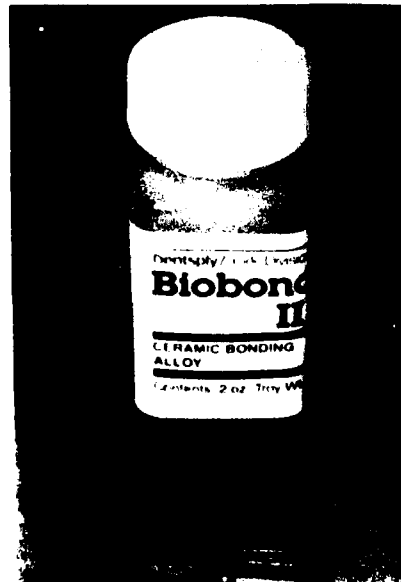


Figure 3-5. In some instances, the ingots can be identified by their shape and/or markings.

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In the absence of ingot identification, there is a greater likelihood of mixing or misuse of materials. This problem can be easily rectified by requiring some sort of product identification to make the alloy recognizable to the consumer. This feature is especially important for facilities where several alloys may be in stock at all times.

c. Ingot Size

In our assessment of each casting alloy, we carefully weighed the contents of every alloy package--not only to assess the size of each ingot, but also to verify the listed weight. Four significant observations were noted as a result of this simple procedure:

First, the majority of precious alloys were manufactured as 2-dwt ingots and all had ingot identification. However, for some alloys, the ingots did not weigh exactly 2 dwt. Therefore, it may be necessary to check each alloy for the level of accuracy per ingot, but expect the total package to weigh the listed amount.

Second, the size of non-precious ingots will vary between brands, from 2 dwt 3 grains (grs) to 4 dwt 4 grs (Figs. 3-6 & 3-7). For example, Novarex* ingots may range in weight from 2 dwt 3 grs to 2 dwt 20 grs, while Forte** ingots will weigh over 4 dwt apiece. The smaller ingots favor the smaller laboratories where single or double unit patterns are cast routinely. On the other hand, the larger dental laboratories derive more benefit from the use of larger size ingots for their multiple unit castings. With the non-precious alloys, in particular, reducing the amount of surface oxidation is important. For multiple castings, the larger ingots minimize the surface area to volume ratio as compared with casting the same weight of metal using numerous small ingots and buttons.



Figure 3-6. The size and weight of some non-precious alloys may vary from ingot to ingot (Rexillium III* shown).



Figure 3-7. Large non-precious ingots invariably generate large buttons of spent metal.

* Rx Jeneric Gold Company, Wallingford, CT.

** Unitek Corporation, Monrovia, CA.

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Third, precious alloys which can be obtained in 1-dwt ingot form, such as Naturelle*, enable laboratories to expend their alloy more efficiently than 2-dwt ingot metals. This point is particularly evident when attempting to control the amount of cast metal by weighing wax patterns. Conservation of resources and prudent management of precious metals can be better obtained through the use of 1-dwt ingots. Scored (or grooved) 2-dwt ingots would be more satisfactory than solid 2-dwt ingots, since an ingot can be separated into 1-dwt halves, if necessary. This option would permit the consumer to be more accurate in selecting the required volume of metal for individual castings. Special metal cutters could conceivably be purchased by users of an alloy sold only in 2-dwt ingots.

Fourth, the use of larger ingot size non-precious alloys invariably leads to the production of large buttons of cast metal (Fig. 3-7). The larger the size of the virgin alloy ingot, the more rapid the accumulation of numerous large buttons, particularly in smaller laboratories. For example, if the wax pattern conversion table calls for 5 dwt 5 grs of metal for a casting, then 2 ingots--of any of the non-precious alloys tested--would be required. With one alloy, the requirement could possibly be met almost exactly. For another, those two ingots would yield a casting 3 dwt heavier than desired; for there was no alternative, since 1 ingot would have been insufficient. The net result would be a 3-dwt button to maintain, and for which a use would have to be found.

d. New (Virgin) Alloy vs. Recast Alloy

One of the major advantages of using precious alloys is that the recast alloy can be easily recycled by enriching it with new (virgin) metal. The specific guidelines vary considerably among manufacturers, but the large majority support a minimum recommendation of 50% new metal added to recast alloy. If the weight of a button is 2 dwt, then 50% of that amount (or 1 dwt) should be added for the casting, assuming of course, that you need 3 dwt of metal after weighing the wax patterns and using the conversion table (Table 1). Other manufacturers would prefer a 1:1 ratio of new metal to recast metal to ensure that the minor alloying elements are replenished.

The non-precious alloys should be handled a bit differently to ensure the attainment of maximum properties. For the etched-metal resin bonded retainer (Maryland Bridge), the general belief now is that all new metal is a more appropriate choice than attempting to enrich recast metal (buttons).

Full metal castings may be produced with the recommended ratios of new metal to recast alloy without much fear, if not overheated. Buttons can certainly be used to cast post and cores, and need not be thrown away.

* Rx Jeneric Gold Co., Wallingford, CT.

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d. Alloy Composition vs. Alloy Performance

Alloy composition is but one aspect to consider in the selection of an acceptable alloy, and should not be considered the sole criterion when purchasing a new metal. The fact that two alloys have the same percentage composition for the major constituents listed on the packaging label is NO GUARANTEE THAT THE TWO ALLOYS WILL PERFORM SIMILARLY. If your alloy has a history of proven success with your dental porcelain, there is no assurance a lesser priced alloy, of similar make-up, will have the same predictable results. Do not permit substitutions which have not been fully tested by you with your particular brand of porcelain.

Small changes to the minor alloying elements, major differences in the purity of raw materials, or differences in the alloy manufacturing process (quality control, in-house refining of ingredients, etc.) are features the consumer can not assess from an alloy package.

The Dental Laboratory Officer and the NCOIC of the Dental Laboratory should be solely responsible for the selection of dental casting alloys. No substitutions should be considered without their expressed approval; for there are no guarantees of comparable performance, based solely on the information included on alloy packaging.

3-7. THE ROLE OF SILVER IN PORCELAIN DISCOLORATION

This is no single, generally accepted explanation of how or why silver reacts with dental porcelain to produce discolorations. The explanations proposed are simply theories, advanced to describe the possible mechanisms of porcelain "greening." There are only two companies which market dental porcelains which are reportedly resistant to discoloration when used with silver-containing alloys. The chemical features of these dental porcelains are unique in this regard, and the secret to their success is considered proprietary information.

The older porcelain system is Will-Ceram*, and (as stated in Section 2) it is available in four shade ranges. Artis-Tech** was introduced in the Fall of 1984 and is available in two shade ranges. No porcelain discoloration was observed with either porcelain when using the palladium-silver alloys.

Aside from Will-Ceram* and Artis-Tech** porcelains, caution should be exercised when pairing other dental porcelains with an alloy containing more than 10% silver. Although the porcelain discoloration is generally referred to as "greening," it may actually fall within a spectrum of colors from yellow, to green, to orange or brown.^{17,18} More often than not, the color changes occur at, or near, the porcelain-metal junction.¹⁷ Two factors come into play when assessing the potential for discoloration with silver-containing alloys: the chemical composition of the porcelain, and the firing technique.¹⁷

* Williams Gold Refining Company, Buffalo, NY.

** Rx Jeneric Gold Company, Wallingford, CT.

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In addition, when a dental porcelain not resistant to silver discoloration is used with a silver-containing alloy, the discoloration may not appear with every restoration. When the discoloration does develop, it is more likely to occur with the lighter than the darker shades.¹⁹ Some contend that the lighter shades have fewer opacifiers and more sodium, so they are more at risk than the darker shades by virtue of their chemical make-up.¹⁹ Others believe that the basic porcelain is the same, and that only the pigments and opacifiers change.⁵ With the lighter shades, any discoloration is simply easier to see.⁵

a. Possible Mechanisms of Porcelain Discoloration

One explanation of the silver-porcelain reactions is the silver-sodium exchange mechanism theory.¹⁸ The process begins as silver is vaporized from the substructure (coping) during the sintering (firing) of the porcelain, because silver has a high vapor pressure.^{17,18} Thus, silver simply exchanges with sodium in the dental porcelain as long as sufficient oxygen is available (oxidizing atmosphere). On the other hand, if a reducing atmosphere is present (limited or no oxygen) as a result of the creation of a vacuum, then the silver-sodium exchange occurs less rapidly.¹⁸ Since all dental porcelains are vacuum-fired, how does the exchange take place? Some believe the answer may be vapor transport.²⁰ Although a restoration will be fired under vacuum, there are times when that vacuum is not present. For example, the porcelain restoration is generally dried thoroughly and preheated at temperatures between 540-650 °C (1004-1202 °F). Once the vacuum-firing cycle is complete, the vacuum is generally released at maximum temperature; and the work is withdrawn. A few porcelains are even air-fired at high temperature for proper maturity. In the intervals before and after vacuum-firing, little carbon monoxide is available to inhibit the silver-sodium exchange.

Being particularly active near the surface of the alloy, the silver gas is readily available for chemical interaction with the porcelain.¹⁷ The silver absorbed by the porcelain precipitates during the cooling phase, and the discoloration appears.¹⁷ Some of the silver vapors may remain in the porcelain furnace, condense, and collect in cool regions. The silver then revaporizes in subsequent operations and may collect and contaminate units with non-silver-containing alloy.

A second possible explanation involves the transport of silver into the porcelain at the porcelain-metal interface and then through the porcelain to the surface, all by some unknown mechanism.¹⁹ Tuccillo described this as a "bulk transfer mechanism."¹⁸ The fact that areas of discoloration can be ground from the porcelain surface may lend some support to this belief. Yet, this theory does not explain why the discoloration occurs mainly at the margin of the porcelain and the metal and at the surface.¹⁹

A third theory holds that "surface diffusion" is responsible for the porcelain discoloration.¹⁹ The silver in the alloy repeatedly diffuses to the metal surface, and contaminates the dental porcelain at the porcelain-metal margin.¹⁹ Some support is lent to this type of concept, as opposed to

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the "bulk transfer mechanism", since the discolored areas may be ground from the porcelain surface.¹⁹ If the entire porcelain veneer were discolored, surface grinding would not be expected to remove the discoloration.

The varied alkali and trace elements found in dental porcelains might help to explain why dental porcelains behave so differently with silver-containing alloys.¹⁸ The color changes are, also, not always green, but may be yellow or brown; and they can vary among the different porcelains.¹⁸ The discoloration may also be more intense with porcelains of higher sodium content, as compared with the porcelains containing potassium.¹⁹

b. Techniques to Diminish Porcelain Discoloration by Silver

How is the discoloration prevented? The simplest solutions would be either to use a non-silver-containing alloy, or to switch to a porcelain which is resistant to discoloration (Will-Ceram* or Artis-Tec**). Other recommendations include the firing of carbon pellets with all work to generate carbon monoxide and to produce a reducing atmosphere in the porcelain furnace to inhibit any silver-sodium exchange.¹⁸ As mentioned previously, this technique does have limitations, and reports of its success are mixed.¹⁸

Metal and ceramic bonding agents have also been suggested to produce a physical barrier for the porcelain-bearing area of the metal substructure. The bonding agent supposedly reduces the surface activity of silver, and reportedly helps eliminate the possibility of porcelain discoloration. Such materials have only limited value, since they neglect the internal aspect of the metal substructure and the non-porcelain bearing external surfaces of a coping (metal occlusal or lingual). These large untreated areas are free to release silver vapor.

Carbon pellets and metal conditioners (bonding agents) are certainly not foolproof techniques, and the latter requires an additional procedure and firing cycle. As a result, the palladium-silver alloys have been considered more technically demanding by some. However, one can take full advantage of the excellent physical properties and economy of palladium-silver alloys by simply using one of the two dental porcelains resistant to discoloration.

If silver-containing alloys are to be used on a regular basis, then the porcelain furnace should be purged routinely. A high production facility might purge their furnaces on a daily basis, while 1-3 times per week would be sufficient to control the collection of silver in the furnace muffle of less frequent users. A furnace-purging technique is included in Section 8, on the palladium-silver alloys.

* Williams Gold Refining Company, Buffalo, NY.

** Rx Jeneric Gold Company, Wallingford, CT.

3-8. CASTING ALLOY-DENTAL PORCELAIN COMPATIBILITY

Very often little, if any, attention is given to an examination of the compatibility of a dental porcelain with a particular alloy. With the multitude of alternative alloys flooding the market, it is unwise to assume that a given dental porcelain can be used with every alloy system. Moreover, success with the single unit FPM crown is no guarantee of suitable pairing in a fixed partial denture. Occasionally, a metal and a porcelain lack a predictable level of compatibility; and, as a result, the porcelain may fracture or a portion may unexpectedly pop off the metal surface (Fig. 3-8). Porcelain crazes and fractures may be indicative of incompatibility between the metal and the porcelain. On the other hand, not all mismatches are readily identifiable.

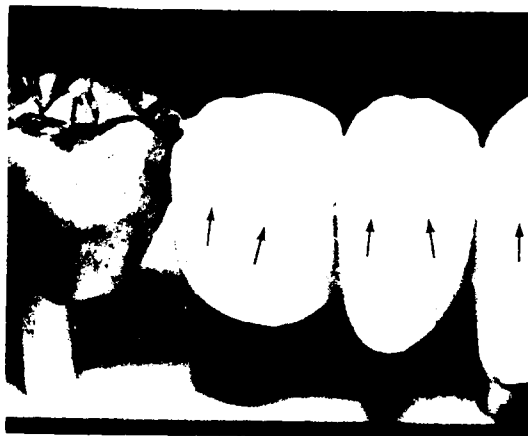


Figure 3-8. Porcelain fractures (arrows) may be an indication of a porcelain-metal incompatibility. Immediate or delayed fractures may be observed, especially during the cooling phase.

Perhaps the discussion of compatibility could be better understood if it were examined from two different perspectives: physical compatibility, and chemical compatibility. The segregation of compatibility into categories is the choice of the author, and may be a point for discussion by more learned specialists in dental materials. However, this differentiation does permit recognition of different types of compatibility and incompatibility, and permits identification of specific problem areas.

a. Physical Compatibility

An example of physical compatibility would be in the establishment of the relationship between the metal substructure and the dental porcelain. It is generally believed that the coefficient of thermal expansion for the metal substrate should be slightly higher than that of the dental porcelain, in order for the porcelain veneer to be under compression.⁶ Dental porcelain is at its strongest when compressed, and most vulnerable when subjected to shear stresses. A mismatch of the coefficients of thermal expansion could result in cracking and fracturing of the dental porcelain: i.e., a physical incompatibility.

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Although it may not always be made clear, there is undoubtedly a range of physical compatibility. In other words, the metal and the porcelain can vary just so far; and, when conditions take either material outside this "range" of compatibility, then problems may arise. When we observe porcelain cracking or crazing during the cooling phase, we may not always think of this as an example of a less than ideal match of coefficients of thermal expansion. The cracking could be due to poor technique, or it might be an indication of pairing outside the workable range of physical compatibility, especially if such an event occurs routinely with single unit crowns. A greater challenge would be to test the two materials in a three-unit fixed partial denture with a metal pontic. Should cracking or a complete bond failure occur, then one should suspect a mismatch of coefficients of thermal expansion.

A comparison of the coefficient of thermal expansion can not be used to predict the compatibility of a dental porcelain and an alloy. Many factors contribute to compatibility, and the coefficient of thermal expansion is but one.

b. Chemical Compatibility

Perhaps the best example of chemical compatibility is the porcelain-alloy bond. Dental porcelain is believed to adhere to PFM alloys through a combination of mechanisms, but the attachment is primarily thought to be a chemical bond.^{3,6} The surface oxides on the metal substrate are able to interact favorably with the porcelain oxides and form a porcelain-metal oxide bond. This is a prime example of chemical compatibility.

Another example of chemical compatibility, or incompatibility, may be silver discoloration of dental porcelain. What happens when that metal substructure is an alloy which contains more than 10% silver? With some dental porcelains, there may be an undesirable chemical reaction between silver vapors and some components in the porcelain. The result may be the production of a green, yellow, or brown discoloration of the porcelain adjacent to the porcelain-metal junction.¹⁹

How better to describe this occurrence as an undesirable chemical reaction or, to put it more simply, a chemical incompatibility. As mentioned previously, there are two dental porcelains which reportedly are resistant to porcelain discoloration when used with silver-containing alloys: Will-Ceram,* and Artis-Tech.** These porcelains apparently differ from those which are not as resistant to discoloration, and perhaps may also be described as chemically compatible with silver-containing alloys.

Either a metal or ceramic bonding agent is recommended for those dental porcelains not possessing such a chemical compatibility with silver-containing metals. Bonding agents may help to produce a physical barrier and to prevent undesirable chemical interactions.

* Williams Gold Refining Company, Buffalo, NY.

** Rx Jeneric Gold Company, Wallingford, CT.

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SECTION 4:

SPRUNG, INVESTING, AND CASTING TECHNIQUES

4-1. INTRODUCTION

A great deal of the success for the production of high quality PFM restorations is achieved through an appreciation of the theory and practice of proper spruing, investing, and casting, particularly when switching from a gold-base alloy to a non-gold base system. Certain modifications in technique have been recommended for the non-gold base metals and the non-precious alloys, in particular.

To prevent potential pitfalls or misunderstandings when using these alternative alloys, the subjects of spruing, investing, and casting are addressed separately here. After a general introduction, each topic is examined, with emphasis on those factors affecting non-gold base metals, in particular.

4-2. SPRUING TECHNIQUES

One of the initial decisions a technician must make, when preparing a wax-up for investing, is the selection of an appropriate sprue system. Each case must be analyzed to ensure that adequate molten alloy will be made available to each unit. Several important factors to consider are: the spruing method (direct vs. indirect); sprue placement (or location); sprue gauge; sprue length; reservoir location; constricted spruing; the Rousseau Casting System; sprue composition (wax vs. plastic); and the use of prefabricated sprues.

a. SPRUING METHODS

Wax patterns can be sprued by one of two different methods--directly or indirectly. There are advantages and disadvantages to both techniques, and the philosophy behind each should be understood.

1. Direct Spruing - As the name alone indicates, with direct spruing the path created for the flow of molten metal is straight, or direct, from the crucible to the wax pattern area in the mold. The concept is often easier to create than indirect spruing, and generally requires less time and effort. More often than not, this approach is recommended for single units or small patterns. A straight sprue is simply luted to the thickest portion of the wax pattern at one end and secured to the sprue former at the other (Fig. 4-1). However, the technique can also be modified to include a ball, or round reservoir, between the pattern and the button. Despite the introduction of the small reservoir, the technique is still regarded as DIRECT spruing.

A basic weakness of DIRECT spruing is the inherent potential for suck-back porosity at the junction of casting and the sprue.

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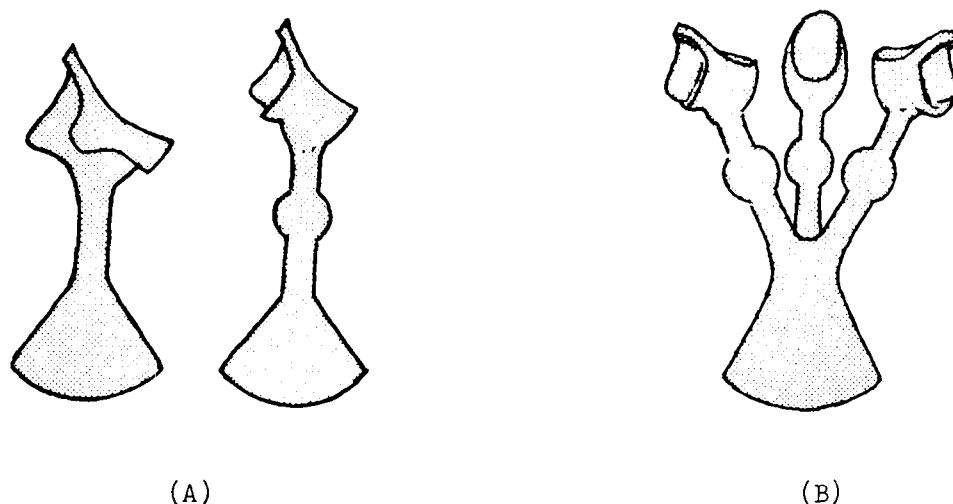


Figure 4-1. Direct spruing for single units: (A) with both a straight and a reservoir type sprue; and (B) with multiple single units arranged with reservoir sprues.

2. Indirect Spruing - The development of an indirect system to feed molten metal to a series of patterns is the basis for INDIRECT spruing. With this particular spruing technique, the molten metal does not flow directly from the casting crucible to the pattern area in the heated mold. Instead, the voids in the mold created by the wax patterns fill first and draw needed molten alloy from an adjoining reservoir area. The reservoir, or connector, bar can be created by using a 6- or 8-GAUGE sprue which extends beyond the width of the end patterns and is fed by two sprue leads (Fig. 4-2). A larger size reservoir bar may be necessary for multiple molar or pontic patterns. The Rousseau Casting System, another example of INDIRECT spruing, relies on unidirectional (metal) flow, that is, one feed to the reservoir area (Fig. 4-3).¹

There are differences of opinion on the need for INDIRECT spruing with cases involving single unit crowns, or multiple single units. Although DIRECT spruing may produce acceptable results in many instances, INDIRECT spruing may be a more predictable and reliable approach. In addition, the use of prefabricated INDIRECT sprues permits standardization, within the technique, to improve consistency and to help eliminate errors in sprue design and reservoir placement.

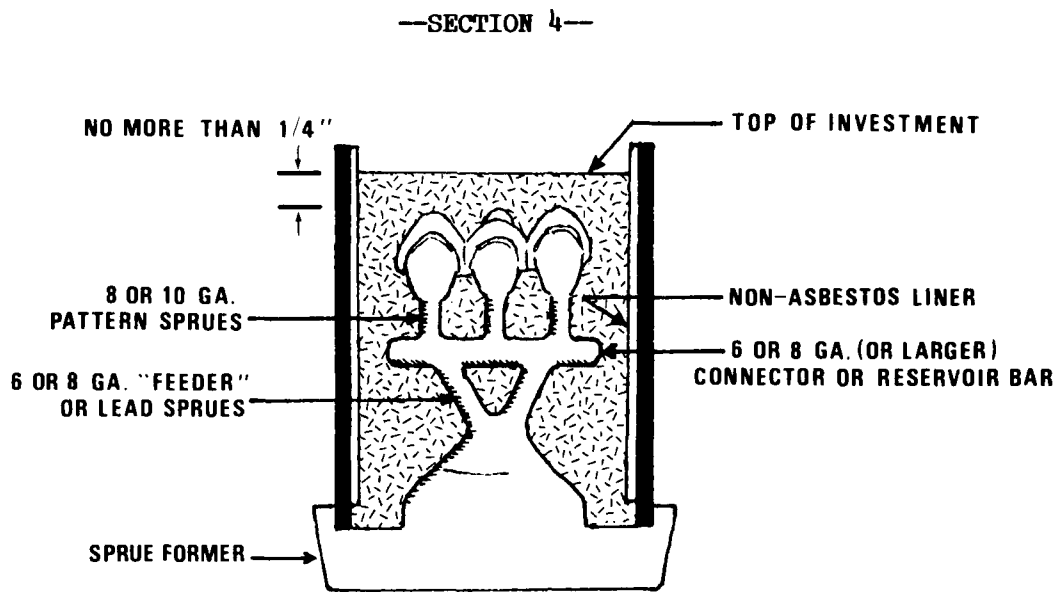


Figure 4-2. Indirect spruing for a three-unit fixed partial denture. (Follow this example for indirect spruing of multiple and single units, if you prefer; and refer to the respective alloy instructions for the specific gauges of the various components.)

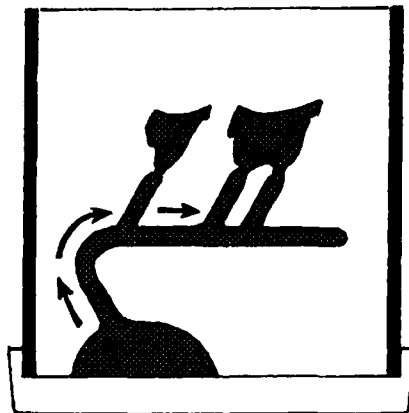


Figure 4-3. The Rousseau Casting System is based upon unidirectional (metal) flow and constriction of the pattern sprue at the sprue-pattern junction.

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b. SPRUE PLACEMENT

The sprue to the wax pattern (pattern sprue) should be attached to the largest cross-sectional area of the wax pattern, thus ensuring a flow of molten alloy from a region of large volume (thickest area) to regions of lesser volume (thin sections). Failure to follow this prescribed sequence might result in incomplete castings, should a low volume (thin section) undergo solidification before the mold has filled completely--or should shrinkage porosity occur if the patterns do not have access to a reservoir of molten metal.

c. SPRUE GAUGE

A pattern sprue of sufficient size should be selected to supply the amount of alloy needed to fill the pattern mold. The round wax sprue gauges are conveniently identified with a gauge number; i.e., 10, 8, 6, etc. The larger the gauge number, the smaller the size (diameter) of the sprue. Often an alloy manufacturer will include recommendations for sprue size selection to assist the technician. However, such suggestions are made without benefit of examining the individual wax patterns in question. Therefore, it is the technician's responsibility to measure the wax patterns, evaluate the particular requirements of each case, and determine the most desirable sprue gauge. When fashioning an indirect spruing system, make certain the reservoir is larger than the thickest cross-sectional area of the pattern. This requirement is particularly important when spruing metal pontics and large molar retainers. Even prefabricated indirect sprues have different gauge reservoir bars, so select a size appropriate for the particular patterns to be cast.

d. SPRUE LENGTH

With the DIRECT spruing method, the sprue should be long enough to position the wax pattern in a cold zone (areas outside the heat center) at the opposite end from the sprue former. That length will vary with the type of sprue former and the size of the particular casting ring used.

There are differences in opinion as to the ideal length of the sprue from the reservoir bar to the wax pattern in INDIRECT spruing. Some have recommended the elimination of an intermediate, or pattern, sprue in favor of pattern placement directly on the reservoir bar.² Others suggest maintaining 1/4 in. (6 mm) between the reservoir and the wax pattern.³ Pattern placement off the reservoir bar is highly recommended to ensure location of the patterns outside the thermal zone, or heat center of the casting ring.⁴ Experience has shown that a 5-mm pattern sprue is often sufficient to meet this requirement.

e. LOCATION OF THE RESERVOIR

There appears to be general agreement that the reservoir portion of a spruing system, be it a 6-, 3- or 1-GAUGE bar or round ball, should be positioned in the heat center of a casting ring. In this way, the reservoir can provide molten alloy for the patterns during the pattern solidification

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process. The sprued case should be weighed, and the weight of the sprue former subtracted. The difference is the weight of the indirect spruing system, and that is all that is necessary to cast. No button is desired with indirect spruing, because the button competes with the reservoir as the largest mass of metal, and influences the location of the heat center of the casting ring. This subject is explained in greater detail in Section 4 (subsection 4-4).

f. CONSTRICTED SPRUING

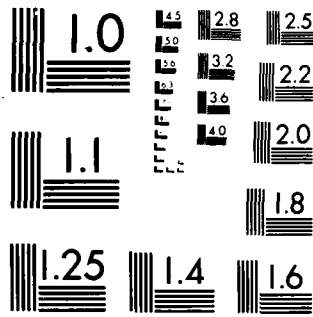
Tapering the sprue at the junction of the wax pattern rather than bulking up this area is referred to as "constricted spruing" (Fig. 4-3). McLean contends that the taper enables the sprue to function more like a true reservoir, thereby decreasing the likelihood of suck-back porosity.⁴ However, a study by Compagni et al. found that the "bottleneck connection" (constricted sprue) had the worst results.² Unfortunately, they did not use pattern sprues to separate the wax patterns from the reservoir--a fact which may have had an effect on their results. However, they were consistent in not including the intermediate (pattern) sprue in all their indirect spruing.²

The Unitek Corporation recommends constricted spruing for their nickel-chromium beryllium-free alloy, Forte.* With this lower density, non-precious metal, a constricted sprue literally sprays molten alloy into the heated mold.³ However, in their instructions for spruing the high palladium-copper alloy, PG-80+*, they stress the opposite: "Do not constrict the sprue/pattern opening." Why the difference? The answer is probably attributed to alloy density. The constriction is helpful in the mold-filling process for lower density non-precious alloys. But, as the density of the metal increases and approaches that of gold-base alloys, the benefit is diminished. Constriction is more apt to interfere with the molding filling of denser metals, and may increase the likelihood of suck-back porosity. The basic concept is that the greater the alloy density, the greater the sprue-pattern access. The opposite may be true for lower density, non-precious alloys.

In one castability study employing a nickel-chromium alloy and ingate widths (widths of sprue-pattern attachment) of 1, 2, and 3 mm, however, the constricted sprue (1 mm width) had the least favorable results.⁵ It was also found that vented patterns cast more completely than unvented. Yet, all the castings with a sprue width of 1 mm were defective, regardless of whether or not vents were used.⁵ The type of failure in the castings was suck-back porosity at the sprue-pattern interface.⁵

Invariably, some individuals will encounter success using constricted spruing for all alloy systems, regardless of density levels. This is not to say that both techniques will not work. However, the recommendation for the limited use of constricted spruing is to promote a technique which is more likely to offer consistent and highly reproducible results.

* Unitek Corporation, Monrovia, CA 91016.



MICROCOPY RESOLUTION TEST CHART
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g. THE ROUSSEAU CASTING SYSTEM

The Rousseau Casting System (RCS), developed by Mr. Carl H. Rousseau in 1981, is principled after the INDIRECT spruing concept with several changes¹ (Fig. 4-3). The flow of molten metal is indeed indirect, but unidirectional. The reservoir bar is located in the thermal zone, and pattern (intermediate) sprues are used to POSITION the wax patterns outside the heat center.¹ The pattern sprues are, however, constricted at the sprue-pattern junction as suggested by McLe²n.⁴

This particular system was not studied in our testing program, but should be considered for evaluation by those interested in new spruing techniques.

h. SPRUE COMPOSITION - WAX VS. PLASTIC

Although it is not often emphasized, investment burnout techniques should vary for plastic sprues as opposed to an all wax system. In fact, the burnout instructions included in Sections 6-11 are for users of wax sprues. Wax melts readily in the normal course of the burnout process, leaving little concern for carbon residues after proper heat-soaking at the recommended maximum heat-soaking temperature.

As compared with wax, plastic sprues do not burn out as readily through the lower temperature range; and there is more potential for carbon residue to remain in the mold. Plastic also undergoes more expansion before softening, a characteristic which can be responsible for investment cracking. More importantly, if the pathway for the escape of molten wax is blocked by an unmelted plastic spruing system, the wax may overheat (boil) and deteriorate the mold surface. The resultant castings might exhibit a high degree of surface roughness.

Manufacturers of plastic sprues may recommend applying a layer of wax over the entire surface area of the sprue to produce an escape mechanism for the melting wax patterns. That procedure not only requires more time, but may lead to surface irregularities in the investment if the wax is not flowed evenly and smoothly over the plastic. If plastic sprues are used, a two-stage burnout procedure is highly recommended. Burn out at 600 °F for 30 minutes (single ring); then reset the oven to the desired high, heat-soaking temperature, and continue the burnout procedure. If no specific two-stage burnout technique is provided with your present alloy, contact the alloy manufacturer for guidance.

1. PREFABRICATED SPRUES

The task of spruing and investing can be made easier, and certainly more consistent, when prefabricated wax sprues are used. These ready-made patterns offer an efficient and time-saving method for spruing, with minimal product modification (Figs. 4-4 to 4-7). More importantly, prefabricated sprues can eliminate the need for each technician to construct a personal interpretation of an appropriate INDIRECT sprue design. However, the sprue must be used with an appropriately sized ring and in keeping with the Laws of Casting.

—SECTION 4—

1. Casting Oval System (Belle de St. Claire)*

The design of the prefabricated indirect sprue (Ready Sprue) permits rapid placement of the pattern in the accompanying sprue former and consistent location of the reservoir bar in the oval casting ring. Products such as the Casting Oval System help ensure consistent placement of the reservoir bar in the heat center of the casting ring when they are used as a system (prefabricated sprue, sprue former and matching casting ring).

Removal of the solid center web is suggested to permit isolation of the runner bar as recommended in INDIRECT spruing (Figs. 4-5 & 4-6). This modification does represent a departure from the Belle de St. Claire philosophy, which contends that the web enables the molten alloy to enter the mold very quickly and without disturbance. That contention may indeed be true; however, the web does permit metal flow directly to the patterns as in DIRECT spruing. The elimination of the web also creates a true INDIRECT spruing system, isolating the horizontal runner bar from the sprue leads that feed it.

The runner bar is 6-gauge for both the large and the small wax Ready Sprue patterns. This gauge is appropriate for reservoir bars which are used for small- and medium-size wax patterns (copings and metal occlusal substructures) for single units or small fixed partial dentures.

The oval sprue former should be indexed with a drop of wax to permit identification of the trailing edge of the wax patterns (Fig. 4-6). This step makes it possible for the technician to orient the ring in the cradle of the casting machine to enable the molten alloy to flow toward the trailing edge (margins) of the patterns.

2. Tri-Wax System (Williams Gold Refining Company)**

The prefabricated Tri-Wax indirect sprue system has a 3-GAUGE runner bar and 7-GAUGE sprue leads which make it particularly useful for large pontics or thick wax molar patterns. The cross-sectional area of a Tri-Wax reservoir bar is much larger than that of the Ready Sprues (Fig. 4-8).

Although the Tri-Wax pattern will seat in the small Belle de St. Claire* oval sprue former, the runner bar must be shortened at each end to make room for the ring, the ring liner, and an adequate amount of investment. Despite the differences in size, the position of the Tri-Wax reservoir bar in the oval ring of the Casting Oval System is approximately the same as that of a Ready Sprue. Therefore, both prefabricated wax patterns could be used with the Belle de St. Claire oval rings and sprue formers.

* Belle de St. Claire, Van Nuys, CA.

** Williams Gold Refining Company, Buffalo, NY.

--SECTION 4--



Figure 4-4. The Belle de St. Claire Ready Sprue and oval sprue former.

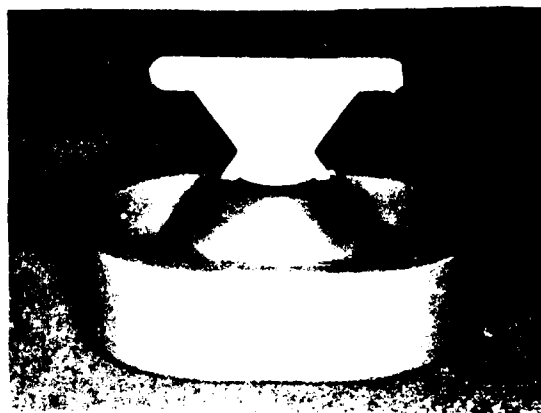


Figure 4-5. The prefabricated Ready Sprues fit easily in the sprue former.

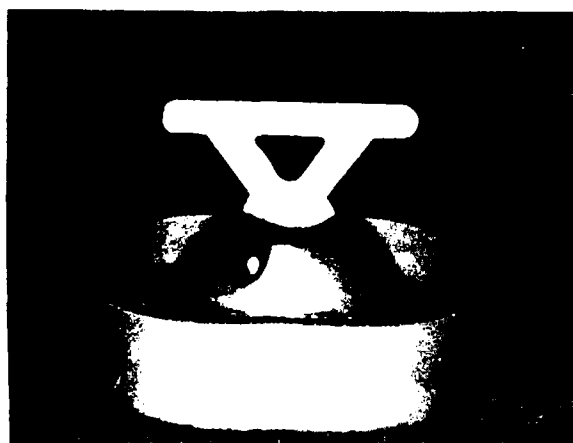


Figure 4-6. After removing the web and sealing the Ready Sprue to the sprue former, place a wax orientation dot.

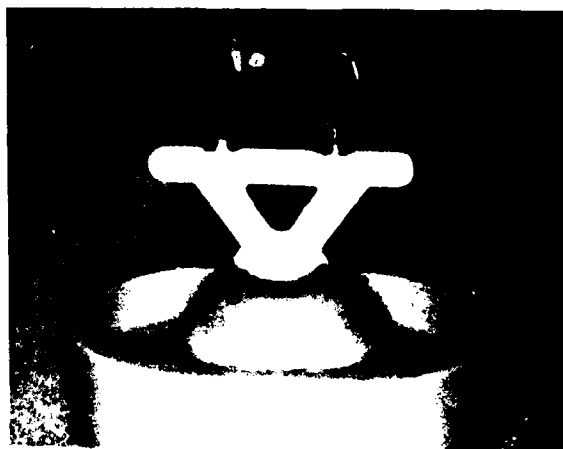


Figure 4-7. Wax patterns can be quickly and easily attached to the reservoir bar of the Ready Sprue.

Figure 4-8. The cross-sectional area of the reservoir bar of the Tri-Wax sprue (left) is much larger than the Ready sprue (right).



—SECTION 4—

4-3. CASTING INVESTMENTS AND INVESTING TECHNIQUES

The non-gold base, PFM alloys often require some modifications to the investing procedures typically associated with high-gold content metals. These changes are required to avoid potential unfavorable interactions, between components of the investment and elements in the various alloys, which might result in an unsatisfactory casting.

a. TYPES OF HIGH-HEAT INVESTMENTS

The high melting ranges of PFM alloys exceed the upper limits of the gypsum-bonded investments, and require the use of the phosphate-bonded or silica-bonded casting investments. Our experience has been limited to the two varieties of phosphate-bonded investments: the carbon-containing, and the non-carbon containing.

1. Carbon-Containing Phosphate-Bonded Investments. This first type of high-heat investment is gray-black in color, due to the presence of carbon. One reason carbon is added to the investment is to facilitate divestment. The investment itself may appear coarse by comparison with a gypsum-bonded investment. Generally the phosphate type of investments requires a special liquid for mixing rather than distilled water. When the liquid is used full strength, maximum investment setting expansion and working time are achieved. By diluting the special liquid, the expansion can be adjusted to the requirements of the particular alloy used; but the working time will also be decreased.

Suggested dilution ratios for some investments are included in the technical descriptions for the alloys tested. These ratios should only be considered starting points which may be adjusted to meet your particular requirements.

2. Non-Carbon Containing Phosphate-Bonded Investments. The non-carbon investments are easily identified by their white color, before and after mixing. They were developed for those who wished to avoid any possible interaction between carbon and the nickel- and cobalt-base, non-precious alloys, as well as the palladium-base, precious metals. Apparently, these alloy systems are capable of dissolving available carbon. Carbon absorption can result in carbide formation and/or porosity due to carbon inclusions. Some manufacturers of carbon-containing investments contend that, if a ring is burned out appropriately and heat-soaked at the prescribed high temperature, no carbon residue should remain. They suggest more risk of carbon contamination lies with an improperly adjusted torch than in a carbon-containing investment. Proponents of the non-carbon investments like the added security that using a carbon-less system provides. Their contention is: "Why use an investment which contains carbon, and thus run any risk at all?"

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The non-carbon investments are also generally coarse-grained, like their carbon-containing counterparts. The one exception encountered was the fine-particle investment, Vestra-fine* (Fig. 4-9). This particular material mixes to a smooth, creamy consistency with ample working time, even when the special liquid has been diluted (Fig. 4-10).



Figure 4-9. Vestra-fine is a non-carbon (white) phosphate-bonded investment, suitable for use with all PFM alloys as well as Type III gold.



Figure 4-10. When mixed, Vestra-fine produces a smooth, creamy investment that can be poured into the casting ring.

b. INVESTMENT-CASTING ALLOY INTERACTIONS

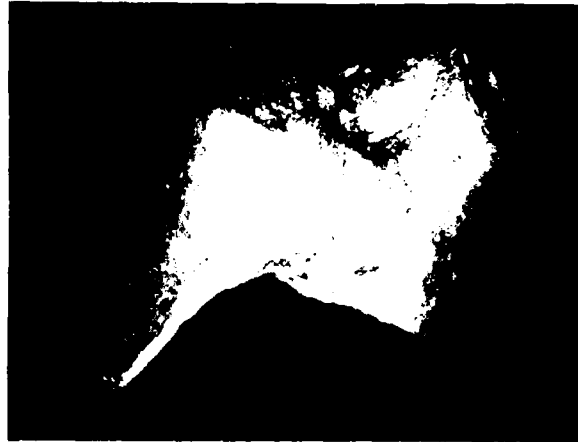
In the course of this evaluation, variations in the performance of alloys with different investments were observed. It became apparent that initial problems attributed to a given metal were, in fact, possibly due to the particular investment used. Excessive nodule formation and fins might occur more frequently with one investment, but not at all with another (Fig. 4-11).

Alloy manufacturers frequently state that their alloys may be used with virtually any commercially available phosphate-bonded investment. That has not been our experience; and other studies support the belief that casting alloy-investment pairing can influence results.^{6,7} For example, Barreto et al. have even recommended testing alloy-investment interaction prior to actual clinical use.⁶ They suggest that conflicting and/or controversial castability results for the non-precious alloys may not be due to the alloys themselves, but to an improper investment-alloy pairing.⁶ The findings of our study support that belief; and the results of any castability study should be evaluated, with attention being given to the particular casting investment(s) used.

* Unitek Corporation, Monrovia, CA.

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Figure 4-11. The nodules present on this palladium-silver alloy were attributed to an investment-alloy interaction. Simply changing the investment can often eliminate such problems.



4-4. MELTING AND CASTING TECHNIQUES

Assuming a case has been properly sprued, invested, and burned out, the next crucial steps involve melting and casting techniques. A poorly adjusted torch or improper casting method can ruin all one's efforts up to this point. Therefore, specific recommendations for melting and casting have been included in the technical instructions for each alloy in the various groups and systems. Be sure to refer to these sections before beginning such procedures.

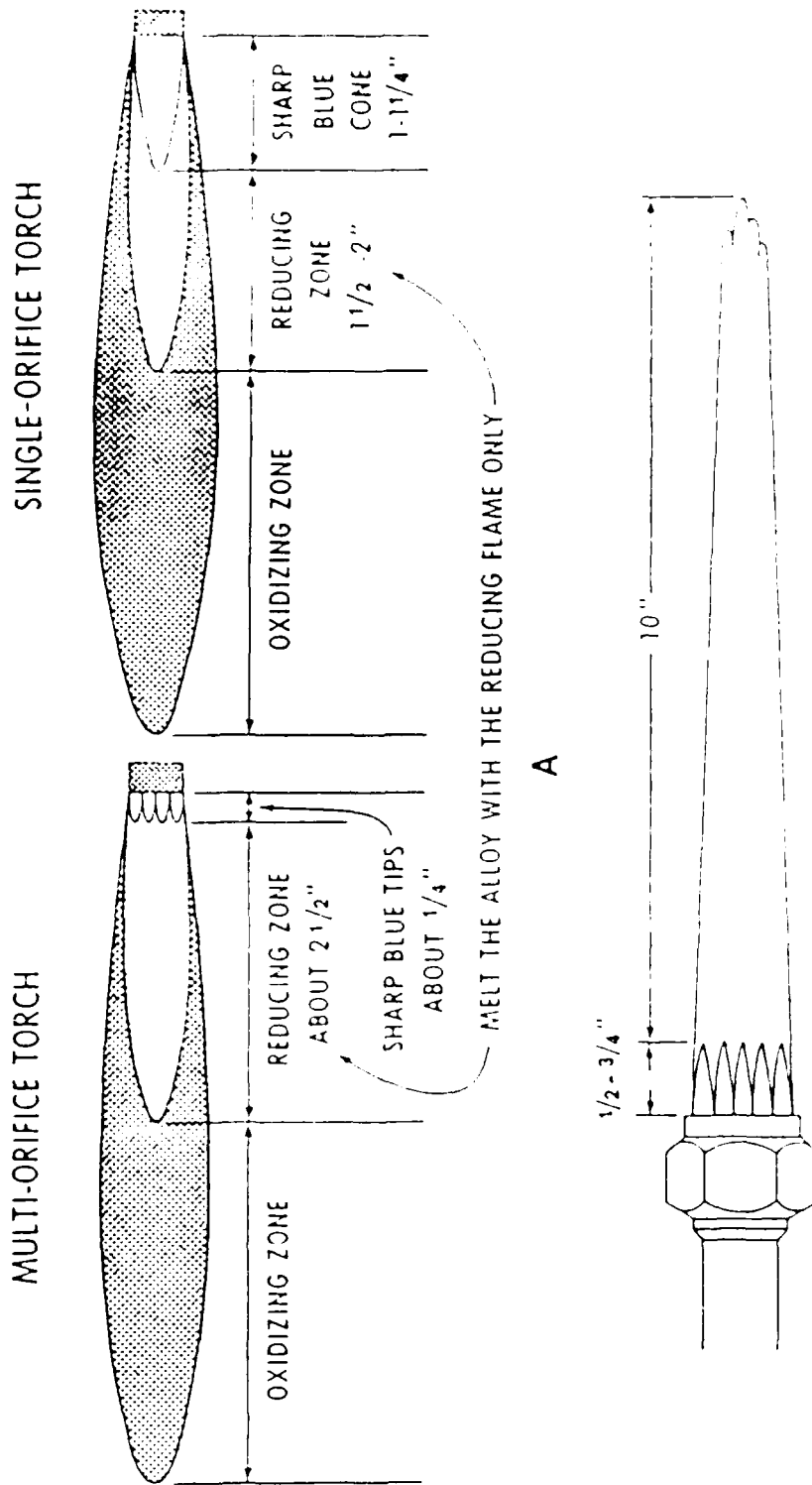
a. CASTING TORCH SELECTION

There are two types of torch tips from which to choose when selecting casting equipment: a multi-orifice, or a single orifice (Fig. 4-12). The type most widely used for PFM alloys is probably the multi-orifice tip. The main advantage of the multi-orifice design is the distribution of heat over a wide area to permit even heating. It is particularly helpful in melting the high-fusing, non-precious alloys. The single orifice torch tip actually may concentrate more heat in a single area, but that area is smaller than that heated by the multi-orifice tip.

The Harris 16-S torch with a #1390H multi-orifice tip was used in this project, and it performed quite well. However, numerous casting torches are on the market today, and many of them might prove equally satisfactory. Select one that is lightweight, has a comfortable handle, is easy to manipulate, and has tips for both casting and soldering.

PROPER FLAME PATTERNS

--SECTION 4--



A

B

Figure 4-12: A. The proper flame patterns for the multi-orifice and single orifice torch tips. B. The non-precious alloys may require additional adjustments to the length of the inner blue cones. Refer to the manufacturer's instructions for the specific alloy to be cast.

--SECTION 4--

b. CHOICE OF FUELS

The selection of an appropriate fuel source is an item often overlooked, or neglected, despite its importance in the casting procedure. The three gases which merit specific discussion are: acetylene, natural gas, and propane.

1. Acetylene - This is a colorless gas possessing a very distinct, garlic-like odor.⁸ Acetylene will burn in air and can generate a flame approaching 3000 °F, which is hotter than that produced by natural gas.⁸ Unfortunately, acetylene is a contaminated fuel source (contains carbon, among other elements), and it should not be used to melt PFM alloys.
2. Natural Gas - This naturally occurring gas is the by-product of the "natural" decomposition of organic matter in the ground.⁸ When natural gas is mixed with air, the resultant flame approaches a temperature of 2200 °F. Higher temperatures can be achieved to melt the high-fusing precious and non-precious PFM alloys, simply by substituting oxygen for air.

Natural gas is an acceptable fuel source, although it is not ideal. Some of the problems confronting natural gas users (not necessarily Air Force facilities) include: inadequate pressure level within the gas line; fluctuation in the pressure level while casting; water contamination in the line; and variations in composition by different gas companies. Despite these limitations, natural gas is a widely used fuel.

3. Propane - The major limitations of natural gas can be overcome by the use of bottled propane gas. A constant, regulated mixture of propane and oxygen ensures a clean, consistent burn and a more ideal melt.

c. CENTRIFUGAL CASTING

All of the precious and non-precious non-gold base ceramic alloys can be satisfactorily cast in a conventional centrifugal casting machine. Although induction casting might be more helpful, it is certainly not a requirement for those who wish to use alternative alloys. However, the lower density alloys normally require one additional wind of the casting machine arm.

d. INDUCTION CASTING

The idea of making the casting process more of a mechanical operation, devoid of human variability and ineptness, is what makes induction casting appear attractive. Unfortunately, the equipment is so costly that this casting method is left to the much larger area dental laboratories. Moreover, not all induction casting machines are as helpful as others. Finding an acceptable unit is not as easy a task as it might appear.

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e. CASTING CRUCIBLES

Both the precious and the non-precious PFM alloy should be heated in either an alumina or a quartz crucible (Fig. 4-13). Clay and carbon crucibles should NOT be used. Clay can not withstand the high melting temperatures of these alloys. The clay will literally break down during the casting process, and possibly contaminate the molten alloy. Carbon crucibles are potentially more damaging to nickel- and palladium-base alloys, because the molten alloy can absorb the readily available carbon. Carbon absorption can actually cause the metal to re alloy in the casting crucible, forming carbides which embrittle the casting.

It is best to preheat the alumina or quartz crucible in the burnout oven with the casting rings. Preheating gradually warms the crucible, prevents crucible cracking (spalling), and prolongs the life of the crucible. These crucibles are self-glazing and, therefore, do not require a crucible liner.

Either use color-coded crucibles (Belle de St. Claire), or carve the alloy name in the crucible itself to prevent alloy contamination (Fig. 4-14). Do not use different alloys in the same crucible.

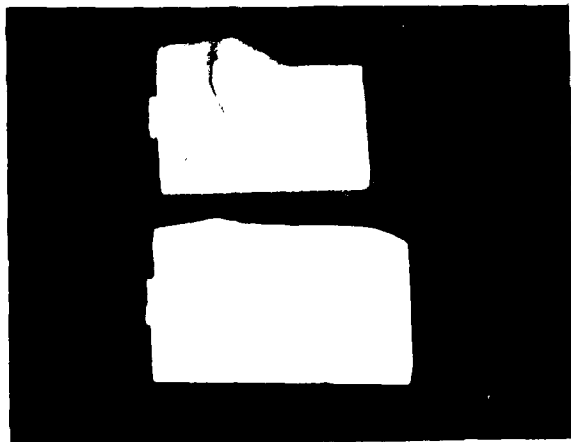


Figure 4-13. The smaller clay crucible (top) is suitable for Type III gold; but quartz crucibles (shown at bottom) or, more preferably, zircon-alumina, are recommended for PFM alloys.

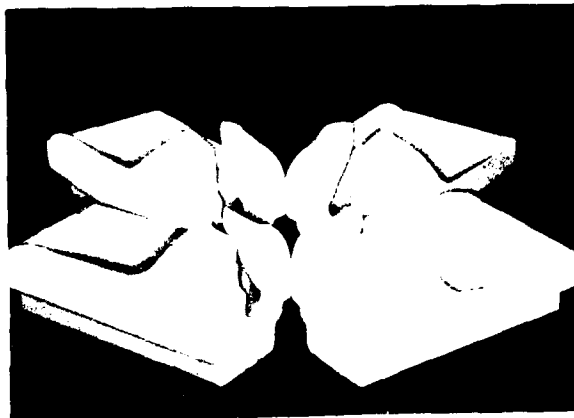


Figure 4-14. The Belle de St. Claire* color-coded, zircon-alumina crucibles can each be assigned to a specific alloy to avoid cross-contamination by different alloy systems.

* Belle de St. Claire, Van Nuys, CA.

--SECTION 4--

f. THERMATROL 2500 CASTING MACHINES

Electric casting machines, such as the Thermitrol 2500, are not generally recommended for the palladium-, nickel-, or cobalt-base metals, if they involve the use of a carbon crucible.

g. BLASTING COMPOUNDS

The commercially available abrasive compounds on the market today include: aluminum oxide (Al_2O_3); general purpose blasting compound; and glass beads.

All three compounds can remove casting investment and surface oxides from a casting after divesting. Pure, non-recycled aluminum oxide (white color) is most frequently used to air-abrade the porcelain-bearing surfaces of the metal substrate prior to oxidation (Fig. 4-15). A 50- μm grit variety is generally recommended for this procedure, reserving the 25- μm size abrasive for carving occlusal anatomy in fired porcelain.

Figure 4-15. Dental porcelain and porcelain-bearing areas of a metal substructure should only be air-abraded with pure, white aluminum oxide (right). The gray abrasive powders contain impurities which may contaminate the porcelain.



4-5. THE LAWS OF CASTING

Casting dental alloy castings should be considered both an art and a science, governed by some very specific rules or laws. While many general concepts prevail, a great deal of personalization is often in each dental technician's approach to casting; i.e., the art of casting. The science of casting pertains to those facts, or features, which reflect the influence of the science of dental technology. Many of the casting problems encountered can be attributed to a lack of understanding of appropriate casting protocol and/or a failure to adhere to the basic principles of casting.

One of the important foundations of the laws of casting is that every casting contains porosity, due to solidification shrinkage. That porosity invariably occurs in the last portion of metal to cool. Therefore, the challenge before the technician is to understand the science of casting to control the location of that porosity within the spruing system and produce a porosity-free restoration. The **Laws of Casting** are presented as they pertain to spruing, investing and burnout, and as they

—SECTION 4—

In 1934, the Williams Gold Refining Company* began work on an audio-visual film on casting which included 14 laws relative to the principles involved from spruing to casting. Some additional laws have been added, based on the observations, findings, and conclusions from this project. The end result is a set of 17 separate recommendations for spruing, investing, burning out, melting, and casting procedures. Collectively, these guidelines will be referred to as the LAWS OF CASTING.⁹

SPRUING

a. THE 1st LAW OF CASTING

Attach the pattern sprue to the thickest cross-sectional area of the wax pattern. The flow of molten alloy from the reservoir to the pattern margins should be from regions of greater volume to areas of lesser volume (margins). This aim is best accomplished by attaching the pattern sprue to the most practical portion of the occlusal/incisal surface. It is ill-advised to consider sprue placement in a cut-back area 0.4 mm thick, if an adjacent, fully contoured cusp is available. Molten metal flowing from a thin area (0.4 mm) to a thicker region (full wax-up) may solidify before the mold is completely filled.

The PENALTIES for not obeying this law are: COLD SHUTS, SHORT MARGINS, or INCOMPLETE CASTINGS.

b. THE 2nd LAW OF CASTING

Orient the wax pattern margins to the right and mark their location (Fig. 4-16). With centrifugal casting, the wax patterns should be positioned so that their margins face to the right, to take advantage of the centrifugal, rotational, and gravitational forces on the molten metal.¹⁰ Place a small dot of wax on the sprue former so you will know how to position the ring properly in the casting cradle, once the patterns have been invested (Fig. 4-16)

The PENALTIES for not obeying this law are: COLD SHUTS and SHORT MARGINS.

Figure 4-16. A wax orientation dot has been placed on the sprue former as a reference for the location of the margins of the wax patterns.



*Williams Gold Refining Company, 1000 Broadway, New York, N.Y.

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c. THE 3rd LAW OF CASTING

Place the wax patterns (restorations) in a COLD ZONE of the investment mold, and position the reservoir in the HEAT CENTER of the ring (Fig. 4-17). The coolest portions of the mold (COLD ZONES) are located at the end of the ring opposite the crucible and along the ring periphery. By limiting the amount of casting investment over the wax patterns to no more than 1/4 in., there is greater opportunity for molten alloy in this area to cool first. On the other hand, the hottest portion of the casting ring is located near the center and thus is referred to as the "HEAT CENTER."⁴ Ideally, the reservoir should remain molten longest to obey this law and permit the patterns to cool first. Adherence to this law improves the likelihood that casting porosity will occur in the reservoir rather than in the restoration.

The PENALTY for not obeying this law is SHRINKAGE POROSITY in the restoration.

d. THE 4th LAW OF CASTING

The reservoir must have enough molten alloy available to fill the shrinkage that occurs within the restoration.⁹ The alloy which enters the pattern (restoration) area should cool first.¹⁰ During the cooling process, the metal shrinks inside, thus creating a vacuum. For the restoration to be a complete casting, the vacuum must be able to draw additional molten alloy from an adjacent source--the reservoir. One effective reservoir is a runner bar equivalent to the thickest cross-sectional area of the wax pattern (Fig. 4-18).

The PENALTIES for not obeying this law are: SHRINKAGE POROSITY and/or SUCK-BACK POROSITY. A very common location for such porosity is at the sprue-pattern junction.

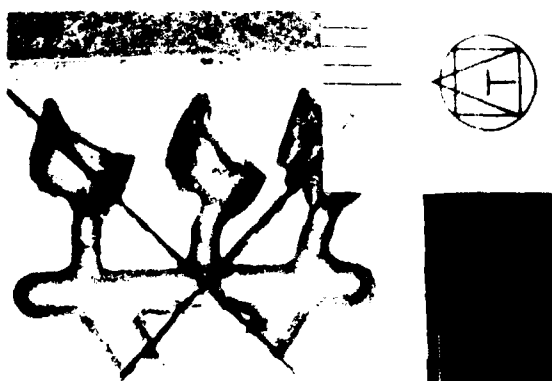
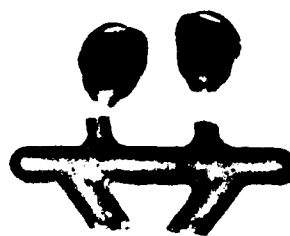


Figure 4-17. Ideally, the reservoir bar should be located in the "HEAT CENTER" of the casting ring.

Castings 19 gr



Litecast B 2 dwt 16 gr

Figure 4-18. The reservoir bar's diameter is at least equal to the thickest part of the castings, and contains ample metal to cast the two units without a button.

--SECTION 4--

e. THE 5th LAW OF CASTING

Do not cast a button if a runner bar, or other internal reservoir, is used (Fig. 4-19).⁹ In INDIRECT SPRUING, the largest mass of molten metal should be the reservoir, and the presence of a button is counterproductive. The large exposed surface area ensures that the button cools before the patterns. As a result, the button draws available molten metal from the reservoir, thereby reducing the feed of molten alloy to the restorations. The best method to eliminate a button is to weigh the wax patterns. Simply weigh the sprue former, and weigh the completed wax-up; then the difference between the two is the amount of wax above the top of the sprue former; i.e., the INDIRECT SPRUE SYSTEM (Figs. 4-20 to 4-27). An alternative method is to multiply the weight of the wax-up times the density of the alloy. The product is the approximate amount of metal needed.

The PENALTIES for not obeying this law are: SHRINKAGE POROSITY, SUCK-BACK POROSITY, and potential DISTORTION during porcelain firing.

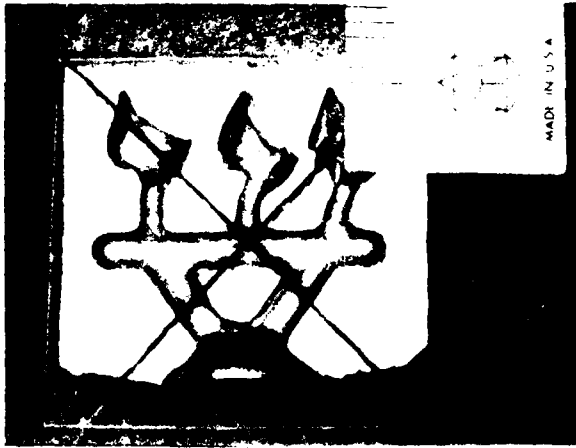


Figure 4-19. The use of too much metal can produce a large button which then competes with the reservoir bar as the largest mass of molten metal. A large button can also prevent the bar from being in the heat center of the investment.

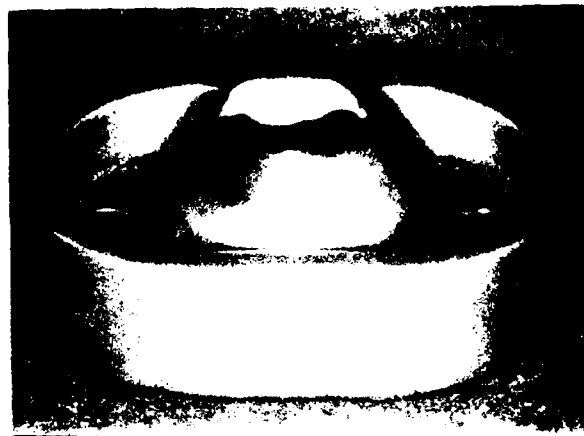


Figure 4-20. Weigh the sprue former after filling its base with wax. Once this initial weight has been determined, it should be recorded; for this step does not have to be repeated.

* Belle de St. C aire, Van Nuys, CA.

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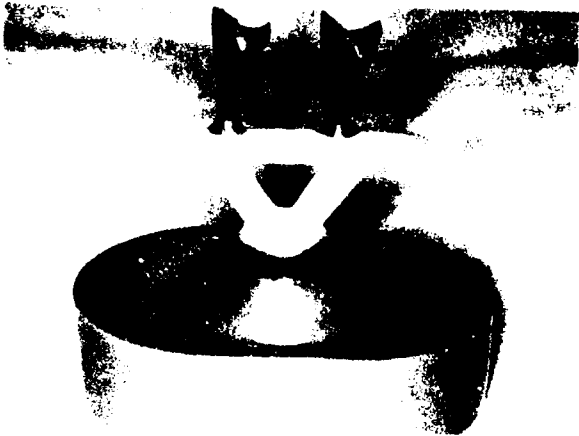


Figure 4-21. Remove the wax from the oval sprue former, insert a prefabricated sprue (Ready Sprue* shown), and attach the wax patterns to the reservoir bar. Be sure to seal the base of the prefabricated sprue to the oval sprue former.

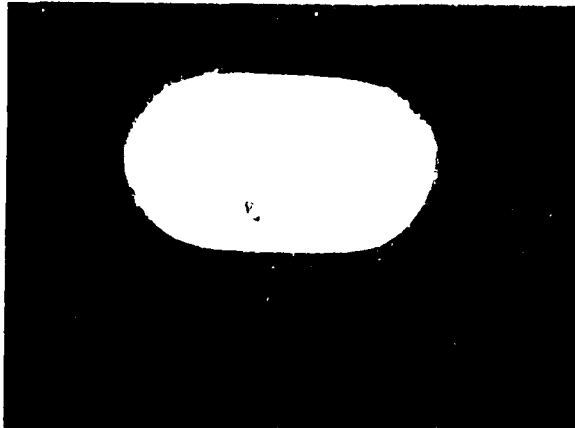


Figure 4-22. If the wax patterns have been weighed and the amount of metal properly estimated, no button should be cast. Allow the casting ring to bench cool before divesting.



Figure 4-23. With no button present, the largest mass of metal is the reservoir bar.

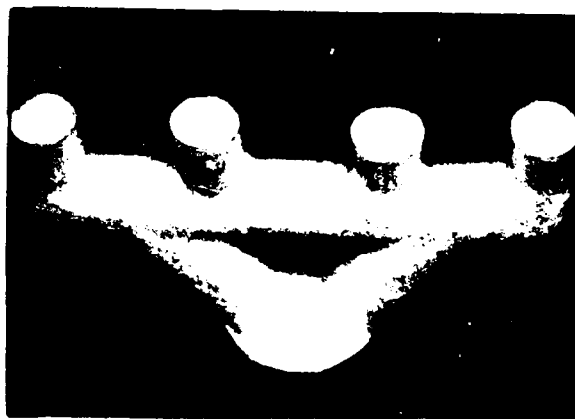


Figure 4-24. With non-precious alloys, totally eliminating a button is often difficult, because the insets of low metal are hard.

* Ready Sprue, Van Nuys, CA.

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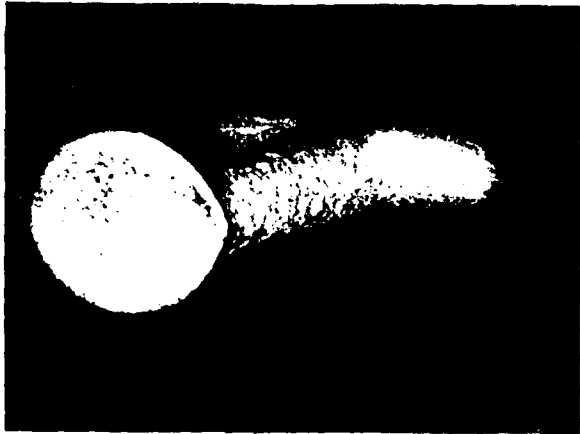


Figure 4-25. Although a button has not been totally eliminated, the casting porosity has been restricted to the underside of the reservoir bar, away from the cast restorations.

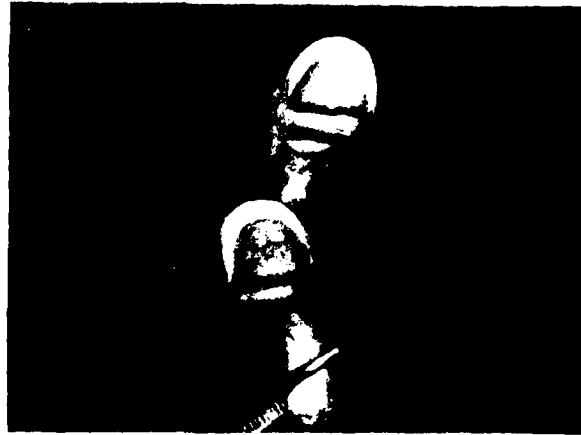


Figure 4-26. This non-precious casting (Biobond II*) was made by weighing the wax patterns and alloy. Note the dense casting and sharp margins.

Figure 4-27. The porosity in this same casting (as in Fig. 4-26) was limited to the underside of the reservoir bar, away from the cast restorations. Note that no button was cast.



* Dentsply International, Inc., York, PA.

f. THE 6th LAW OF CASTING

Turbulence must be minimized, if not totally eliminated.⁹ The pathways for the flow of molten metal during the cast must be smooth, gradual, and without impediments. It is important to eliminate sharp turns, restrictions, points, or impingement on flat surfaces. Some disagreement exists on the use of constricted spruing, as previously discussed.^{1,2,4} However, turbulence can occlude air in the casting. Any restrictions, or constrictions, can accelerate the metal's rate of flow and lead to abrasion of the mold surface, MOLD WASH.⁹

The PENALTIES for not obeying this law are: VOIDS in the casting and/or SURFACE PITTING. The VOIDS are created by the occlusion of air produced by the turbulent flow of the molten metal. When MOLD WASH occurs, investment particles are removed from the mold surface and carried ahead of the molten alloy. The presence of SURFACE PITS and incomplete margins can be attributed to these entrapped investment particles.

g. THE 7th LAW OF CASTING

Select a casting ring of sufficient diameter and length to accommodate the patterns to be invested (Fig. 4-28). The casting ring should be large enough to enable the patterns to be spaced 1/4 in. apart with at least 3/8 in. of investment between the patterns and the ring liner. The patterns need this amount of investment to prevent investment breakage and ensure equal and adequate expansion. The ring should also be long enough to permit 1/4 in. of casting investment to cover the wax patterns. If too little investment covers the wax patterns, the molten alloy is likely to break through the mold. When too much investment covers the wax-ups, the restorations may become located in the HEAT CENTER of the mold and SHRINKAGE POROSITY may occur (Fig. 4-29).

The PENALTIES for not obeying this law are: MOLD FRACTURE, CASTING FINS, and SHRINKAGE POROSITY.



Figure 4-28. The wax patterns are far enough apart and placed well away from the walls of the ring to ensure sufficient investment coverage.

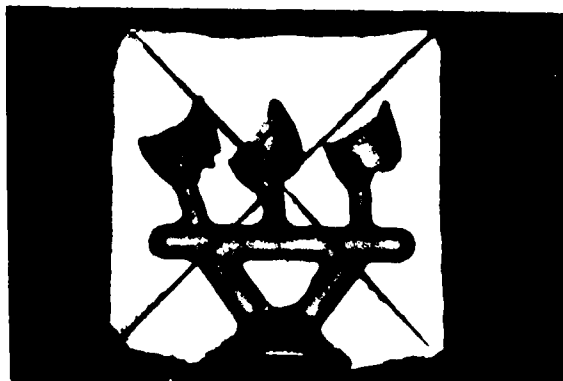


Figure 4-29. When too much investment covers the patterns, there is a greater likelihood the restorations may lie too close to the ring's HEAT CENTER.

—SECTION 4—

INVESTING AND BURNOUT

h. THE 8th LAW OF CASTING

The surface tension of the wax patterns must be reduced. A wetting agent should be brushed or sprayed on the patterns, and permitted to dry thoroughly. Reduction of the wax surface tension will enable the casting investment to wet the patterns more completely. However, either too much or too little wetting agent is equally detrimental.

The PENALTY for not obeying this law is BUBBLES on the surface of the casting, as a result of the entrapment of air (too little wetting agent) or excess liquid (too much wetting agent).

i. THE 9th LAW OF CASTING

Weigh all casting investment powder and measure all investment liquids for a precise liquid-powder ratio. The ratio of the powder to liquid and any dilution of the (special) liquid with distilled water should be determined and recorded for each alloy and investment pairing. Not all alloy-investment pairings offer the same level of castability.^{6,7}

The PENALTY for not obeying this law is ILL-FITTING CASTINGS. Generally, a thick mix of investment (too little liquid) results in added expansion and loose fitting castings. Too much liquid (special liquid and distilled water, if any) produces a thinner mix which yields less expansion and tighter fitting castings. In addition, a mix of 100% special liquid results in more expansion and more working time than a 50/50 dilution of special liquid and distilled water.

j. THE 10th LAW OF CASTING

Eliminate the incorporation of air in the casting investment during mixing and pouring. Vacuum mixing is preferred to hand spatulation to minimize the amount of air in the investment. Vacuum investing, or careful pouring of the ring, will help reduce air entrapment in the body of the investment.

The PENALTY for not obeying this law is A WAK MALL or DISTORTION of the casting. The areas of the mold which contain dense, bubble-free investment will expand differently than areas which contain large voids due to entrapped air.

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k. THE 11th LAW OF CASTING

Allow the casting investment to set completely before beginning the burnout procedure. If setting is not complete when the ring is placed in the oven, the mold will be weak and unable to withstand steam expansion during burnout. As a result, the investment may fracture or, perhaps, blow apart in the furnace. After final set has been achieved, 45-60 min, the investment will begin to dry unless placed in a humidifier. A mold that has been permitted to dry out, and has not been rewetted, may crack during the burnout or cast. Therefore, best results may be obtained when invested patterns are burned out immediately after the recommended setting time, as opposed to delayed burnout (next day).

The PENALTIES for not obeying this law are: MOLD CRACKING and/or BLOWOUT FINS on the casting.

l. THE 12th LAW OF CASTING

Use a burnout technique that is specific for the type of patterns used (wax vs. plastic) and suitable for the particular casting alloy selected. The rate of rise for the mold should be adjusted differently for wax patterns vs. plastic patterns. Plastic sprues need to be heated slowly so they soften and do not exert pressure on the mold. Therefore, a two-stage burnout is recommended. In addition, the rate of rise should be slow enough to permit the heat to move through the investment for uniform expansion to occur. The heat-soaking temperature is the high temperature setting recommended by the alloy manufacturer to ensure adequate expansion and a complete cast.

The PENALTIES for not obeying this law are: COLD SHUTS, SHORT MARGINS, COLD WELDS, MOLD CRACKS and/or CASTING FINS. If burnout is incomplete, the channels of the spruing system within the investment may be blocked by wax or plastic residual carbon. As a result, air in the mold cavity can not escape when the liquid alloy enters the ring, resulting in cold shuts, short margins, or cold welds.

MELTING AND CASTING

m. THE 13th LAW OF CASTING

Adequate heat must be available to properly melt and cast the alloy selected for use. The heat source used must be capable of melting the alloy and providing the proper temperature to achieve sufficient fluidity for complete mold filling. Inadequately heated alloy does not attain maximum fluidity and is, therefore, unable to fill the mold completely or to compensate for heat loss. Too much heat, or too high a temperature, can burn off minor alloying elements through vaporization and/or oxidation (burned metal).

The PENALTIES for not obeying this law are: COLD SHUTS, SHORT MARGINS, and COLD WELDS (too little heat), or ROUGH CASTINGS and INVESTMENT BREAKDOWN (too much heat).

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n. **THE 14th LAW OF CASTING**

Use the REDUCING ZONE of the casting torch to melt the alloy and not the oxidizing zone when torch casting. Carbon or oxygen can be inadvertently added to the alloy during the heating of the molten metal. The oxidizing portion of the flame can introduce oxygen into the melt, and adversely affect the alloy's properties. A melt achieved by the exclusive use of the REDUCING ZONE minimizes the likelihood of metal oxidation and carbon absorption, and ensures a proper melt. Non-carbon crucibles are generally recommended for palladium-, nickel-, and cobalt-base alloys.

The PENALTIES for not obeying this law are: GAS POROSITY and/or a change in the alloy's COEFFICIENT OF THERMAL EXPANSION.

o. **THE 15th LAW OF CASTING**

Enough force must be provided to cause the liquid alloy to flow into the heated mold, regardless of the type of casting machine used. The nature of the force employed will vary with the type of casting unit: a broken-arm casting machine uses INERTIA; a straight-arm machines relies on CENTRIFUGAL FORCE; and the pressure or vacuum/pressure casting machine employs PRESSURE to fill the mold. The cross-sectional strength of the casting investment is reduced in those areas taken up by the patterns. Therefore, the force of entry of the molten alloy must be balanced with the cross-sectional strength of the investment. Too much force is just as harmful as not enough.

The PENALTIES for not obeying this law are: COLD SHUTS, SHORT MARGINS, COLD WELDS (insufficient force), or MOLD FRACTURE and FINS (too much force).

p. **THE 16th LAW OF CASTING**

Cast TO your margins. Place the casting ring in the casting cradle with the pattern margins facing the trailing edge. In a centrifugal casting machine the metal will flow DOWNWARD and TO THE RIGHT, with early solidification at the trailing edge.¹⁰ Position the casting ring to take advantage of this behavior.

The PENALTIES for not obeying this law are: COLD SHUT, SHORT MARGINS, and otherwise INCOMPLETE CASTINGS.

q. **THE 17th LAW OF CASTING**

Do NOT quench the ring immediately after casting. Allow the ring to bench cool before quenching. The metal will cool much faster than the casting investment. However, the casting ring should not be disturbed (divested/quenched) until both the metal and the investment have cooled completely. The uneven cooling and shrinkage between the alloy and the investment can result in tensile forces being applied to the restoration by the investment. With premature quenching, the metal is still too hot to possess sufficient strength to resist these forces, and the restoration can tear.

The PENALTY for not obeying this law is HOT TEARS in the restoration.

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SECTION 5:

THE PORCELAIN-TO-METAL BOND

5-1. INTRODUCTION

No discussion of the PFM restoration would be complete without mention of the current theories to explain the mechanism, or mechanisms, by which dental porcelain "bonds" or "attaches" to a metal substructure. Use of the word: "bond," might imply that the relationship between the dental porcelain and the metal substructure is a purely chemical one.¹ However, non-chemical mechanisms are also thought to participate in the bonding process. As a result, it may be equally correct to refer to the union of dental porcelain and metal as attachment mechanisms.^{2,3} Whether this bond is a chemical or a mechanical attachment is, perhaps, of lesser significance. What is important is a basic understanding of the processes involved in attaining an optimum attachment.

5-2. THEORIES FOR THE PORCELAIN-METAL BOND

At least four recognized modes of bonding dental porcelain to metal are recognized: Van der Waals forces,⁴ mechanical entrapment,²⁻⁴ direct chemical bonding,²⁻⁴ and compression bonding.³ However, not everyone accepts all four of the suggested mechanisms. Nonetheless, the general agreement seems to be that the chemical type is the predominant and the most important of the four proposed bonding mechanisms.⁴

a. VAN DER WAALS BONDING

Van der Waals forces are derived from the attraction between polarized atoms which are in intimate contact, yet which do not actually exchange electrons.⁴ These forces are generally weak, since nearly all the positive and negative charges present in the atoms are satisfied in a single molecule. Therefore, only minimal attraction exists between the electrons and nuclei of atoms in one molecule, and the nuclei and electron of atoms in another molecule.⁵

Some measure of true adhesion is believed to exist, as related to the extent to which the metal substructure is wetted by the softened porcelain.⁴ In other words, the better the wetting of the metal by the dental porcelain, the greater the Van der Waals forces. This adhesion of the porcelain to the metal reportedly can be diminished or enhanced by altering the character of the porcelain-bearing surface.⁴ A rough, contaminated metal surface will actually inhibit the wetting process and, therefore, reduce the Van der Waals bond strength.⁴ Conversely, a slightly textured surface, created by finishing with uncontaminated aluminum oxide abrasives, and followed by blasting with a 50- μ m aluminum oxide abrasive, will promote wetting by the liquid porcelain and enhance adhesion by Van der Waals forces.⁴ Nonetheless, the Van der Waals forces are undoubtedly minor contributors to the attachment process.

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b. MECHANICAL ENTRAPMENT

The surface of a metal casting, even after finishing and air-abrading with aluminum oxide, contains many microscopic irregularities into which liquid opaque porcelain may flow.⁴ In fact, the air-abrasion process is believed to enhance mechanical retention by eliminating very rough areas (stress concentrations), and actually increasing the overall surface area for bonding.^{2,3}

Lacy described the mechanism for mechanical bonding to be much like the manner in which unfilled composite resin is retained by etched enamel.⁴ The enamel surface is eroded by the acid treatment creating micropores. The unfilled resin flows into these irregularities and is mechanically locked in place when set.

The contribution by mechanical bonding to the overall attachment process may be relatively small, since dental porcelain will attach to a well polished metal surface.⁴ Mechanical bonding alone is insufficient to explain the attachment process.

c. CHEMICAL BONDING

The single, most important method of porcelain-metal attachment is believed to be a chemical bond between oxygen in the porcelain and oxidizable metals from the oxide layer on the metal surface.⁴ Only a monomolecular (single molecule) layer of metallic oxides is needed for bonding to occur. In fact, too much oxidation could lead to an attachment failure through the oxide layer itself.

McLean contends that two mechanisms might exist to explain the chemical or, as he terms it, "the molecular bonding process."³ The first theory suggests that the oxide layer remains permanently bonded to the metal substructure on one side and the dental porcelain on the other.³ Thus, the oxide layer is sandwiched between the metal and the porcelain. The second theory contends that the oxide layer does not remain intact but dissolves, or is only partially dissolved by, the dental porcelain.³ As a result, the porcelain is brought into atomic contact with the metal surface for enhanced wetting and direct chemical bonding.³ If too little oxide is present and subsequently dissolved by the porcelain, then no chemical bond is left.

The consequences can also be detrimental should too much oxidation of the metal substructure occur, as with certain alloy systems. If the porcelain-metal attachment does not fail through the oxide layer itself, excessive oxide absorption can lead to changes (lowering) in the porcelain's coefficient of thermal expansion, or to alterations in the porcelain shade (graying/bluing).⁴ It is not uncommon to observe bond failures with the heavily oxidizing non-precious alloys. In some instances, the failure is not due to a loss of any bond between the dental porcelain and the oxide layer. In fact, the porcelain might remain firmly bonded to the oxides and be clearly visible (Figs. 5-1 & 5-2). The separation of the porcelain veneer from the metal substrate is more

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of a loss of attachment of the porcelain due to excessive oxidation. The porcelain and the oxide film retain their bond, yet become detached or delaminated.

Consequently, the terms "bond" and "attachment" can both be applied to describe the porcelain-oxide and the oxide-metal relationships. Each should be considered when assessing the nature of a particular failure.



Figure 5-1. The bond between this nickel-chromium-beryllium alloy (Rexillium III*) and Vita porcelain** failed 18 months after insertion. Rx. Jeneric has an alloy, Rexillium V, recommended for Vita porcelain.



Figure 5-2. A layer of oxides from the alloy remains bonded to the dental porcelain. This is a good example of a porcelain-metal bond failure, through the oxide layer itself, resulting in a delamination of the porcelain.

d. COMPRESSION BONDING

Dental porcelain is known to be stronger under compression and weaker under tension. Therefore, if the coefficient of thermal expansion of the metal substrate is greater than that of the porcelain placed over it, the porcelain should be placed under compression on cooling.^{2,3} The theory of compression bonding assumes that the restoration is a full porcelain veneer crown or retainer and NOT a partial veneer (i.e., facial surface of porcelain and metal occlusal/lingual) or pontic (Figs. 5-3 & 5-4). In the case of a pontic with full porcelain coverage, the metal substructure will cool more slowly than the porcelain covering it.

When cooling a restoration with a full porcelain veneer, the metal attempts to contract faster than the porcelain--but is resisted by the lower coefficient of thermal expansion of the porcelain.² This behavior creates tensile forces on the metal and corresponding compressive forces on the porcelain² (Fig. 5-3).

* Rx Jeneric Gold Company, Wallingford, CT.

** Vident, Baldwin Park, CA.

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Compression bonding is more likely to influence porcelain-to-metal attachment in restorations with full porcelain coverage (porcelain occlusals/linguals), and less apt to affect the attachment process in a partially veneered restoration (Figs. 5-3 & 5-4). If anything, the likelihood of stress development may be greater in some partial veneer restorations.³ The partial porcelain veneer restoration, nonetheless, is a recommended substructure design.

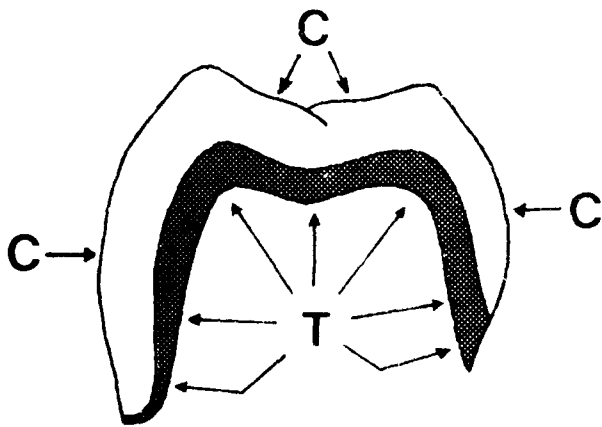


Figure 5-3. A restoration with a full porcelain veneer is more likely to maintain the dental porcelain under compression (C), and the metal under tension (T).

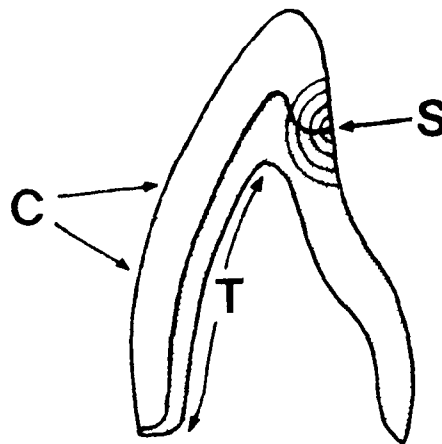


Figure 5-4. Stresses (S) are more apt to develop at the porcelain-metal junction when a partial porcelain veneer is used. (Compression = C; and tension = T)

5-3. PREPARATION OF THE METAL SUBSTRUCTURE

Despite the time and attention devoted to the preparation of a smooth, well designed wax pattern, the resultant casting is not immediately ready for porcelain. After the removal and reshaping of the pattern sprue attachment area, the exposed metal surface of the metal substrate must be subsequently finished.

Minor surface irregularities, also termed "stress raisers," may exist in the form of sand catches, ridges, pits, and small holes.⁶ Each restoration must be carefully examined for such irregularities. The finishing process should then proceed to remove these irregularities. At the same time, the finishing process should increase the wettability of the metal surface and remove traces of oxidation, investment or other surface contaminants.⁶

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Non-contaminating aluminum oxide stones are some of the most widely used abrasives, in addition to diamond stones and carbide burs. The abrasives should not be used interchangeably for different types of alloys, to avoid potential contamination of the metal surface. The finishing procedure itself is best accomplished in one direction to avoid surface air entrapment and subsequent bubbling of the opaque.⁶ The metal surface is then air-abraded with 50- μ m aluminum oxide to create a satin finish, and either steam cleaned, or placed in an ultrasonic unit for 5-10 minutes. From this point on, the porcelain-bearing areas of the restoration should be handled with an instrument to avoid contact with the fingers and, thus, possible contamination.

5-4. THE OXIDATION (DEGASSING) PROCESS

The vast majority of PFM alloys are heat treated in a porcelain furnace to a recommended high temperature, in either air or a vacuum, and are often held at temperature for a specified period of time. The procedure has been described both as a **degassing** and as an **oxidizing** step.

Degassing reportedly cleanses the metal surface of contaminants and removes surface entrapped gases such as hydrogen; hence the term degas.³ Such high temperature processing is performed to remove volatile surface contaminants which can not otherwise be eliminated by steam cleaning or air-abrading.³ Concurrent with the decontamination of the metal is the formation of an oxide layer on the metal surface. These surface oxides are responsible for the porcelain-metal bond.

The term "oxidation" (oxidizing) appears to be competing with the older designation of degassing in the dental literature, as well as in many of the manufacturers' written technical instructions. The oxidation process is the same as the degassing procedure: the heat treatment of the metal in a porcelain furnace. The major distinction may be the significance of the procedure itself. One **oxidizes** a casting to enable the oxidizable elements in the alloy to form an oxide layer for porcelain-metal attachment (bonding).

The type of atmosphere and the time at temperature will vary for the particular alloy system used. For example, a high-gold content alloy must contain oxidizable trace elements in order for oxidation to occur. Gold, and the other noble metals, do not readily form oxides; and it is often necessary to hold these castings at temperature for several minutes. The non-precious alloys will readily oxidize, and trace elements are added to enhance a particular type of oxide for a stable bond. Consequently, the oxidation process is often carried out in a vacuum to minimize the amount of oxidation; and the hold time may be omitted. In fact, allowing some non-precious metals to oxidize in air, or to remain at temperature, could lead to overoxidation and possible porcelain-metal attachment (bond) failure. Since the oxidizing technique is alloy specific, follow the manufacturer's recommendations.

The oxide film that is produced should be an adherent and stable one, if bonding is to be maximized. Therefore, follow the manufacturer's oxidation

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(degassing) instructions for each specific alloy. The appearance of a properly oxidized casting may have a distinctive color and character (texture, thickness, etc.) (Figs. 5-5 and 5-6). Variations outside these particular results should be reassessed and, perhaps, discussed with the manufacturer.

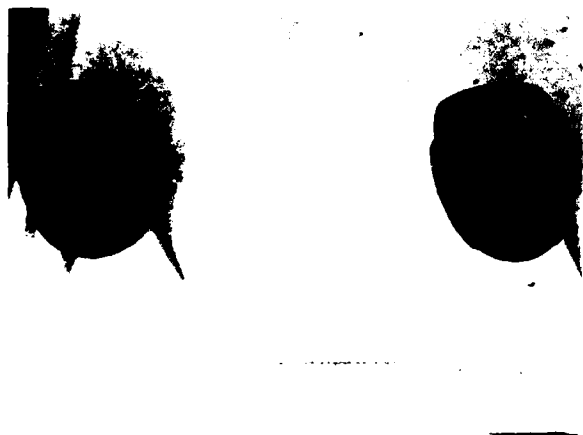


Figure 5-5. The gold-palladium alloy on the left (Olympia*) produces a light gray oxide layer, while the high palladium-copper alloy on the right (Naturelle**) has a much darker and thicker oxide.



Figure 5-6. The appearance of a properly oxidized Deguplus 2*** coping is an even, dark gray oxide layer. Although the color is not discernible in this black-and-white photograph, the oxide layer appears uniform in texture as well as in color.

Bear in mind that a few alloy manufacturers do not recommend an oxidation (degassing) step. The Unitek Corporation, which produces alloys such as PG-80+ and Forte, is one example. Others have suggested that oxidizing a casting is actually a heat-treatment procedure which can heat-soften the metal through molecular rearrangement of the alloy.⁷ The net result can be (marginal) distortion and a decrease in bond strength.⁷ It is equally important that some alloys in the same alloy system may be more prone to this distortion (thermal creep) than others. McLean contends that heat-softening, if it does occur, is merely a surface phenomenon affecting the metal to a depth of just a few microns.³ He feels that the advantages of oxidation certainly outweigh any purported disadvantages.³ Nonetheless, one should not consider the oxidation process as necessary for every FPM alloy, especially if the alloy manufacturer does not recommend it. Follow the alloy manufacturer's instructions, and do not attempt to apply general, processing information to every alloy system.

* J. S. DeLong & Co., Armonk, NY.
** American Gold Company, Wallingford, CT.
*** Degussa Dental Inc., New York, NY.

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5-5. POST-OXIDATION TREATMENT OF THE METAL SUBSTRUCTURE

As with many of the technical procedures involved in the processing of alloys for the PFM restoration, opinions differ in regard to recommended post-oxidation treatment. Some alloy manufacturers suggest air-abrading the casting with 50- μ m, non-recycled aluminum oxide to remove most of the oxide layer (Figs. 5-7 & 5-8). Despite this procedure, a monomolecular layer of oxides reportedly remains on the porcelain-bearing surfaces for porcelain bonding. Air-abrading also minimizes the thickness of oxides. Any blasting should be followed by steam cleaning, or a 5-to 10-minute cleaning in an ultrasonic unit.

With some alloys, it is best not to remove the oxide layer but to proceed directly to the application of opaque porcelain. The manufacturers may regard the initial oxide layer as the most suitable one for porcelain bonding. The palladium-silver alloys containing tin (without indium), which we tested, were two such examples.



Figure 5-7. The dark gray oxide layer of this high palladium-copper alloy (Deguplus 2*) should be removed with aluminum oxide or glass beads.



Figure 5-8. After air-abrading the casting with pure, non-recycled, 50- μ m aluminum oxide, the metal should have an even, matt finish.

5-6. THE TWO-STAGE OPAQUING PROCESS

A successful porcelain-metal bond begins with the proper firing of the initial opaque layer. It is important not only for the opaque to mask the underlying metallic color, but also to properly wet the metal surface to promote maximum coverage and a strong, uniform bond.

As a result, the two-stage opaquing process has gained considerable favor as one means to achieve this end.^{3,7} The technique is quite simple. First, the porcelain-bearing areas of the casting are lightly painted with either the opaquing liquid or distilled water, and any excess is removed. Second, a mix of

* Degussa Dental Inc., New York, NY.

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the appropriate opaque porcelain shade is applied thinly (a skim) to the metal casting, and is dried, and fired according to the porcelain manufacturer's instructions⁷ (Fig. 5-9). The restoration should be permitted to cool completely before continuing. Do not attempt to mask the metal with this initial layer of opaque porcelain. Finally, a second coat of opaque porcelain is applied to all the porcelain-bearing areas, and is dried and fired.

The initial opaque layer reportedly wets the metal surface and establishes a porcelain-metal bond, yet is thin enough to permit gases to pass through it. On the other hand, a single, thick opaque layer can trap surface contaminants and gases, and promote bubble formation if these materials can not move through the opaque layer.

Figure 5-9. The initial layer of opaque porcelain should be very thin and fired to the proper maximum temperature to establish a good porcelain-metal bond.



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SECTION 6:

THE HIGH PALLADIUM-COPPER ALLOYS

6-1. GENERAL DESCRIPTION

The inflationary rise in the price of gold has been responsible, in part, for the development of the high palladium alloys. The concern that gold might remain at such unprecedented high levels fueled competition for alternative alloys which were still precious systems. In addition, concerns over the potential health risks associated with nickel and beryllium may have prevented some consumers from switching to non-precious alloys.

So in the early 1980's, we saw the introduction of palladium-base metals with a palladium content far greater than that of recognized systems, such as palladium-silver. These new alloys have been designated as "high" palladium alloys, because the palladium content ranges between 70 and 80% of the total composition.¹ The maximum palladium content in a palladium-silver alloy may range from 53 to 60%. Therefore, palladium levels that approach, or exceed, 80% can reasonably be considered as high.

Although the fact is seldom acknowledged, not all the high palladium alloys contain the same composition of minor alloying elements for oxide formation. We have seen this difference with the nickel-base metals where there are two groups: those which contain beryllium, and those which are beryllium-free. A similar analogy exists with the high palladium alloys. One group of high palladium metals contains copper (up to 15%), with a palladium content ranging from 74 to 80%.¹ A second group of high palladium alloys contains cobalt (up to 8%) in place of copper.^{1,2} Due to the differences in composition and performance, the high palladium system has been divided into the foregoing two groups. Therefore, the high palladium-copper and high palladium-cobalt alloys are discussed separately (Tables 2 and 3).

Within the high palladium system, copper has several functions, for it:³ (1) lowers the alloy's melting range; (2) helps to promote a single-phase alloy structure; (3) is a component of the surface oxide involved in porcelain bonding; (4) strengthens the alloy; and (5) increases the linear coefficient of thermal expansion.

Another distinguishing factor for some of the high palladium alloys, especially the copper group, is the addition of trace amounts of noble metals, such as gold and platinum. In fact, many of the early high palladium alloys were actually high palladium-copper alloys with 2% gold. The marketing of these metals highlighted the presence of 2% gold, and thus a few manufacturers and consumers may refer to them as "gold-palladium" or "high palladium-gold."⁴ In truth, the presence of 1-2% gold and/or platinum is not generally regarded as significant enough to influence the structure of the alloy. Some view such additives (gold/platinum) as being more helpful, from a marketing standpoint,

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since they provide nothing more than "good luck." One manufacturer, Degussa Dental, Inc.,* contends that the addition of 1% gold in combination with 1% platinum ensures that their alloy, Deguplus 2, has a true micro-fine grain structure.⁵ That particular opinion is not held widely, and may best be addressed by future research. In the interim, we have witnessed the introduction of high palladium-copper alloys without the 2% gold.

The oxide formed during the oxidation process is rather distinctive for the high palladium-copper alloys. Invariably, a rather substantial black to dark brown oxide is produced over the entire metal surface (Fig. 6-1). The black copper oxide is not as desirable for porcelain bonding as the more adherent brown copper-gallium oxide. More importantly, the copper-gallium oxide supposedly adheres better to the metal substructure, thus resulting in a stronger bond. In general, these alloys oxidize so heavily that some reports list porcelain-metal bond failures as a weakness for this particular group.⁶ Some bubbling of the opaque was observed with a few of the alloys, but no bond failures of the kind reported for the non-precious alloys were ever noted (Fig. 6-2). If bubbling did occur, the metal was refinished, and reoxidized; then the opaque was reapplied, rather than discard the castings (Figs. 6-3 & 6-4).



Figure 6-1. The oxide layer of the high palladium-copper alloys is generally very dark and quite thick (Deguplus 2,* shown). The oxide color may range from brown to gray to black, depending on the alloy and the manner in which the casting was oxidized.



Figure 6-2. Bubbling of the opaque porcelain may occur when the metal is contaminated or improperly oxidized. Surface contaminants or entrapped gases in this high palladium-copper alloy (Athenium***) could not pass through the thick opaque layer.

* Degussa Dental Inc., New York, NY.

** Williams Gold Refining Company, Buffalo, NY.

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Figure 6-3. The porcelain fails to bond, and bubbles in the affected areas as a result of the expanding gases. Note the numerous areas of exposed metal where no bond formed.



Figure 6-4. The opaque porcelain on the Athenium substructure was removed. The metal was refinished, reoxidized, and reopaqueed without any further evidence of bubbling.

A major complaint with the oxide layer of high palladium-copper alloys is the inability of the opaque porcelain to mask the oxides (Figs. 6-5 & 6-6). The oxidation was so thick and dark that it was not uncommon for the restoration to appear "gray" or "blue." The problem was particularly pronounced with anterior units, and less detectable in posterior units surrounded by amalgam restorations (Figs. 6-7 & 6-8). Since the metal will continue to oxidize with each subsequent firing, the graying may become more apparent also with additional firings. Such potential for discoloration may be inherent in the metal, and not every dental porcelain opaque is able to mask the oxides to the same degree. Consequently, some porcelains may have greater color fidelity with these alloys than others, if their opaque is better able to control the oxide influence.



Figure 6-5. The thick, dark oxide of this high palladium-copper alloy covers the surface of the alloy.



Figure 6-6. The second opaque layer is unable to mask the dark oxides completely, gray areas.

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Figure 6-7. When the opaque porcelain is unable to mask the oxides, then "graying" of the body porcelain may occur.



Figure 6-8. The PFM crown on the maxillary right first molar (Naturelle* metal and Will-Ceram** porcelain) did not "gray."

The oxides also interfere with metal polishing, because the oxide layer must be removed in order to polish the parent metal (Fig. 6-9). In some instances, the final polish does not possess the same high sheen noted with gold-base alloys. Areas which look like oxide smudges may appear, and are difficult to remove completely. Even refinishing of the affected areas is ineffective. Such an occurrence may be an indication of fine pinhole porosity (microporosity),⁷ or possibly a two-phase atomic structure.

Another difficulty noted with the high palladium-copper alloys is the potential for marginal distortion (thermal creep) after firing the dental porcelain.¹ Again, this was not a routine occurrence with the single unit castings used in this study, and may be more of a problem with fixed partial dentures.¹



Figure 6-9. The dark oxides on the non-porcelain bearing areas must be removed in order to polish the metal surface (Naturelle*). In some instances, the surface oxides are difficult to remove, and the quality of the final polish is less than ideal.

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** Williams Gold Refining Company, Buffalo, NY.

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From the limited experiences with soldering in this project, the high palladium-copper alloys were not easy to pre-solder. The inherent tendency of these metals to oxidize readily and quite heavily prevented us from obtaining satisfactory pre-solder connectors (joints) when using natural gas and oxygen (Fig. 6-10). However, to say that these alloys can not be successfully soldered would be incorrect. These alloys do not lend themselves to pre-soldering using conventional pre-soldering techniques.¹ Alternative methods may be needed to retard oxide formation, yet permit solder flow. New solders would be helpful in order to provide a greater separation between the solder and the parent alloys.

Despite these limitations, the high palladium-copper alloys are very economical, melt readily, pool like gold-base alloys, and are compatible with a wide array of dental porcelains.



Figure 6-10. In the process of attempting to pre-solder this high palladium-copper alloy (Naturelle*), the solder did not flow and the substructure was overheated.

6-2. ECONOMIC CONSIDERATIONS

In general, the high palladium alloys are much more economical than either the high-gold or the gold-palladium PFM alloys. Even the addition of 2% gold has only a slight influence on the cost of these alternative metals. With a prevailing gold price of \$348.00/oz, the high-gold and gold-palladium metals might cost approximately \$423.00/oz and \$296.20/oz, respectively, at government prices. At the same time, a high palladium-copper alloy could be purchased for between \$110.60 and \$147.54/oz.

Since the high palladium alloys have a lower density (~10.5 g/cc) than either the high-gold (~17.5 g/cc) or the gold-palladium (~13.5 g/cc), productivity may be increased because more castings can be obtained per ounce.

* Rx. Jeneric Gold Co., Wallingford, CT

--SECTION 6--

6-3. TARNISH RESISTANCE

These alloys are primarily composed of the noble metal palladium, which enables them to be highly tarnish resistant. No restorations were observed to have undergone intraoral tarnishing.

6-4. ADVANTAGES:

Are PRECIOUS alloys.
Have a high noble metal content.
Can be used with carbon and non-carbon phosphate-bound investments.
Melt and cast like gold-base PFM alloys.
Are less dense than gold-base alloys resulting in more castings per ounce.
Are compatible with many dental porcelains.
Are less expensive than high-gold and gold-palladium alloys.
Have a high noble metal content and do not tarnish.
Are available in 2-dwt ingots.
Some are available in economical 1-dwt ingots.
The buttons are reusable.

6-5. DISADVANTAGES:

Are not A.D.A. CERTIFIED.
Are not A.D.A. "ACCEPTABLE" or "PROVISIONALLY ACCEPTABLE."
A non-carbon containing phosphate-bonded investment is preferred.
Should not be cast in carbon crucibles (Thermaxcol 2500)
As with all palladium-base alloys, they are prone to gaseous absorption (hydrogen, oxygen, etc.).
Most produce a heavy, dark oxide (black to brown color).
Porcelain-metal bond failures may occur due to heavy oxide.
The dark oxide may discolor some dental porcelains (graying).
Metal distortion (thermal creep) may occur after porcelain firing.
Gas entrapment may cause bubbling of the opaque porcelain.
Have a poor potential for burnishing.
Do not pre-solder easily.
Are sometimes difficult to polish to a high shine.

6-6. BIOCOMPATIBILITY

These alloys are composed primarily of the noble and precious metal, palladium. They do not contain nickel, beryllium, or any other elements presently suspected of being potentially harmful to patients, technicians, or clinicians. Therefore, at the present time the high palladium-copper alloys appear to be biologically safe alternatives to the gold-base systems.

—SECTION 6—

6-7. REFERENCES

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2. Bertolotti, Raymond L.: Selection of alloys for today's crown and fixed partial denture restorations. J Am Dent Assoc 108:959, 1984.
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4. Use-Survey - 1985. Clinical Research Associates Newsletter. Vol. 9(8), Aug. 1985, p. 2.
5. Personal Communication: Degussa Dental, Inc., Long Island City, N.Y., 1985.
6. Ceramics. The Dental Advisor. Vol 2(2):2, June 1985.
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EDITOR'S NOTE: The following Attachments provide comprehensive information on four examples of the high palladium-copper group; specifically, ATHENIUM, DEGUPLUS 2, NATURELLE, and PG-80+.

—SECTION 6: ATTACHMENT 1—

ATHENIUM

I. GENERAL INFORMATION

ALLOY TYPE: "PRECIOUS"

ALLOY SYSTEM: High Palladium-Copper

ALLOY CONTENT: 74% Palladium, 14.5% Copper, 5% Indium, and 6.5% Tin, Gallium, and unspecified grain refiners and deoxidizers

MANUFACTURER:

Williams Gold Refining Co.
2978 Main Street
Buffalo, New York 14214

TOLL-FREE PHONE NUMBER:

1-(800) 828-1003
1-(800) 462-7688 (in New York State)
1-(800) 852-7066 (in California)
1-(800) 824-7925 (west of the
Rocky Mountains)

COMMERCIAL PHONE NUMBER:

1-(716) 837-1000

TELEPHONE CONTACTS:

Education Department
1-(800) 828-1538

REGIONAL SALES REPRESENTATIVES:

Yes

ALLOY INTRODUCED IN: 1982

F.D.A. LISTED: Yes

A.D.A. ACCEPTANCE OR PROVISIONAL ACCEPTANCE: No

II. PHYSICAL DESCRIPTION

Ingot color - Platinum

Ingot shape - Rectangle

Ingot weight - 2 dwt

Ingots per ounce - 10 per oz

Ingot Identification - "Williams
Athenium"

Alloy Packaging- 1- and 5-oz

III. PHYSICAL AND MECHANICAL PROPERTIES

Specific gravity (density) - 11.0 g/cc

Brinell hardness number - Not determined

Vickers hardness number - 270 (after porcelain application)

Percentage elongation (in 1 in.) - 25%

Ultimate tensile strength - 123,400 psi (after porcelain application)

Yield strength (0.1% offset) - 76,100 psi (after porcelain application)

Bond strength - No value available

Coefficient of thermal expansion - $14.12 \times 10^{-6}/^{\circ}\text{C}$ from 600-20 °C

MELTING RANGE - 2120-2330 °F
(1161-1277 °C)

CASTING TEMPERATURE - 2430 °F
(1331 °C)

—SECTION 6: ATTACHMENT 1—

IV. WAXING AND SPRUING INSTRUCTIONS--ATHENIUM

A. MINIMUM RECOMMENDED WAX THICKNESS:

1. SINGLE UNITS - 0.3 mm
2. THREE-UNITS FIXED PARTIAL DENTURES - 0.5 mm
3. FIXED PARTIAL DENTURES GREATER THAN 3 UNITS - 0.5 mm.

B. RECOMMENDED SPRUING TECHNIQUE:

1. SINGLE UNITS - Use an INDIRECT spruing technique, with 8-GAUGE connector sprues, 2-3 mm in length, to each pattern; and attach them to a 6-GAUGE runner bar (distribution channel). Attach the runner bar to the sprue former with two offset 6-GAUGE lead sprues (Fig. 4-1).
2. MULTIPLE SINGLE UNITS - Use an INDIRECT spruing technique, with 8-GAUGE connector sprues, 2-3 mm in length, to each pattern; and attach them to a 6-GAUGE runner bar (distribution channel). Attach the runner bar to the sprue former with two offset 6-GAUGE lead sprues (Fig. 4-2).
3. FIXED PARTIAL DENTURES - Use an INDIRECT spruing technique, with 8-GAUGE connector sprues, 2-3 mm in length, to each wax pattern. Attach them to a 6-GAUGE runner bar (distribution channel) which extends slightly beyond the ends of the patterns.

NOTE: Adjust the connector or runner bar to conform to the contour of the fixed partial denture; cut the bar; and re wax it to eliminate wax memory. Design any INDIRECT spruing system so the runner bar is in the heat center of the casting ring (Fig. 4-2).

4. VENTING - You may include a blind vent, attached to the thickest portion of each wax pattern to help cool the restoration first. However, this step is not required.
5. WAX PATTERN POSITIONING - If the wax pattern is seated too low in the casting ring, build up the sprue former with wax and raise the pattern to within 1/4 in. of the top of the ring. This technique facilitates casting solidification and the escape of gases.

--SECTION 6: ATTACHMENT 1--

V. INVESTMENT AND BURNOUT TECHNIQUE--ATHENIUM

A. RECOMMENDED INVESTMENTS:

1. PHOSPHATE-BONDED INVESTMENTS: A NON-CARBON-containing investment (white color) is preferred. Increase burnout time if a CARBON-containing investment (black color) is used.

<u>NON-CARBON TYPE:</u>	<u>SPECIAL LIQUID</u>	<u>DISTILLED WATER</u>
a. Vestra (Unitek) -	10.0 cc	5.5 cc
b. Hi-Temp (Whip-Mix) -	4.5 cc	4.5 cc
<u>CARBON TYPE:</u>		
a. Biovest (Dentsply) -	8.0 cc	3.0 cc
b. Complete (Jelenko) -	5.5 cc	5.0 cc
c. Deguvest HFG (Degussa)	7.0 cc	2.0 cc

2. GYPSUM-BONDED INVESTMENTS: Not recommended for this alloy.

B. RECOMMENDED METHOD OF INVESTMENT: HIGH HEAT

C. MANUFACTURER'S RECOMMENDED ASBESTOS SUBSTITUTE: Unspecified.

We prefer to use one WET layer of NON-ASBESTOS ring liner (Whip-Mix), rather than ASBESTOS FREE LINER (Degussa), NOBESTOS (Jelenko), or KAOLINER (Dentsply). Place the liner flush with the top of the casting ring, with at least 1/8-in. clearance at the bottom of the ring. The 1/8-in. clearance will lock the investment in the ring when the investment expands.

D. BURNOUT TECHNIQUE:

PHOSPHATE-BONDED INVESTMENT: Start with a COLD oven; raise temperature to 1500 °F (816 °C) at the rate of 25 °F/min.; and HEAT SOAK as follows:

- a. Single units - 1 hr
- b. Three units in a single ring - 1 hr
- c. Multiple units, 2-3 rings - 1 hr and 20 min (add 10 min for each additional ring).

--SECTION 6: ATTACHMENT 1--

VI. MELTING AND CASTING INSTRUCTIONS--ATHENIUM

A. CASTING EQUIPMENT:

1. CASTING MACHINE (DO NOT USE THERMATROL 2500 WITH CARBON CRUCIBLE):
 - a. Manufacturer's recommendation - Williams Inductocast Machine
 - b. Alternative systems include - Centrifuge
2. CASTING TORCH - Harris 16-B with a #1390 H multi-orifice tip.
(Williams recommends their MAGIC WAND Torch.)
3. CASTING CRUCIBLES - Quartz or alumina. Do NOT use clay.

B. QUANTITY OF ALLOY NEEDED:

1. VOLUME OF METAL NEEDED - Refer to conversion chart (Table 1).*
2. PREFERRED RATIO OF NEW METAL TO RECAST METAL - 50/50% by weight
3. MINIMUM RATIO OF NEW METAL TO RECAST METAL - 33/67% by weight.

C. MELTING AND CASTING TECHNIQUE:

1. OXYGEN-GAS RATIO - Use 10 psi OXYGEN and 5 psi NATURAL GAS.
2. SETTING CASTING MACHINE - Add 1 extra turn for the alloy's lower density.
3. FLAME ADJUSTMENT - The multiple light blue inner cones should be set to 1/8- to 1/2-in. lengths with a maximum flame length of 8- to 10-in. (Fig. 4-12). Hold the torch tip 2 in. above the metal, with the flame perpendicular to the alloy. Guide the flame in a slight circular motion with the alloy in the REDUCING ZONE of the flame.
4. APPEARANCE OF THE MELT - The alloy will melt readily, "pool", and then "clear", like gold-based PFM alloys.
5. CASTING FLUX - Do NOT use casting flux or attempt to remove oxides.
6. WHEN TO CAST - When the molten alloy "clears" and "spins".
7. RECOVERY OF CASTING - BENCH COOL; DO NOT QUENCH; DO NOT PICKLE.

D. INDUCTION CASTING:

1. Set speed between 400 and 500 RPM
2. Set temperature to 2431 °F (1333 °C)
3. CAST at temperature.

* At close of text.

--SECTION 6: ATTACHMENT 1--

VII. ADJUSTING AND FINISHING--ATHENIUM

A. REMOVING THE SPRUE:

1. SEPARATING DISC - Use any thin separating disc of your choice.
2. GRINDINGS - This is a precious alloy, so its grindings have scrap value. Vacuum your clothing and work area.

B. FITTING THE CASTING:

1. QUALITY CONTROL CHECK - Unsatisfactory castings (poor fit, overheated alloy, porosity) should be remade.
2. REMOVE INTERNAL NODULES - Carefully inspect the inside of each casting under magnification, and remove any irregularities.
3. EVALUATE THE FIT - Verify an acceptable level of occlusal/incisal seat and marginal seal, before proceeding to any additional finishing steps.
4. INITIAL OCCLUSAL ADJUSTMENT - Articulate the casting and refine the occlusion, as necessary.

C. FINISHING THE CASTING:

1. STONES AND WHEELS - Use stones, carbide burs, and burlew wheels.
2. POLISHING - Use the same compounds employed to polish gold-base PFM alloys such as Buffing Bar Compound (BBC) and rouge.
3. AVOID METAL CONTAMINATION - Set aside a set of finishing stones for this particular alloy to prevent metal contamination.
4. ADJUSTMENT TECHNIQUE - Use uncontaminated aluminum oxide abrasives to produce a smooth, even textured surface for all porcelain-bearing areas. Finish the metal surface in one direction.

--SECTION 6: ATTACHMENT 1--

VIII. PREPARATION OF THE METAL FOR PORCELAIN--ATHENIUM

A. PREPARATION OF THE METAL SUBSTRATE:

1. NON-PORCELAIN BEARING SURFACES - "Rubber wheel" all non-porcelain bearing areas (lingual/occlusal surfaces, interproximal struts, and metal collars) to remove all scratches prior to the application of porcelain.
2. PORCELAIN BEARING SURFACES - Air-abrade the finished metal surfaces with a 50- μ m non-recycled, uncontaminated aluminum oxide (white) abrasive under 90-100 psi.
3. CLEANING - Steam clean the metal substrate, or place in distilled water in an ultrasonic unit for 10 min, after rubber-wheeling and air-abrading.

B. OXIDATION (DEGASSING) OF THE METAL SUBSTRATE:

1. LOW temperature setting - 1200 °F (649 °C)
2. HIGH temperature setting - 1850 °F (1010 °C)
3. Rate of rise - 100 °F (55 °C)
4. Atmosphere - FULL VACUUM (26-28 in. of Hg)
5. HOLD time at HIGH temperature - 5 min, under VACUUM
6. Appearance of the oxide layer:
 - a. A PROPERLY oxidized layer - LIGHT to MEDIUM BROWN color (surface finish will influence the appearance of the oxide)
 - b. An OVERoxidized layer - DARK BROWN to BLACK color (air-abrade; clean; and reoxidize at a lower temperature)
 - c. An UNDERoxidized layer - NO READILY DISCERNIBLE color. (reoxidize at a higher temperature)

C. POST-OXIDATION TREATMENT:

1. REMOVE THE OXIDE LAYER - Air-abrade the casting with non-recycled, 50- μ m aluminum oxide.
2. CLEAN THE CASTING - Steam clean or place in distilled water in an ultrasonic unit for 5 min.

---SECTION 6: ATTACHMENT 1---

IX. PORCELAIN COMPATIBILITY--ATHENIUM

A. PORCELAIN SYSTEM COMPATIBILITY CHART: The following information has been provided by the alloy manufacturer (X):

<u>DENTAL PORCELAIN</u>	<u>PORCELAIN COMPATIBILITY</u>			
	<u>YES</u>	<u>NO</u>	<u>MARGINAL</u>	<u>UNKNOWN</u>
1. <u>ARTIS-TECH</u> (Jeneric) -	X			
2. <u>BIOBOND</u> (Dentsply) -	X			
3. <u>CERAMCO</u> (Johnson & Johnson) -	X			
4. <u>CRYSTAR</u> (Unitek) -	X			
5. <u>JELENKO</u> (Jelenko) -	X			
6. (BIOBOND) <u>SHADEMATE</u> (Dentsply) Reg- Low-	X	X		
7. <u>VITA</u> (Vident) -	X			
8. <u>WILL-CERAM</u> (Williams) -	X			

B. KNOWN OR SUSPECTED PORCELAIN-METAL INCOMPATIBILITIES: None

C. SPECIAL HANDLING INSTRUCTIONS: None

—SECTION 6: ATTACHMENT 1—

X. PRE-SOLDERING INSTRUCTIONS—ATHENIUM

A. RECOMMENDED MATERIALS:

1. SOLDER - Use Will-Ceram Super Solder (flows at about 2075 °F/1135 °C)
2. FLUX - Williams High Fusing Bondal Flux
3. INVESTMENT - Use Hi-Heat Soldering Investment (Whip-Mix), or a high-heat, non-carbon casting investment with distilled water (no special liquid).

B. SOLDERING TECHNIQUE: Use the MAGIC WAND Torch (Williams) with its #248 torch tip or the HARRIS 16-S torch with a 2N tip, for precise heating. (Use 5 psi OXYGEN and 2 psi NATURAL GAS.)

1. Grind, with aluminum oxides stones, surfaces to be soldered. This process will remove any oxides or contaminants which might impede soldering.
2. Create a GAP DISTANCE of approximately 0.3 mm.
3. Mix investment so it is thick; turn the fixed partial denture upside down; fill the inside of the castings with the mix; and invert onto a patty of investment. Do not let the castings settle into the investment. Keep investment patty as small as possible.
4. Allow the investment to reach final set, trim, smooth to remove sharp angles, and allow to dry thoroughly.
5. Apply heat in excess of 800 °F (425 °C) to eliminate the wax or acrylic resin joint (Duralay); dry thoroughly; remove from furnace; cool to room temperature. (Carbon will burn off at 800 °F (425 °C), and a dry investment will draw less heat from the parent metal.)
6. Blast THROUGH, not down into, the connector (joint) area with uncontaminated 50- μ m aluminum oxide to remove the oxides. (Oxides will impede, if not prevent, the solder-parent metal union.)
7. You now want to GLAZE your solder rod. First, heat the rod to a DULL ORANGE color; dip the rod in the flux, and you should hear it sizzle. (A GLAZED solder rod will act to retain the flux on the outside of the connector, and prevents its incorporation into the soldered joint. Only a thin glaze is necessary.)
9. WEAR DARK GLASSES IN ORDER TO SEE AT THESE PRE-SOLDER TEMPERATURES, AS WELL AS TO PROTECT YOUR EYES FROM INJURY.
10. Heat the parent metal with the REDUCING atmosphere at the end of the inner blue cone(s) to prevent OXIDE FORMATION, and introduce the GLAZED solder rod to the connector area from the occlusal.
11. Solder should flow on contact, but ensure joint is filled before removing the reducing flame. BENCH COOL. Finish and polish.

—SECTION 6: ATTACHMENT 1—

XI. POST-SOLDERING INSTRUCTIONS—ATHENIUM

- A. RECOMMENDED MATERIALS: It is presupposed that the porcelain units have been glazed and polished, and the metal substructures have been designed appropriately for the post-soldering procedure.
1. SOLDER - Williams Low Fusing Solder (flows at 1350 °F/732 °C)
 2. FLUX - Williams Bondal Flux
 3. INVESTMENT - Use High-Heat Soldering Investment (Whip-Mix) or a high-heat, non-carbon casting investment with distilled water (no special liquid).
- B. POST-SOLDERING TECHNIQUE: Use a porcelain furnace for this procedure. It is especially helpful if the oven has a muffle view port (also referred to as a "sight window") to permit observation of the soldering process.
1. Invest in the normal manner for oven soldering (protect all glazed porcelain surfaces by covering them with colorless wax).
 2. Once the investment has set, heat the invested work to 800 °F (425 °C) to remove the wax or acrylic resin uniting the units.
 3. Air-abrade the joints with 50- μ m aluminum oxide to clean them.
 4. Flux each joint LIGHTLY.
 5. Dip the solder in #7 Flux (Williams), and place it in a Bunsen burner flame at the tip of the inner blue cone. The solder will immediately ball up. Remove the ball from the flame and allow it to cool.
 6. Cut the solder approximately 1/4 in. from the ball, leaving a small tail. Place one ball (tail first) in small joints, and two balls in larger connector areas.
 7. Vacuum-fire the case to approximately 1400 °F (760 °C).
 8. Hold at 1400 °F (760 °C) for 2-3 min.
 9. The solder should flow readily and fill the joint space(s).
 10. Withdraw the soldered work to the muffle door and cool.
 11. Remove the investment and polish the joint areas.

—SECTION 6: ATTACHMENT 2—

DEGUPLUS 2

I. GENERAL INFORMATION

ALLOY TYPE: "PRECIOUS"

ALLOY SYSTEM: High Palladium-Copper

ALLOY CONTENT: 80% Palladium, 1% Gold, 1% Platinum, and 18% Tin, Gallium, and Copper (exact formulation is proprietary information)

MANUFACTURER:

Degussa Dental, Inc.
21-25 44th Avenue
Long Island City, New York 11101

TOLL-FREE PHONE NUMBER:
1-(800) 221-0168, ext. 43 or 46

COMMERCIAL PHONE NUMBER:
1-(212) 392-7272

TELEPHONE CONTACTS:

Laboratory - Ms. Susan Denton, ext. 43
Research - Dr. Manohar Lal Malhotra

REGIONAL SALES REPRESENTATIVES:

No; call for assistance

ALLOY INTRODUCED IN: 1983

F.D.A. LISTED: Yes

A.D.A. ACCEPTANCE OR PROVISIONAL ACCEPTANCE: No

II. PHYSICAL DESCRIPTION

Ingot Color - Platinum
Ingot Weight - 2 Dwt
Ingot Identification - "DeguPlus 2"

Ingot Shape - Square
Ingots Per Ounce - 10 per oz
Alloy Packaging - 1 oz only

III. PHYSICAL AND MECHANICAL PROPERTIES

Specific gravity (density) - 11.5 g/cc
Brinell hardness number - 240 (soft) and 240 (hard)
Vickers hardness number - 260 (soft) and 260 (hard)
Percentage elongation (in 1 in.) - 30% (soft) and 30% (hard)
Ultimate tensile strength - 118,900 psi (soft) and 118,900 psi (hard)
Yield strength (0.2 % offset) - 83,380 psi (soft) and 83,380 psi (hard)
Bond strength - Not available
Coefficient of thermal expansion - 14.1×10^{-6} in/in/°C (+ 0.3)

MELTING RANGE - 2111-2354 °F
(1155-1155 °C)

CASTING TEMPERATURE - 2550 °F
(1399 °C)

—SECTION 6: ATTACHMENT 2—

IV. WAXING AND SPRUING INSTRUCTIONS--DEGUPLUS 2

A. MINIMUM RECOMMENDED WAX THICKNESS:

1. SINGLE UNITS - 0.3 mm
2. THREE-UNITS FIXED PARTIAL DENTURES - 0.5 mm
3. FIXED PARTIAL DENTURES GREATER THAN 3 UNITS - 0.5 mm.

B. RECOMMENDED SPRUING TECHNIQUE:

1. SINGLE UNITS - Use the DIRECT METHOD, with 8- or 6-GAUGE sprues, 10-15 mm. in length, attached directly to the thickest portion of the wax pattern (Fig. 4-1).
2. MULTIPLE SINGLE UNITS - Use the INDIRECT METHOD, with 7 mm long, 6- or 8-GAUGE sprues, attached to the wax patterns. Join these sprues to a 6-GAUGE (4 mm diameter) runner bar, which extends just beyond the width of the patterns at each end. Use 8- or 6-GAUGE sprue leads offset from the runner bar to the crucible former cone.
3. FIXED PARTIAL DENTURES - Use the INDIRECT METHOD, with 7 mm long 6- or 8-GAUGE sprues, attached to the thickest portion of each wax pattern. Join these sprues to a 6-GAUGE runner bar which extends just beyond the width of each end pattern. Use several offset 6- or 8- GAUGE sprue leads from the runner bar to the crucible former cone.

NOTE: The runner bar should be shaped to conform to the contour of the fixed partial denture. If the bar must be bent, then cut and re wax it at each cut in order to destroy any memory in the wax (Fig. 4-2).

4. VENTING - Attach 18-GAUGE wire wax to the interproximal areas to serve as chill vents.
5. WAX PATTERN POSITIONING - If the wax pattern is seated too low in the casting ring; build up the sprue former with wax; and raise the pattern to within 1/4 in. of the top of the ring. This technique will facilitate wax elimination and the escape of gases. Design the spruing system so any reservoir is in the HEAT CENTER of the casting ring with the wax patterns in a COLD ZONE (Fig. 4-2).

--SECTION 6: ATTACHMENT 2--

V. INVESTMENT AND BURNOUT TECHNIQUE--DEGUPLUS 2

A. RECOMMENDED INVESTMENTS:

1. PHOSPHATE-BONDED INVESTMENTS: Use either a NON-CARBON investment (white color), or a CARBON-containing investment.

<u>NON-CARBON TYPE:</u>	<u>SPECIAL LIQUID</u>	<u>DISTILLED WATER</u>
a. Vestra-fine (Unitek) -	10.0 cc	5.5 cc
b. Hi-Temp (Whip-Mix) -	4.5 cc	4.5 cc
<u>CARBON TYPE:</u>		
a. Deguvest HFG (Degussa) -	7.0 cc	2.0 cc
b. Biovest (Dentsply) -	8.0 cc	3.0 cc

2. GYPSUM-BONDED INVESTMENTS: NOT suitable for this alloy.

B. RECOMMENDED METHOD OF INVESTMENT: HIGH-HEAT rather than hygroscopic.

C. MANUFACTURER'S RECOMMENDED ASBESTOS SUBSTITUTE: Degussa Asbestos Free Ring Liner. Use WET.

You may also use one WET layer of NON-ASBESTOS LINER (Whip-Mix).

D. BURNOUT TECHNIQUE:

PHOSPHATE-BONDED INVESTMENT: Start with a cold oven and raise to a temperature of 600 °F (316 °C) until all wax has been eliminated; then raise to a temperature of 1560 °F (849 °C) at the rate of 68 °F/min; and HEAT SOAK as follows:

a. <u>Ring Size</u>	<u>Wax Elimination Time</u>	<u>Heat Soaking Time</u>
1x Ring	30 min	20 min
3x Ring	40 min	30 min
6x Ring	50 min	45 min
9x Ring	60 min	60 min

- b. Three units in a single ring - 40 min for 3x rings

- c. Multiple units, 2-3 rings - 60 min for 9x rings

NOTE: A longer soaking time, and/or burnout temperature, may be required to ensure complete carbon elimination when using plastic sprues.

--SECTION 6: ATTACHMENT 2--

VI. MELTING AND CASTING INSTRUCTIONS--DEGUPLUS 2

A. CASTING EQUIPMENT:

1. CASTING MACHINE (Do NOT use a THERMATROL 2500 with CARBON crucibles):
 - a. Manufacturer's preferred casting equipment - Centrifuge.
 - b. Alternative systems include - Broken-arm casting machine, centrifuge.
2. CASTING TORCH - Harris 16-S with a #1390H multi-orifice tip or Degussa torch.
3. CASTING CRUCIBLES - Use either a quartz or alumina crucible.
DO NOT USE a clay crucible.

B. QUANTITY OF ALLOY NEEDED:

1. VOLUME OF METAL NEEDED - Refer to conversion chart (Table 1)*
2. PREFERRED RATIO OF NEW METAL TO RECAST METAL - 50/50% by weight
3. MINIMUM RATIO OF NEW METAL TO RECAST METAL - 50/50% by weight.

C. MELTING AND CASTING TECHNIQUE (PROPANE preferred, NATURAL GAS alternate):

1. OXYGEN-GAS RATIO - 10 psi OXYGEN or 5 psi PROPANE (for natural gas, open valve all the way).
2. SETTING CASTING MACHINE - Add one turn to casting machine to compensate for the lower density of the alloy.
3. FLAME ADJUSTMENT - Set inner blue cone to a length of 1/2 in. or less.
4. APPEARANCE OF THE METAL - Alloy will melt rapidly, and the ingots will pool, like high-temperature alloys.
5. CASTING FLUX - Not needed.
6. WHEN TO CAST - When a solid dent, metal surface appears.
7. RECOVERY OF CASTING FLUX - See separate instructions.
8. DO NOT PICKLE.

*At close of text.

--SECTION 6: ATTACHMENT 2--

VII. ADJUSTING AND FINISHING--DEGUPLUS 2

A. REMOVING THE SPRUE:

1. SEPARATING DISC - Use any thin separating disc of your choice.
2. COLLECT GRINDINGS - This is a precious alloy, and its grindings have scrap value. Vacuum your finishing and work area.

B. FITTING THE CASTING:

1. REMOVE INTERNAL NODULES - Carefully inspect the inside of each casting under magnification, and remove all irregularities.
2. EVALUATE THE FIT - Verify an acceptable level of occlusal/incisal seat and marginal seal, before proceeding to any additional finishing steps.
3. QUALITY CONTROL CHECK - Unsatisfactory castings (poor fit, overheated alloy, porosity) should be remade.
4. INITIAL OCCLUSAL ADJUSTMENT - Articulate the casting and refine the occlusion, as necessary.

C. FINISHING THE CASTING:

1. STONES AND WHEELS - Use the same materials you have learned to finish precious PPM alloys; i.e., uncontaminated aluminum oxide stones, diamond burs, etc.
2. AVOID METAL CONTAMINATION - Set aside a set of finishing stones for this particular alloy to prevent contamination of the metal.
3. ADJUSTMENT TECHNIQUE - Use the uncontaminated aluminum oxide burs to produce a smooth, fine-textured surface for all porcelain-facing areas. Flatten the metal surface in one direction, and then in the perpendicular.

VIII. PREPARATION OF THE METAL FOR PORCELAIN--DEGUPLUS 2

A. PREPARATION OF THE METAL SUBSTRATE:

1. NON-PORCELAIN BEARING SURFACES - Rubber wheel all non-porcelain bearing areas (lingual/occlusal surfaces, interproximal struts and metal collars) to remove all scratches prior to the application of porcelain.
2. PORCELAIN BEARING SURFACES - Air-abrade the finished metal surfaces with a 50- μ m non-recycled, uncontaminated aluminum oxide (white) abrasive under 90-100 psi.
3. CLEANING - Steam clean the metal substrate, or place in distilled water in an ultrasonic unit for 10 min.

B. OXIDATION (DEGASSING) OF THE METAL SUBSTRATE:

1. LOW temperature settings - 1200 °F (649 °C)
2. HIGH temperature setting - 1760 °F (960 °C)
3. Rate of rise - Not specified.
4. Atmosphere - Air (NO VACUUM)
5. HOLD time at HIGH temperature - 10 min
6. Appearance of the oxide layer:
 - a. A properly oxidized layer - DARK GRAY color
 - b. An OVERoxidized layer - UNSPECIFIED
 - c. An UNDERoxidized layer - LIGHT GRAY color

C. POST-OXIDATION TREATMENT:

1. REMOVE THE OXIDE LAYER - Air-abrade the casting with non-recyclable 50- μ m aluminum oxide, or glass beads, simply as a precautionary step to remove metal contaminants from dissolved gases, investment, etc. directly over porcelain bearing surfaces.
2. CLEANING - Steam clean or place in distilled water in an ultrasonic unit for 10 min, after air-abrading. Then proceed with the application of opaque porcelain.

—SECTION 6: ATTACHMENT 2—

IX. PORCELAIN COMPATIBILITY--DEGUPLUS 2

A. PORCELAIN SYSTEM COMPATIBILITY CHART: The following information has been provided by the alloy manufacturer (X).

<u>DENTAL PORCELAIN</u>	<u>PORCELAIN COMPATIBILITY</u>			
	<u>YES</u>	<u>NO</u>	<u>MARGINAL</u>	<u>UNKNOWN</u>
1. <u>ARTIS-TECH</u> (Jeneric) -				X
2. <u>BIOBOND</u> (Dentsply) -			X	
3. <u>CERAMCO</u> (Johnson & Johnson) -	X			
4. <u>CRYSTAR</u> (Unitek) -			X	
5. <u>JELENKO</u> (Jelenko) -				X
6. (<u>BIOBOND</u>) <u>SHADEMATE</u> (Dentsply) Reg-	Low - X	X		
7. <u>VITA</u> (Vident) -	X			
8. <u>WILL-CERAM</u> (Williams) -	X			

B. KNOWN OR SUSPECTED PORCELAIN-METAL INCOMPATIBILITIES:

See Section A above. No other information provided.

C. SPECIAL HANDLING INSTRUCTIONS: None

—SECTION 6: ATTACHMENT 2—

X. PRE-SOLDERING INSTRUCTIONS—DEGUPLUS 2

A. RECOMMENDED MATERIALS:

1. SOLDER - Use Degudent U1 Solder (2048 °F, or 1120 °C), or Degudent N1 Solder (1940 °F, or 1060 °C)
2. FLUX - Use Degussa Anoxsan flux.
3. INVESTMENT - A soldering investment such as Deguvest L is the IDEAL material to use, but a casting investment with all distilled water may be substituted.

B. SOLDERING TECHNIQUE: For precise heating, use the Magic Wand torch (Williams) with a # 248 tip, the Harris 16-S torch and a 2N tip, or the Degussa Gas/Oxygen torch with #2 tip.

1. Propane-oxygen is the preferred heat source, although natural gas-oxygen is an acceptable alternative.
2. Be certain the surfaces to be soldered are large enough to provide adequate strength to the joint.
3. Prepare a uniform GAP DISTANCE of no more than 0.05-0.1 mm.
4. The surfaces to be soldered must have a rough finish and be clean.
5. Invest the units to be soldered in a soldering investment.
6. Trim the investment patty to a uniform but stable thickness.
7. After boiling the sticky wax out of the joint(s); clean the joint areas(s); and apply Degussa Anoxan Flux. This procedure will prevent the build-up of oxides which might interfere with the soldering process.
8. Preheat the investment block in an electric furnace at 1150 °F (621 °C).
9. Use 5 psi OXYGEN with NATURAL GAS or PROPANE.
10. Heat the solder connections until they reach the working temperature of the solder.
11. Once soldering is complete, allow the investment block to cool slowly to room temperature before divesting.
12. Grind the joint(s) with uncontaminated stones; air-abrade; and clean in an ultrasonic unit to remove all traces of flux and investments.
13. Remove the cleaned castings, and proceed with the OXIDATION process.

—SECTION 6: ATTACHMENT 2—

XI. POST-SOLDERING INSTRUCTIONS--DEGUPLUS 2

A. RECOMMENDED MATERIALS:

1. SOLDER - Use Regular White Solder (working temp. 1360 °F, or 738 °C)
2. FLUX - Use Degussa T-Flux (DO NOT APPLY FLUX TO THE PORCELAIN)
3. INVESTMENT - A soldering investment such as DEGUVEST L is the IDEAL material, but a casting investment with distilled water may be used.

B. SOLDERING TECHNIQUE: Use a porcelain furnace with a view port to monitor the soldering process.

1. Prepare a uniform GAP DISTANCE of no more than 0.05-1.0 mm.
2. Position the units to be joined on a cast and join them with sticky wax. Alternatively, the units may be united with the resin directly in the mouth with an index for reassembly, if necessary.
3. The surfaces to be soldered should be rough finished and clean.
4. Cover all the porcelain surfaces with wax, to prevent direct contact with the soldering investment, and possible porcelain discoloration.
5. Invest and trim the investment block to a minimum but stable thickness.
6. Boil out the sticky wax, and coat the joints to be soldered with T-Flux. DO NOT APPLY THE FLUX TO THE PORCELAIN.
7. Carefully melt the solder strip over a Bunsen burner until a small ball, or globule, is formed. Cut the ball off the strip, leaving a small tail.
8. Use the tail to seat each solder piece in the soldering investment. Apply T-Flux to each solder ball.
9. Preheat the assembly in front of the furnace muffle for 10-15 min.
10. Set the furnace maximum temperature to the solder working temperature.
11. Slowly insert the invested castings into the muffle to permit uniform heat absorption.
12. Leave the unit in the furnace for 2-3 min, depending on the size of the soldering work. If necessary, the temperature may be increased in 10 °F increments until the solder flows.
13. Carefully remove the work and inspect the solder joints. Allow the metal to cool uniformly, before divesting and repolishing.

--SECTION 6: ATTACHMENT 3--

NATURELLE

I. GENERAL INFORMATION

ALLOY TYPE: "PRECIOUS" ALLOY SYSTEM: High Palladium-Copper

ALLOY CONTENT: 79% Palladium, 2% Gold, 10% Copper, 9% Gallium, and
trace amounts of Aluminum, Zinc, and Ruthenium

MANUFACTURER:

Rx. Jeneric Gold Company
Jeneric Industries, Inc.
P.O. Box 724
Wallingford, Connecticut 06492

TOLL FREE PHONE NUMBER:
1-(800) 243-3969, Ext 212 or 310

COMMERCIAL PHONE NUMBER:
1-(203) 265-7397 (in Connecticut
and outside U.S., call "Collect")

TELEPHONE CONTACTS:

Laboratory: Mr. Grant Day
 Mr. Rick Tobey
Research: Dr. Arun Prasad

REGIONAL SALES REPRESENTATIVES:

None

ALLOY INTRODUCED IN: 1982

F.D.A. LISTED: Yes

A.D.A. ACCEPTANCE OR PROVISIONAL ACCEPTANCE: No

II. PHYSICAL DESCRIPTION

Ingot Color - Platinum	Ingot Shape - Square
Ingot Weight - 1 dwt	Ingots Per Ounce - 20
Ingot Identification - YES, "N"	Alloy Packaging - 1 oz only

III. PHYSICAL AND MECHANICAL PROPERTIES

Specific gravity (density) - 10.6 g/cc
Brinell hardness number - 320
Vickers hardness number - 350
Percentage elongation (in 1 in.) - 10%
Ultimate tensile strength - 185,000 psi (13,010 kg/cm²)
Yield strength (0.2% offset) - 160,000 psi (11,252 kg/cm²)
Bond strength - 16,000 psi
Coefficient of thermal expansion - .596% @ 450 °C

MELTING RANGE - 2140-2175 °F
 (1171-1190 °C)

CASTING TEMPERATURE - 2350 °F
 (1288 °C)

--SECTION 6: ATTACHMENT 3--

IV. WAXING AND SPRUING INSTRUCTIONS--NATURELLE

A. MINIMUM RECOMMENDED WAX THICKNESS:

1. SINGLE UNITS - 0.4 mm
2. THREE-UNITS FIXED PARTIAL DENTURES - 0.4 mm
3. FIXED PARTIAL DENTURES GREATER THAN 3 UNITS - 0.4 mm.

B. RECOMMENDED SPRUING TECHNIQUE:

1. SINGLE UNITS - Use the DIRECT METHOD, with 8- or 10- GAUGE sprues, 1/4 in. to 3/8 in. (6-7 mm) long, attached to the thickest part of the wax pattern. If a RESERVOIR sprue is used, the distance between the wax pattern and the reservoir should be approximately 1/16 in. (1.5 mm). (The manufacturer also suggests narrowing down the sprue as it approaches the pattern.)
2. MULTIPLE SINGLE UNITS - Use the INDIRECT METHOD, with 1/4 in. (6 mm) 10-GAUGE sprues to each pattern, an 8-GAUGE runner bar, and offset 8-GAUGE leads connecting the sprue former to the runner bar. Extend the length of the runner bar beyond the width of the patterns at each end (Fig. 4-2).
3. FIXED PARTIAL DENTURES - Use the INDIRECT METHOD, with 1/4 in. (6 mm) 10-GAUGE sprues to each pattern, an 8-GAUGE runner bar and offset 8-GAUGE leads connecting the sprue former to the runner bar. Extend the length of the runner bar beyond the width of the patterns at each end.

NOTE: The runner bar should be shaped to conform to the contour of the fixed partial denture. If the bar must be bent, then cut and re wax it at each cut in order to destroy any memory in the wax (Fig. 4-2).

4. VENTING - Is not considered necessary.
5. WAX PATTERN POSITIONING - If the wax pattern is seated too low in the casting ring; build up the sprue former with wax; and raise the patterns to within 1/4 in. of the top of the ring. This technique will facilitate wax elimination and the escape of gases during investment burnout. Arrange the spruing system so the reservoir portion is in the HEAT CENTER of the casting ring with the wax patterns in a COLD ZONE (Fig. 4-2).

—SECTION 6: ATTACHMENT 3—

V. INVESTMENT AND BURNOUT TECHNIQUE--NATURELLE

A. RECOMMENDED INVESTMENTS:

1. PHOSPHATE-BONDED INVESTMENTS: Start with a dilution ratio between 80-50% special liquid and 20-50% distilled water.

<u>NON-CARBON TYPE:</u>	<u>SPECIAL LIQUID</u>	<u>DISTILLED WATER</u>
a. Vestra-fine (Unitek)	5.5 cc	10.0 cc
b. Hi-Temp (Whip-Mix)	4.5 cc	4.5 cc
c. Shur-Temp (Modern Materials)	6.5 cc	6.0 cc

CARBON TYPE: Not tested.

NOTE: A carbon-containing investment may be used with this alloy, but all carbon must be eliminated during burnout.

2. GYPSUM-BONDED INVESTMENTS: NOT suitable for this alloy.

B. RECOMMENDED METHOD OF INVESTMENT: HIGH-HEAT rather than hygroscopic.

C. MANUFACTURER'S RECOMMENDED ASBESTOS SUBSTITUTE: KAOLINER (Dentsply), DRY

You may also use one WET layer of NON-ASBESTOS ring liner (Whip-Mix) or NOBESTOS (Jelenko). Place the ring liner flush with the top of the casting ring, but leave at least a 1/8-in. clearance at the bottom of the ring. Th 1/8-in. clearance will help lock the investment in the ring when it expands (Fig. 4-2). If additional expansion is needed, use two layers of asbestos substitute and/or more special liquid and less distilled water.

D. BURNOUT TECHNIQUE:

PHOSPHATE-BONDED INVESTMENT: Start with a cold or room temperature oven and raise to 1500 °F (816 °C) at the rate of 20 °F/min; then HEAT SOAK as follows:

- Single ring - 1-1/2 hr
- Three units in a single ring - 1-1/2 hr
- Multiple units, 2-3 rings - 1-1/2 hr, add 10 min for each additional casting ring.

—SECTION 6: ATTACHMENT 3—

VI. MELTING AND CASTING INSTRUCTIONS—NATURELLE

A. CASTING EQUIPMENT:

1. CASTING MACHINE (DO NOT USE A THERMATROL 2500 WITH CARBON CRUCIBLES):
 - a. Manufacturer's Preferred Casting Equipment - Torch and centrifuge or Induction casting
 - b. Alternative Systems Include - Centrifuge.
2. CASTING TORCH - Harris 16-S with #1390 H multi-orifice tip.
3. CASTING CRUCIBLES - Alumina or quartz; DO NOT USE CLAY OR CARBON TYPE.

B. QUANTITY OF ALLOY NEEDED:

1. VOLUME OF METAL NEEDED - Refer to conversion chart (Table 1).*
2. PREFERRED RATIO OF NEW METAL TO RECAST METAL - 50/50% by weight
3. MINIMUM RATIO OF NEW METAL TO RECAST METAL - 50/50% by weight.

C. MELTING AND CASTING TECHNIQUE (PROPANE preferred, NATURAL GAS adequate):

1. OXYGEN-GAS RATIO - 20 psi OXYGEN to NATURAL GAS, or 3-5 psi PROPANE.
2. SETTING CASTING MACHINE - Add one additional turn to casting machine to compensate for the alloy's lower density.
3. FLAME ADJUSTMENT - Adjust torch to produce inner blue cones 1/2 in. in length for the multi-orifice torch tip.
4. APPEARANCE OF THE MELT - Place the alloy in a preheated crucible, and keep the torch moving in a rotating motion to heat all the metal evenly. The individual ingots or buttons will pool together like high-gold content alloys, but they will also retain a thin OXIDE FILM.
5. CASTING FLUX - DO NOT USE FLUX, and DO NOT DISTURB THE OXIDE FILM.
6. WHEN TO CAST - When literally ROLLING around in the crucible from the pressure of the torch flame, the alloy is READY to CAST. DO NOT ATTEMPT TO BREAK THE OXIDE SKIN.
7. RECOVERY OF CASTING - BENCH COOL; DO NOT QUENCH; DO NOT PICKLE.

D. INDUCTION CASTING (Start with a preheated crucible):

1. Set ARM SPEED to 450 rpm.
2. Set POWER to 50%.
3. Set TEMPERATURE to 2350 °F (1288 °C).
4. HEAT SOAK for 5 sec.
5. Appearance of melt when ready to cast is the same with torch casting.
6. Use Jeneric's PD Flux to minimize overheating and crucible melting.

* At close of text.

--SECTION 6: ATTACHMENT 3--

VII. ADJUSTING AND FINISHING--NATURELLE

A. REMOVING THE SPRUE:

1. SEPARATING DISC - Use any thin separating disc of your choice.
2. COLLECT GRINDINGS - This is a precious alloy and its grindings have scrap value. Vacuum your clothing and work area.

B. FITTING THE CASTING:

1. REMOVE INTERNAL NODULES - Carefully inspect the inside of each casting under magnification, and remove any irregularities.
2. EVALUATE THE FIT - Verify an acceptable level of occlusal/incisal seat and marginal seal before proceeding to any additional finishing steps.
3. QUALITY CONTROL CHECK - Unsatisfactory castings (poor fit, overheated alloy, extensive porosity) should be remade.
4. INITIAL OCCLUSAL ADJUSTMENT - Articulate the casting and refine the occlusion, as necessary.

C. FINISHING THE CASTING:

1. STONES AND WHEELS - Use the same materials you have on hand to finish gold-base PFM alloys; i.e., uncontaminated aluminum oxide stones, diamond points, etc.
2. AVOID METAL CONTAMINATION - Set aside a set of finishing stones for this particular alloy to prevent contamination of the metal.
3. ADJUSTMENT TECHNIQUE - Use the uncontaminated aluminum oxide abrasives to produce a smooth, even textured surface for all porcelain-bearing areas. Finish the metal surface in one direction, using light pressure.

—SECTION 6: ATTACHMENT 3—

VIII. PREPARATION OF THE METAL FOR PORCELAIN—NATURELLE

A. PREPARATION OF THE METAL SUBSTRATE:

1. NON-PORCELAIN BEARING SURFACES - Rubber wheel all non-porcelain bearing areas (lingual/occlusal surfaces, interproximal struts and metal collars) to remove all scratches prior to the application of porcelain.
2. PORCELAIN-BEARING SURFACES - Air-abrade the finished metal surfaces with a 50- μ m non-recycled, uncontaminated aluminum oxide (white) abrasive under 60-70 psi.
3. CLEANING - Steam clean the metal substrate, or place in distilled water in an ultrasonic unit for 10 min.

B. OXIDATION (DEGASSING) OF THE METAL SUBSTRATE:

1. LOW temperature setting - 1200 °F (649 °C)
2. HIGH temperature setting - 1800 °F (982 °C)
3. Rate of rise - 90-100 °F (50-55 °C)/min
4. Atmosphere - Air (NO VACUUM)
5. HOLD time at HIGH temperature - None
6. Appearance of the oxide layer:
 - a. A PROPERLY oxidized layer - DARK-BROWN color
 - b. An OVERoxidized layer - DARK REDDISH-BROWN color
 - c. An UNDERoxidized layer - GRAY to BLACK color

C. POST-OXIDATION TREATMENT: The manufacturer has indicated that two options are available in the management of the oxidized casting.

1. REMOVE THE OXIDE LAYER - Air-abrade all porcelain-bearing areas with non-recycled, 50- μ m aluminum oxide (white in color).
2. CLEANING - Steam clean or place in distilled water in an ultrasonic unit for 10 min, if you air-abraded the oxide layer. Proceed with the application of opaque porcelain after this cleaning step.
3. RETAIN THE OXIDE LAYER - You may apply opaque porcelain directly over the oxide layer (manufacturer's preference).

--SECTION 6: ATTACHMENT 3--

IX. PORCELAIN COMPATIBILITY--NATURELLE

A. PORCELAIN SYSTEM COMPATIBILITY CHART: The following information has been provided by the alloy manufacturer (X):

<u>DENTAL PORCELAIN</u>	<u>PORCELAIN COMPATIBILITY</u>			
	<u>YES</u>	<u>NO</u>	<u>MARGINAL</u>	<u>UNKNOWN</u>
1. ARTIS-TECH (Jeneric) -	X			
2. BIOBOND (Dentsply) -	X			
3. CERAMCO (Johnson & Johnson) -	X			
4. CRYSTAR (Unitek) -	X			(post-soldering is questionable)
5. JELENKO (Jelenko) -	X			
6. (BIOBOND) SHADEMATE (Dentsply) Reg-	Low- X			
7. VITA (Vident) -	X			
8. WILL-CERAM (Williams) -	X			

B. KNOWN OR SUSPECTED PORCELAIN-METAL INCOMPATIBILITIES:

Apparently there may be some risk of porcelain-metal bond failure when post-soldering units constructed of Crystar porcelain on Naturelle metal. An elevation in the coefficient of thermal expansion of Crystar porcelain reportedly may occur. If the porcelain's expansion goes above that of the alloy, an incompatibility can be introduced.

C. SPECIAL HANDLING INSTRUCTIONS: None

--SECTION 6: ATTACHMENT 3--

X. PRE-SOLDERING INSTRUCTIONS--NATURELLE

A. RECOMMENDED MATERIALS:

1. SOLDER - CN Solder (flows between 1950 °F and 1970 °F)
2. FLUX - Use of flux is optional.
3. INVESTMENT - Use any conventional soldering investment, or a high-heat phosphate-bonded casting investment with distilled water.

B. PRE-SOLDERING TECHNIQUE: Use the MAGIC WAND Torch (Williams) with its #248 tip, or the HARRIS torch with a 2N tip for precise heating.

1. Grind, with aluminum oxides stones, surfaces to be soldered. This process will remove any oxides or contaminants which might impede soldering.
2. Create a GAP DISTANCE of approximately 0.3 mm.
3. Mix investment so it is thick; turn fixed partial denture upside down; fill the inside of the casting with the mix; add a little extra on top; and invert onto a patty of investment. Do not let it settle. Keep the investment patty as small as possible.
4. Trim the investment patty and form a "v" groove underneath each joint.
5. Allow the investment to reach final set; then boil out the wax; and preheat the assembly to 1050 °F (566 °C) for about 20 min. If acrylic resin (Duralay) is used, be sure to remove all traces of the resin before initiating the solder process.
6. Wear #5 welding glasses as protective eye wear.
7. Use 5 psi OXYGEN and 2 psi NATURAL GAS (or 2 psi PROPANE). Adjust the inner blue cone of the flame until it is defined and has no feathered edge at its tip.
8. Place the invested units on a soldering block so that the length of the assembly is perpendicular to your body. In other words, the lingual side of the units is to your right, and the facial to your left.
9. Apply the flux to the joint area using the solder strip as a carrier. It is imperative that the flux be liquified and made to flow into the joint by brushing with the flame. Repeat this step for each joint area.
10. Position the flame so that it is directed at an angle of about 80° from the lingual side, in order for it to go diagonally through the joint and heat both sides of the joint evenly.

—SECTION 6: ATTACHMENT 3—

X. PRE-SOLDERING INSTRUCTIONS-NATURELLE (Cont'd.)

11. The tip of the inner blue cone should be 1/4 in. - 1/2 in. from the joint.
12. As the surfaces to be joined turn ORANGE/WHITE, feed the fluxed end of the solder into the lower-third of the connector on the lingual (the same side where the flame is entering at the occlusal third). Continue to feed the joint until it is filled.
13. Once the joint is filled, keep the joint area red for 4-5 sec; remove the flame; and allow to cool to ROOM TEMPERATURE.
14. Remove traces of flux with stones, or blast with 50- μ m aluminum oxide abrasives.
15. Finish the metal and prepare for porcelain application.

C. OXIDATION OF PRE-SOLDERED UNITS: Castings which have been pre-soldered should be oxidized differently from non-soldered, single units substructures. Rather than removing the fixed partial denture immediately after reaching maximum temperature, HOLD the work at 1800 °F (982 °C) for 10 min in air; then remove the prosthesis from the furnace.

--SECTION 6: ATTACHMENT 3--

XI. POST-SOLDERING INSTRUCTIONS--NATURELLE

- A. RECOMMENDED MATERIALS: It is presupposed that the PFM units have been glazed and polished, and that the metal substructures have been designed appropriately for the post-soldering procedure.
1. SOLDER - WLF Solder (flows between 1310 °F and 1370 °F).
 2. FLUX - Use of LF flux is optional.
 3. INVESTMENT - Same as pre-soldering technique.
- B. POST-SOLDERING TECHNIQUE: Use a porcelain furnace for this step. It is especially helpful if the oven has a muffle view port (also referred to as a "sight window") to permit observation of the soldering process.
1. Grind joint surfaces with a fine vitrified aluminum oxide stone.
 2. Create a GAP DISTANCE of 0.3 mm.
 3. Place the units on the master cast, and seal the joint(s) with sticky wax.
 4. Added rigidity can be obtained by placing a metal rod across the occlusal or incisal surfaces, and sealing it with sticky wax.
 5. Once the sticky wax has cooled, remove the work from the master cast, and cover all the porcelain to be embedded in the investment with white wax. This step will prevent discoloration of the glazed porcelain.
 6. Invest the castings in a soldering investment (or equivalent), and allow the mix to set for 20 min.
 7. Trim the patty to a 3/8 in. thickness with 1/4 in. borders, and remove all the wax with boiling water
 8. Shape the WLF solder strip to fit the joint area in such a fashion that it fills the joint and protrudes 1/8 in. from the joint.
 9. While the work is still warm (from wax boil-out procedure), paint the joint area with LF flux. Also dip the WLF solder strip in flux before placing it in the joint itself.
 10. Dry the invested work thoroughly, and slowly introduce it into a porcelain furnace set at 1000 °F (540 °C); then heat-soak it for 2 min.
 11. With a full vacuum, increase the temperature to 1575 °F (857 °C) at the rate of 75 °F/min; and the solder should flow accordingly.
 12. Remove the work; allow it to cool; and repolish the metal.

—SECTION 6: ATTACHMENT 4—

IV. WAXING AND SPRUING INSTRUCTIONS--PG-80+

A. MINIMUM RECOMMENDED WAX THICKNESS:

1. SINGLE UNITS - 0.4 mm
2. THREE-UNITS FIXED PARTIAL DENTURES - 0.4 mm
3. FIXED PARTIAL DENTURES GREATER THAN 3 UNITS - 0.4 mm.

B. RECOMMENDED SPRUING TECHNIQUE:

1. SINGLE UNITS - Use the DIRECT METHOD, with 8- or 10-GAUGE sprues, 15 mm in length, attached to the thickest portion of the wax pattern. Do NOT constrict the sprue-pattern opening.
2. MULTIPLE SINGLE UNITS - Use either the DIRECT METHOD (above) or the INDIRECT METHOD, with 3-4 mm long 8- or 10-GAUGE pattern sprues, attached to an 8-GAUGE runner bar which extends just beyond the width of the patterns at each end. Use 8-GAUGE sprue leads offset from the runner bar to the crucible former cone.
3. FIXED PARTIAL DENTURES - Use the INDIRECT METHOD, with 3-4 mm long 8-GAUGE sprues, attached to the thickest portion of each wax pattern. Join these sprues to an 8-GAUGE runner bar which extends just beyond the width of each end pattern. Use several offset 8-GAUGE sprue leads from the runner bar to the crucible former cone.

NOTE: The runner bar should be shaped to conform to the contour of the fixed partial denture. If the bar must be bent, then cut and re wax it at each cut in order to destroy any memory in the wax (Fig. 4-2).

4. VENTING - Optional, use 18-GAUGE round wax attached near facial margins of each coping and pontic.
5. WAX PATTERN POSITIONING - If the wax pattern is seated too low in the casting ring; build up the sprue former with wax; and raise the pattern to within 1/4 in. of the top of the ring. This technique will facilitate wax elimination and the escape of gases. Design the spruing system so that any reservoir is in the HEAT CENTER of the casting ring with the wax patterns in a COLD ZONE (Fig. 4-2).

—SECTION 6: ATTACHMENT 4—

V. INVESTMENT AND BURNOUT TECHNIQUE--PG-80+

A. RECOMMENDED INVESTMENTS:

1. PHOSPHATE-BONDED INVESTMENTS: The manufacturer recommends the use of a NON-CARBON investment (white color).

<u>NON-CARBON TYPE:</u>	<u>SPECIAL LIQUID</u>	<u>DISTILLED WATER</u>
a. Vestra-fine (Unitek) -	10.5 cc	5.0 cc
b. Hi-Temp (Whip-Mix) -	4.5 cc	4.5 cc
<u>CARBON TYPE:</u> NOT recommended for this alloy.		
a. Deguvest HFG (Degussa) -	7.0 cc	2.0 cc
b. Biovest (Dentsply) -	8.0 cc	3.0 cc

2. GYPSUM-BONDED INVESTMENTS: NOT suitable for this alloy.

B. RECOMMENDED METHOD OF INVESTMENT: HIGH HEAT rather than hygroscopic.

C. MANUFACTURER'S RECOMMENDED ASBESTOS SUBSTITUTE: No preference.

You may also use one WET layer of NON-ASBESTOS LINER (Whip-Mix).

D. BURNOUT TECHNIQUE:

PHOSPHATE-BONDED INVESTMENT: Start with a cold oven and raise to a temperature of 600 °F (316 °C) and hold for 30 min; then raise the temperature to 1550 °F (843 °C); and HEAT SOAK as follows:

- a. Single ring - 1 hr
- b. Three units in a single ring - 1 hr
- c. Multiple units, 2-3 rings - 1 hr 20 min

NOTE: A longer soaking time may be required, when using plastic sprues to ensure complete carbon elimination.

—SECTION 6: ATTACHMENT 4—

VI. MELTING AND CASTING INSTRUCTIONS—PG-80+

A. CASTING EQUIPMENT:

1. CASTING MACHINE (DO NOT USE THERMATROL 2500 WITH CARBON CRUCIBLES):
 - a. Manufacturer's preferred casting equipment - Unitek Autocast
 - b. Alternative systems include - Centrifuge
2. CASTING TORCH - Harris 16-S with a #1390H multi-orifice tip or Degussa torch.
3. CASTING CRUCIBLES - Use either a quartz or alumina crucible.
DO NOT USE a clay crucible.

B. QUANTITY OF ALLOY NEEDED:

1. VOLUME OF METAL NEEDED - Refer to conversion chart (Table 1).*
2. PREFERRED RATIO OF NEW METAL TO RECAST METAL - 50/50% by weight
3. MINIMUM RATIO OF NEW METAL TO RECAST METAL - 50/50% by weight.

C. MELTING AND CASTING TECHNIQUE (PROPANE preferred, NATURAL GAS adequate):

1. OXYGEN-GAS RATIO - 25 psi OXYGEN or 15 psi PROPANE (for natural gas, open valve all the way)
2. SETTING CASTING MACHINE - Add one turn to casting machine to compensate for the lower density of the alloy.
3. FLAME ADJUSTMENT - Set inner blue cones to a length of 1/2 in. or less.
4. APPEARANCE OF THE MELT - Alloy will melt rapidly, and the ingots will pool, like gold-base PFM alloys.
5. CASTING FLUX - Not needed.
6. WHEN TO CAST - When the alloy begins to roll and glows WHITE-YELLOW, allow 5 to 10 sec of heating to ensure a thorough melt.
7. RECOVERY OF CASTING - BENCH COOL for at least 5 min. DO NOT PICKLE.

D. INDUCTION CASTING INSTRUCTIONS (Pre-heat crucible):

1. Set ACCELERATION to 6-7.
2. Set TEMPERATURE to 2600-2800 °F (1427-1538 °C).
3. APPEARANCE - Alloys will pool; pool will jump as Autocast pulses.

*At close of text.

—SECTION 6: ATTACHMENT 4—

VII. ADJUSTING AND FINISHING--PG-80+

A. REMOVING THE SPRUE:

1. SEPARATING DISC - Use any thin separating disc of your choice.
2. COLLECT GRINDINGS - This is a precious alloy, and its grindings have scrap value. Vacuum your clothing and work area.

B. FITTING THE CASTING:

1. REMOVE INTERNAL NODULES - Carefully inspect the inside of each casting under magnification, and remove any irregularities.
2. EVALUATE THE FIT - Verify an acceptable level of occlusal/incisal seat and marginal seal, before proceeding to any additional finishing steps.
3. QUALITY CONTROL CHECK - Unsatisfactory castings (poor fit, overheated alloy, porosity) should be remade.
4. INITIAL OCCLUSAL ADJUSTMENT - Articulate the casting and refine the occlusion, as necessary.

C. FINISHING THE CASTING:

1. STONES AND WHEELS - Use the same materials you have on hand to finish precious PFM alloys; i.e., uncontaminated aluminum oxide stones, diamond points, etc.
2. AVOID METAL CONTAMINATION - Set aside a set of finishing stones for this particular alloy to prevent contamination of the metal.
3. ADJUSTMENT TECHNIQUE - Use the uncontaminated aluminum oxide abrasives to produce a smooth, even textured surface for all porcelain-bearing areas. Finish the metal surface in one direction, using light pressure.

—SECTION 6: ATTACHMENT 4—

VIII. PREPARATION OF THE METAL FOR PORCELAIN—PG-80+

A. REPARATION OF THE METAL SUBSTRATE:

1. NON-PORCELAIN BEARING SURFACES - Rubber wheel all non-porcelain bearing areas (lingual/occlusal surfaces, interproximal struts and metal collars) to remove all scratches prior to the application of porcelain.
2. PORCELAIN-BEARING SURFACES - Air-abrade the finished metal surfaces with a 50- μ m non-recycled, uncontaminated aluminum oxide (white) abrasive under 90-100 psi.
3. CLEANING - Steam clean the metal substrate, or place in distilled water in an ultrasonic unit for 10 min.

B. OXIDATION (DEGASSING) OF THE METAL SUBSTRATE:

AS OF THIS TIME, THE MANUFACTURER DOES NOT RECOMMEND THAT THIS ALLOY UNDERGO THE CUSTOMARY OXIDATION PROCEDURE TO MINIMIZE THE POTENTIAL FOR THERMAL CREEP.

1. LOW temperature settings - Not applicable (N/A)
2. HIGH temperature setting - N/A
3. Rate of rise - N/A
4. Atmosphere - N/A
5. HOLD time at HIGH temperature - N/A
6. Appearance of the oxide layer:
 - a. A properly oxidized layer - N/A
 - b. An OVERoxidized layer - N/A
 - c. An UNDERoxidized layer - N/A

—SECTION 6: ATTACHMENT 4—

IX. PORCELAIN COMPATIBILITY—PG-80+

A. PORCELAIN SYSTEM COMPATIBILITY CHART: The following information has been provided by the alloy manufacturer (X):

<u>DENTAL PORCELAIN</u>	<u>PORCELAIN COMPATIBILITY</u>			
	<u>YES</u>	<u>NO</u>	<u>MARGINAL</u>	<u>UNKNOWN</u>
1. ARTIS-TECH (Jeneric) -				X
2. BIOBOND (Dentsply) -	X			
3. CERAMCO (Johnson & Johnson) -	X			
4. CRYSTAR (Unitek) -	X			
5. JELENKO (Jelenko) -	X			
6. (BIOBOND) SHADEMATE (Dentsply) Reg -	Low -			X
7. VITA (Vident) -	X			
8. WILL-CERAM (Williams) -	X			

B. NONE OR SUSPECTED PORCELAIN INCOMPATIBILITIES: None

Refer to Section A above. No other information provided.

C. SPECIAL HANDLING INSTRUCTIONS: None

--SECTION 6: ATTACHMENT 4--

X. PRE-SOLDERING INSTRUCTIONS--PG-80+

A. RECOMMENDED MATERIALS:

1. SOLDER - Use UTK High Fusing Gold Solder (1945 °F/1063 °C)
2. FLUX - Use UTK High Fusing Gold Solder flux.
3. INVESTMENT - No preference. Use either a soldering investment or a high-heat casting investment with all distilled water.

B. SOLDERING TECHNIQUE: For precise heating, use the Magic Wand torch (Williams) with a #248 tip, or the Harris 16-S torch and a 2N tip.

1. Grind the metal surfaces to be soldered with uncontaminated abrasives used with PG-80+ exclusively.
2. Prepare a uniform GAP DISTANCE of 0.3 mm.
3. Invest in a high-heat soldering investment with a 3/8-in. base.
4. Trim the investment to remove sharp angles and to create access to each joint area.
5. Boil off the sticky wax or heat to 1000 °F (538 °C) to remove any acrylic resin. Allow to cool to room temperature, and clean the joint areas(s).
6. Cover each joint with solder flux paste, and be sure to get the paste between each unit. Use an instrument, if necessary.
7. Preheat the investment block in an electric furnace at 1150 °F (621 °C).
8. Use 25 psi OXYGEN with NATURAL GAS or 15 psi PROPANE.
9. Place cut sections of the UTK High Fusing Gold Solder in each joint.
10. Heat the solder connections(s) until they reach the working temperature of the solder.
11. Once soldering is complete, allow the investment block to cool slowly to room temperature before divesting.
12. Grind the joint(s) with uncontaminated stones; air-abrade; and clean in an ultrasonic unit to remove all traces of flux and investments.
13. Remove the cleaned castings, and proceed with the application of opaque porcelain.

—SECTION 6: ATTACHMENT 4—

XI. POST-SOLDERING INSTRUCTIONS—PG-80+

A. RECOMMENDED MATERIALS:

1. SOLDER - Unitek Low Fusing Gold Solder (flows at 1544 °F/ 840 °C)
2. FLUX - Use Unitek Low Fusing Gold Solder flux.
3. INVESTMENT - No preference. Use either a soldering investment or a high-heat casting investment with distilled water.

B. SOLDERING TECHNIQUE: Use a porcelain furnace with a view port to monitor the soldering process.

1. Prepare a uniform GAP DISTANCE of no more than 0.1-0.2 mm.
2. Join the units to be soldered with sticky wax or acrylic resin, then reinforce with heavy gauge wire.
3. Cover all the porcelain surfaces with white or ivory wax, to prevent contact with the soldering investment and porcelain discoloration.
4. Invest and trim the investment block to a thickness of 3/8 in.(9 mm).
5. Boil out the sticky wax and clear waxes.
6. Air-abrade the solder area(s) with 50- μ m aluminum oxide under 20 psi.
7. Apply a thin layer of low fusing flux to the solder and place it in each joint. Remove any excess to prevent porcelain discoloration.
8. Preheat the assembly in front of the furnace muffle for 15 min.
9. Slowly introduce the work into a furnace preheated to 1200 °F/649 °C.
10. Raise vacuum to 700 mm Hg.
11. Set the furnace maximum temperature to the solder working temperature (1544 °F/840 °C).
12. Observe when solder has flowed completely.
13. If necessary, the temperature may be increased in 10 °F increments until the solder flows.
14. Carefully remove the work and inspect the solder joints. Allow the metal to cool uniformly, before divesting and repolishing.

SECTION 7:

THE HIGH PALLADIUM-COBALT ALLOYS

7-1. GENERAL DESCRIPTION

The strong interest in an economical precious alternative to gold-base metals probably was responsible for the development of the high palladium-cobalt group. The popularity of the high palladium-copper alloys has been tempered to some degree by the problems associated with this new group of metals. The general attitude was that, if copper were to blame for many of the ills of the high palladium-copper group, then a high palladium alloy with a copper substitute might be more attractive. Apparently, this has not been the case. Of the two high palladium groups, the cobalt-group does not appear to have captured an equal share of the high palladium market with the copper-group.

In general, the palladium content of the high palladium-cobalt alloys ranges between 78 and 88%.¹ The two cobalt-containing alloys we examined contained either 83 or 88% palladium, up to 8% cobalt, and no gold or platinum. The commercial success of the high palladium alloys containing 2% gold has led to the development of high palladium-cobalt alloys with this noble metal addition. Alloy competition is keen in the dental industry. If clinicians and technicians want a 2% gold content in order to describe their alloy as "palladium-gold," they will find several alloys from which to choose.

One of the most obvious features of the cobalt-containing alloys is the production of a characteristic cobalt-blue oxide (Fig. 7-1). The oxide layer is as distinctive for this group as the brown to black oxide is for the copper-containing alloys. However, the substitution of cobalt for copper has also affected the properties of the metal as well (Table 3). These alloys may be more prone to overheating and porcelain bubbling.² Their castability may not be as good as the copper group, and indirect spruing and a minimum burnout temperature of 1450 °F (788 °C) is recommended.² On the other hand, they reportedly are more amenable to pre-soldering, although we did not attempt to confirm this fact.² In addition, it has been suggested that members of the cobalt group have more thermal stability (sag resistance) than their copper-containing counterparts.² In fact, some contend the high palladium-cobalt alloys are the most sag-resistant of all the noble metal alloys.¹ At least one of the high palladium-cobalt alloys has been advertised as possessing a more stable and thin oxide, accompanied by the tendency to inhibit oxide build-up.³ Since these alloys are copper-free alloys, there is no need to hold the castings at temperature for 5 min during the oxidation process. That is a 5-min time savings for the technician.

The high palladium-cobalt alloys we tested appeared to produce a very distinctive cobalt-blue oxide comparable in thickness to the copper-group. The oxide appears to be thicker than that of a gold-palladium alloy (Fig. 7-2). However, this assessment was based on direct visual observation and not a scientific measurement of oxide film thickness. The blue oxide is rather pronounced and might affect porcelain shade (blueing) as the brown-black oxidation does the alloys from the copper group.

--SECTION 7--

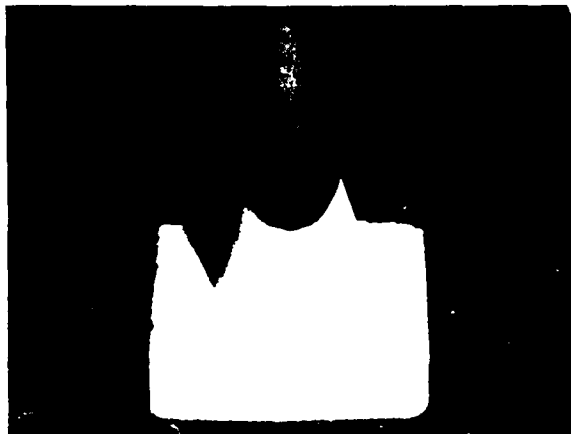


Figure 7-1. This high palladium-cobalt alloy (PTM-88*) produces a rather distinctive oxide layer. Although the blue-purple color is not discernible, the smooth texture of this dark oxide can be observed.

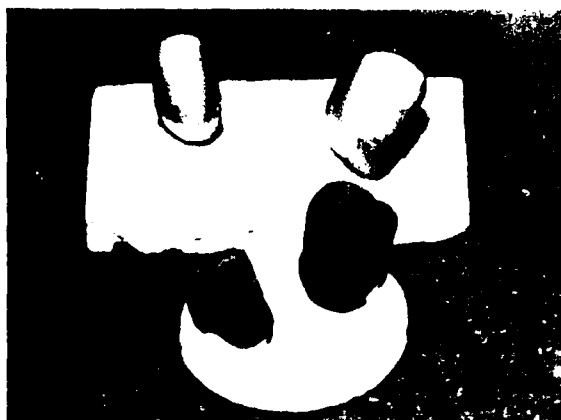


Figure 7-2. The oxidized castings of a gold-palladium alloy (Olympia*) at the top produce a thinner, lighter gray oxide layer than the high-palladium-cobalt (PTM-88*) units at the bottom.

The most striking observation noted with the cobalt-containing alloys was one instance in which a dark (oxide) film formed on glazed porcelain after final cementations (Figs. 7-3 & 7-4). This phenomenon was observed on only one occasion with only one alloy (PTM-88). The cause of this occurrence is still not known, so this finding is reported for information only. We do not wish to imply that such behavior is characteristic of this particular metal or the high palladium-cobalt group as a whole.



Figure 7-3. The dark film, at the cervical area of the maxillary left lateral incisor, formed on the glazed porcelain after the prosthesis had been cemented.



Figure 7-4. The film was limited to the surface of the glazed porcelain, and was easily removed with gentle wiping.

* J. E. DeLena & Co., Ammon, N.Y.

—SECTION 7—

7-2. ECONOMIC CONSIDERATIONS

The high palladium-cobalt alloys are comparable in price to their copper-containing counterparts, and much more economical than gold-base alloys. The density of the cobalt-containing metals is comparable to that of the copper group, and lower than that of the high-gold or gold-palladium metals. Therefore, these alloys can produce more castings per ounce of alloy, the buttons are reusable, and the grindings have scrap value.

7-3. TARNISH RESISTANCE

These alloys are primarily composed of the noble metal palladium which enable them to be highly tarnish resistant. No restorations were observed to have undergone intraoral tarnishing.

7-4. ADVANTAGES:

- Are PRECIOUS alloys.
- Have a high noble metal content.
- Can be used with carbon and non-carbon phosphate-bound investments.
- Melt and cast like gold-base PFM alloys.
- Are less dense than gold-base alloys, thus providing more castings per ounce.
- Are compatible with many dental porcelains.
- Have burnishing characteristics similar to those of gold-palladium alloys.
- Are less expensive than high-gold and gold-palladium alloys.
- Have a high noble metal content and do not tarnish.
- Available in 2-dwt ingots.
- Reportedly are easier to pre-solder than high palladium-copper alloys.
- Reportedly polish like gold-palladium alloys.
- The buttons are reusable.
- Their trace elements reportedly do not burn off as readily as with the high palladium-copper alloys.

7-5. DISADVANTAGES:

- Are not A.D.A. CERTIFIED.
- Are not A.D.A. "ACCEPTABLE" or "PROVISIONALLY ACCEPTABLE."
- Should not be cast in carbon crucibles (Thermatrol 2500).
- A non-carbon containing phosphate-bonded investment is preferred.
- Are prone to gaseous absorption (hydrogen, oxygen, etc.).
- May be more prone to overheating than high palladium-copper group.
- May not have the same castability as the high palladium-copper alloys.
- Most produce a thick blue oxide.
- Porcelain-metal bond failures may occur due to heavy oxide.
- Gas entrapment may cause bubbling of the opaque porcelain.
- The blue oxide may discolor some dental porcelains.
- Generally, have a relatively high thermal expansion coefficient.
- Are more compatible with high expansion dental porcelains.

—SECTION 7—

7-6. BIOCOMPATIBILITY

The cobalt-containing high palladium alloys are composed largely of the noble and precious metal palladium. They do not contain nickel, beryllium, or any other elements presently suspected of being potentially harmful to patients, dental technicians, or clinicians. Therefore, on the basis of present information, the high palladium-cobalt alloys appear to be biologically safe alternatives for the gold-base systems.

7-7. REFERENCES

1. Anusavice, K. J.: Noble metal alloys for metal-ceramic restorations. Dent Clin North Am 29 (4):789, 1985.
2. Personal communication. Mr. Paul Cascone, J. F. Jelenko & Co., Armonk, NY, 1984.
3. PTM-88 and Micro-Star. J. F. Jelenko & Co., Armonk, NY, 1985.

EDITOR'S NOTE: The following Attachments provide comprehensive information on two examples of the high palladium-cobalt group; specifically, PTM-88 and SUPRA-AP.

—SECTION 7: ATTACHMENT 1—

PTM-88

I. GENERAL INFORMATION

ALLOY TYPE: "PRECIOUS" ALLOY SYSTEM: High Palladium-Cobalt

ALLOY CONTENT: 88% Palladium, 8% Gallium, and 4% Cobalt

MANUFACTURER:

J. F. Jelenko & Company
99 Business Park Drive
Armonk, New York 10504

TOLL-FREE PHONE NUMBER:
1-(800) 431-1785

COMMERCIAL PHONE NUMBER:
1-(914) 273-8600

TELEPHONE CONTACTS:

Technical Services Dept.

REGIONAL SALES REPRESENTATIVES:

Yes

ALLOY INTRODUCED IN: 1983

F.D.A. LISTED: Yes

A.D.A. ACCEPTANCE OR PROVISIONAL ACCEPTANCE: No

II. PHYSICAL DESCRIPTION

Ingot Color - Platinum
Ingot Weight - 2 dwt
Ingot Identification - "Jelenko
PTM-88"

Ingot Shape - Rectangle
Ingots Per Ounce - 10
Alloy Packaging - 1 oz

III. PHYSICAL AND MECHANICAL PROPERTIES

Specific gravity (density) - 11.0 g/cc
Brinell hardness number - 210
Vickers hardness number - 235
Percentage elongation (in 1/2 in.) - 25%
Ultimate tensile strength - 115,000 psi
Yield strength (0.1% offset) - 83,000 psi
Bond strength - 18,000 psi
Coefficient of thermal expansion - 14.2×10^{-6} in/in/°C

MELTING RANGE - 2120-2340 °F
(1160-1282 °C)

CASTING TEMPERATURE - 2450 °F
(1343 °C)

--SECTION 7: ATTACHMENT 1--

IV. WAXING AND SPRUING INSTRUCTIONS--PIM-88

A. MINIMUM RECOMMENDED WAX THICKNESS:

1. SINGLE UNITS - 0.5 mm
2. THREE-UNITS FIXED PARTIAL DENTURES - 0.5 mm
3. FIXED PARTIAL DENTURES GREATER THAN 3 UNITS - 0.5 mm.

B. RECOMMENDED SPRUING TECHNIQUE:

1. SINGLE UNITS - Use the INDIRECT METHOD, with 8- or 10- GAUGE sprues 5 mm long, attached to the thickest part of the wax pattern; a 6- or 8-GAUGE runner bar, and offset 8-GAUGE leads connecting the sprue former to the runner bar (Fig. 4-2).
2. MULTIPLE SINGLE UNITS - Use the INDIRECT METHOD, with 8- or 10-GAUGE sprues 5 mm long, attached to the thickest part of each pattern; a 6- or 8-GAUGE runner bar, and offset 8-GAUGE leads connecting the sprue former to the runner bar. Extend the length of the runner bar beyond the width of the patterns at each end.
3. FIXED PARTIAL DENTURES - Use the INDIRECT METHOD, with 8- or 10-GAUGE sprues 5 mm long, attached to the thickest part of each pattern; a 6- or 8-GAUGE runner bar, and offset 8-GAUGE leads connecting the sprue former to the runner bar. Extend the length of the runner bar beyond the width of the patterns at each end.

NOTE: The runner bar should be shaped to conform to the contour of the fixed partial denture. If the bar must be bent, then cut and rewire it at each cut in order to destroy any memory in the wax (Fig. 4-2).

4. VENTING - Is not considered necessary.
5. WAX PATTERN POSITIONING - If the wax pattern is seated too low in the casting ring, build up the sprue former with wax, and raise the patterns to within 1/4 in. of the top of the ring. This technique will facilitate wax elimination and the escape of gases during investment burnout. Arrange the spruing system so the reservoir portion is in the HEAT CENTER of the casting ring with the wax patterns in a COLD ZONE (Fig. 4-2).

--SECTION 7: ATTACHMENT 1--

V. INVESTMENT AND BURNOUT TECHNIQUE--PIM-88

A. RECOMMENDED INVESTMENTS:

1. PHOSPHATE-BONDED INVESTMENTS: Start with a dilution ratio between 80-50% special liquid and 20-50% distilled water.

<u>NON-CARBON TYPE:</u>	<u>SPECIAL LIQUID</u>	<u>DISTILLED WATER</u>
a. Vestra-fine (Unitek)	11.0 cc	4.5 cc
b. Hi-Temp (Whip-Mix)	4.5 cc	4.5 cc
c. Hi-Span (Jelenko)	Not tested with this alloy	
<u>CARBON TYPE:</u>		
Deguest HFG (Degussa)	7.0 cc	2.0 cc

NOTE: A carbon-containing investment may be used with this alloy, but all carbon must be eliminated during burnout.

2. GYPSUM-BONDED INVESTMENTS: NOT suitable for this alloy.

B. RECOMMENDED METHOD OF INVESTMENT: HIGH HEAT rather than hygroscopic

C. MANUFACTURER'S RECOMMENDED ASBESTOS SUBSTITUTE: NOBESTOS (Jelenko)

You may use one WET layer of NON-ASBESTOS ring liner (Whip-Mix) or a similar material. Place the ring liner flush with the top of the casting ring, but leave at least a 1/8-in. clearance at the bottom of the ring. The 1/8-in. clearance will help lock the investment in the ring when it expands (Fig. 4-2). If additional expansion is needed, use two layers of asbestos substitute and/or more special liquid and less distilled water.

D. BURNOUT TECHNIQUE:

PHOSPHATE-BONDED INVESTMENT: Start with a cold or room temperature oven and raise to 1500 °F (816 °C) at the rate of 20 °F/min; then HEAT SOAK as follows:

- a. Single ring - 1 hr
- b. Three units in a single ring - 1 hr
- c. Multiple units, 2-3 rings - 1 hr and 20 min, add 10 min for each additional casting ring.

—SECTION 7: ATTACHMENT 1

VI. MELTING AND CASTING INSTRUCTIONS—PTM-88

A. CASTING EQUIPMENT:

1. CASTING MACHINE (DO NOT USE A THERMAIROL 2500 WITH CARBON CRUCIBLES):
 - a. Manufacturer's Preferred Casting Equipment - Torch and centrifuge
 - b. Alternative Systems Include - Centrifuge
2. CASTING TORCH - Harris 16-S with #1390 H multi-orifice tip.
3. CASTING CRUCIBLES - Alumina or quartz; DO NOT USE CLAY OR CARBON TYPE.

B. QUANTITY OF ALLOY NEEDED:

1. VOLUME OF METAL NEEDED - Refer to conversion chart (Table 1).*
2. PREFERRED RATIO OF NEW METAL TO RECAST METAL - 50/50% by weight
3. MINIMUM RATIO OF NEW METAL TO RECAST METAL - 50/50% by weight

C. MELTING AND CASTING TECHNIQUE (PROPANE preferred, NATURAL GAS adequate):

1. OXYGEN-GAS RATIO - 10 psi OXYGEN to NATURAL GAS, or 10 psi PROPANE.
2. SETTING CASTING MACHINE - Add one additional turn to casting machine to compensate for the alloy's lower density.
3. FLAME ADJUSTMENT - Adjust torch to produce inner blue cones 1/4 in. in length for the multi-orifice torch tip.
4. APPEARANCE OF THE MELT - Place the alloy in a preheated crucible. The individual ingots or buttons will pool together like high-gold content alloys, but they will also take on a cloudy surface appearance (thin OXIDE FILM).
5. CASTING FLUX - Flux is not necessary.
6. WHEN TO CAST - When the cloudiness disappears, the alloy is READY to CAST. DO NOT ATTEMPT TO BREAK THE OXIDE SKIN.
7. RECOVERY OF CASTING - BENCH COOL; DO NOT QUENCH; DO NOT PICKLE.

D. INDUCTION CASTING (Start with a preheated crucible):

Jelenko Procaster

1. Set ARM SPEED to 3-4.
2. Set POWER to 3-4.

* At close of text.

—SECTION 7: ATTACHMENT 1—

VII. ADJUSTING AND FINISHING—PIM-88

A. REMOVING THE SPRUE:

1. SEPARATING DISC - Use Jelenko High-Speed separating disc or similar disc.
2. COLLECT GRINDINGS - This is a precious alloy, and its grindings have scrap value. Vacuum your clothing and work area.

B. FITTING THE CASTING:

1. REMOVE INTERNAL NODULES - Carefully inspect the inside of each casting under magnification, and remove any irregularities.
2. EVALUATE THE FIT - Verify an acceptable level of occlusal/incisal seat and marginal seal, before proceeding to any additional finishing steps.
3. QUALITY CONTROL CHECK - Unsatisfactory castings (poor fit, overheated alloy, extensive porosity) should be remade.
4. INITIAL OCCLUSAL ADJUSTMENT - Articulate the casting and refine the occlusion, as necessary.

C. FINISHING THE CASTING:

1. STONES AND WHEELS - Use the same materials you have on hand to finish gold-base PFM alloys; i.e., Jelenko Brown Mounted Points, uncontaminated aluminum oxide stones, diamond points, etc.
2. AVOID METAL CONTAMINATION - Set aside a set of finishing stones for this particular alloy to prevent contamination of the metal.
3. ADJUSTMENT TECHNIQUE - Use the uncontaminated aluminum oxide abrasives to produce a smooth, even textured surface for all porcelain-bearing areas. Finish the metal surface in one direction and use light pressure.

—SECTION 7: ATTACHMENT 1—

VIII. PREPARATION OF THE METAL FOR PORCELAIN--PTM-88

A. PREPARATION OF THE METAL SUBSTRATE:

1. NON-PORCELAIN BEARING SURFACES - Rubber wheel all non-porcelain bearing areas (lingual/occlusal surfaces, interproximal struts, and metal collars) to remove all scratches prior to the application of porcelain.
2. PORCELAIN-BEARING SURFACES - Air-abrade the finished metal surfaces with a 50- μ m non-recycled, uncontaminated aluminum oxide (white) abrasive under 90-100 psi.
3. CLEANING - Steam clean the metal substrate, or place in distilled water in an ultrasonic unit for 10 min.

B. OXIDATION (DEGASSING) OF THE METAL SUBSTRATE:

1. LOW temperature setting - 1300 °F (704 °C)
2. HIGH temperature setting - 1850 °F (1010 °C)
3. Rate of rise - 90-100 °F (50-55 °C)/min
4. Atmosphere - Air (NO VACUUM)
5. HOLD time at HIGH temperature - None
6. Appearance of the oxide layer:
 - a. A PROPERLY oxidized layer - BLUE-PURPLE color, rough surface
 - b. An OVERoxidized layer - Not obvious, by appearance, with this particular alloy.
 - c. An UNDERoxidized layer -

C. POST-OXIDATION TREATMENT:

1. **REMOVE THE OXIDE LAYER** - Air-abrade the casting with non-recycled, 50- μ m aluminum oxide or quartz.
2. CLEANING - Place in distilled water in an ultrasonic unit for 10 min, then apply the opaque porcelain.

--SECTION 7: ATTACHMENT 1--

IX. PORCELAIN COMPATIBILITY--PTM-88

A. PORCELAIN SYSTEM COMPATIBILITY CHART: The following information has been provided by the alloy manufacturer (X):

<u>DENTAL PORCELAIN</u>	<u>PORCELAIN COMPATIBILITY</u>			
	<u>YES</u>	<u>NO</u>	<u>MARGINAL</u>	<u>UNKNOWN</u>
1. ARTIS-TECH (Jeneric)				X
2. BIOBOND (Dentsply) -		X		
3. CERMACO (Johnson & Johnson) -				X
4. CRYSTAR (Unitek) -		X		
5. JELENKO (Jelenko) -		X		
6. (BIOBOND) SHADEMATE (Dentsply) Reg-	Low -	X		X
7. VITA (Vident) -				X
8. WILL-CERAM (Williams) -				X

B. KNOWN OR SUSPECTED PORCELAIN-METAL INCOMPATIBILITIES:

Refer to Section A above. No other information provided.

C. SPECIAL HANDLING INSTRUCTIONS: None

—SECTION 7: ATTACHMENT 1—

X. PRE-SOLDERING INSTRUCTIONS--PIM-88

A. RECOMMENDED MATERIALS:

1. SOLDER - Olympia Pre-solder (flows between 2030 and 2060 °F)
2. FLUX - Is NOT recommended. Flux may contaminate the porcelain.
3. INVESTMENT - Use any conventional soldering investment or a high-heat phosphate-bonded casting investment with distilled water.

B. PRE-SOLDERING TECHNIQUE: Use the MAGIC WAND Torch (Williams) with its #248 tip, or the HARRIS torch with a 2N tip for precise heating.

1. Grind, with aluminum oxide stone, all surfaces to be soldered. This process will remove any oxides or contaminants which might impede pre-soldering.
2. Create a GAP DISTANCE of approximately 0.5 mm.
3. Mix investment so it is thick; turn fixed partial denture upside down; fill the inside of the casting with the mix; add a little extra on top; and invert onto a patty of investment. Do not let it settle. Keep the investment patty as small as possible.
4. Trim the investment patty, and form a "V" groove underneath each joint.
5. Allow the investment to reach final set; then boil out the wax; and preheat the assembly to 1050 °F (566 °C) for about 20 min. If acrylic resin (Duralay) is used, be sure to remove all traces of the resin before initiating the soldering process.
6. Use 10 psi OXYGEN and 1/4 psi NATURAL GAS (or 10 psi PROPANE). Adjust the inner blue cone(s) until a feathered edge is produced at each tip
7. Place the invested units on a soldering block so the length of the assembly is perpendicular to your body. In other words, the lingual side of the units is to your right, and the facial to your left.
8. Begin soldering.

--SECTION 7: ATTACHMENT 1--

XI. POST-SOLDERING INSTRUCTIONS--PTM-88

- A. RECOMMENDED MATERIALS: It is presupposed that the porcelain units have been glazed and polished, and the metal substructures have been designed appropriately for the post-soldering procedure.
1. SOLDER - Alboro LF Post-solder (flows between 1310 °F and 1370 °F).
 2. FLUX - Use of LF flux is optional.
 3. INVESTMENT - Same as pre-soldering technique.
- B. POST-SOLDERING TECHNIQUE: Use a porcelain furnace for this step. It is especially helpful if the oven has a muffle view port (also referred to as a "sight window") to permit observation of the soldering process.
1. Grind joint surfaces with a fine vitrified aluminum oxide stone.
 2. Create a GAP DISTANCE of 0.5 mm.
 3. Place units on the master cast, and seal the joint(s) with sticky wax.
 4. Once the sticky wax has cooled, remove the work from the master cast; and cover, with white wax, all the porcelain to be embedded in the investment. This step will prevent discoloration of the glazed porcelain.
 5. Invest the castings in a soldering investment (or equivalent), and allow the mix to set.
 6. Trim the patty to remove sharp corners and to increase access to the joint areas.
 7. Remove all the wax with boiling water.
 8. Shape the Alboro LF Post-Solder strip to fit the joint area(s) in such a fashion that the pieces fill the joint(s).
 9. Dry the invested work thoroughly, and slowly introduce it into a porcelain furnace set at 1000 °F (540 °C), then heat soak it for several minutes.
 10. A full vacuum may be drawn to reduce oxide build-up.
 11. Raise the temperature to 1470 °F (760 °C) at the rate of 75 °F/min, and the solder should flow accordingly.
 12. Remove the work; allow it to cool; and repolish the metal.

--SECTION 7: ATTACHMENT 2--

SUPRA-AP

I. GENERAL INFORMATION

ALLOY TYPE: "PRECIOUS" ALLOY SYSTEM: High Palladium-Cobalt

ALLOY CONTENT: 83% Palladium, 6-8% Cobalt, 7% Gallium, and 4% Indium

MANUFACTURER:

Rx. Jeneric Gold Company
Jeneric Industries, Inc.
P.O. Box 724
Wallingford, Connecticut 06492

TOLL-FREE PHONE NUMBER:
1-(800) 243-3969, Ext.212 or 310

COMMERCIAL PHONE NUMBER:
1-(203) 265-7397 (in Connecticut)
and outside U.S., call "Collect")

TELEPHONE CONTACTS:

Laboratory: Mr. Grant Day
 Mr. Rick Tobey
Research: Dr. Arun Prasad

REGIONAL SALES REPRESENTATIVES:

None

ALLOY INTRODUCED IN: 1982

F.D.A. LISTED: Yes

A.D.A. ACCEPTANCE OR PROVISIONAL ACCEPTANCE: No

II. PHYSICAL DESCRIPTION

Ingot color - Platinum	Ingot shape - Rectangle
Ingot weight - Approx. 1 dwt (ingots vary)	Ingots per ounce - 20
Ingot identification - "SAP"	Alloy packaging - 1 oz only

III. PHYSICAL AND MECHANICAL PROPERTIES

Specific gravity (density) - 11.45 g/cc
Brinell hardness number - 250
Vickers hardness number - 265
Percentage elongation (in 1 in.) - 20%
Ultimate tensile strength - 130,000 psi (9,039 kg/cm²)
Yield strength (0.2% offset) - 90,000 psi (6,327 kg/cm²)
Bond strength - 13,000 psi
Coefficient of thermal expansion - .6064% @ 450 °C

MELTING RANGE - 2275-2375 °F
(1246-1302 °C)

CASTING TEMPERATURE - 2475 °F
(1357 °F)

--SECTION 7: ATTACHMENT 2--

IV. WAXING AND SPRUING INSTRUCTIONS--SUPRA-AP

A. MINIMUM RECOMMENDED WAX THICKNESS:

1. SINGLE UNITS - 0.4 mm
2. THREE-UNITS FIXED PARTIAL DENTURES - 0.4 mm
3. FIXED PARTIAL DENTURES GREATER THAN 3 UNITS - 0.4 mm

B. RECOMMENDED SPRUING TECHNIQUE:

1. SINGLE UNITS - Use the DIRECT METHOD, with 8- or 10-GAUGE sprues 1/4 in. to 3/8 in. (6-7 mm) long, attached to the thickest part of the wax pattern. If a RESERVOIR sprue is used, the distance between the wax pattern and the reservoir should be approximately 1/16 in. (1.5 mm). (The manufacturer also suggests narrowing down the sprue as it approaches the pattern.)
2. MULTIPLE SINGLE UNITS - Use the INDIRECT METHOD, with 1/4 in. (6 mm) 10-GAUGE sprues to each pattern, an 8-GAUGE runner bar, and offset 8-GAUGE leads connecting the sprue former to the runner bar. Extend the length of the runner bar beyond the width of the patterns at each end.
3. FIXED PARTIAL DENTURES - Use the INDIRECT METHOD, with 1/4 in. (6 mm) 10-GAUGE sprues to each pattern, an 8-GAUGE runner bar, and offset 8-GAUGE leads connecting the sprue former to the runner bar. Extend the length of the runner bar beyond the width of the patterns at each end.

NOTE: The runner bar should be shaped to conform to the contour of the fixed partial denture. If the bar must be bent, then cut and rewire it at each cut in order to destroy any memory in the wax (Fig. 4-2).

4. VENTING - Use 18-GAUGE wire, placed 1.0 mm from the gingival margin. Extend the vent to the outer edge of the sprue form, but do not connect it.
5. WAX PATTERN POSITIONING - If the wax pattern is seated too low in the casting ring, build up the sprue former with wax, and raise the pattern to within 1/4 in. of the top of the ring. This technique will facilitate wax elimination and the escape of gases during investment burnout. Arrange the spruing system so the reservoir portion is in the HEAT CENTER of the casting ring with the wax patterns in a COLD ZONE (Fig. 4-2).

--SECTION 7: ATTACHMENT 2--

V. INVESTMENT AND BURNOUT TECHNIQUE--SUPRA-AP

A. RECOMMENDED INVESTMENTS:

1. PHOSPHATE-BONDED INVESTMENTS: Start with a dilution ration between 80-50% special liquid and 20-50% distilled water.

<u>NON-CARBON TYPE:</u>	<u>SPECIAL LIQUID</u>	<u>DISTILLED WATER</u>
a. Vestra-fine (Unitek)	5.5 cc	10.0 cc
b. Hi-Temp (Whip-Mix)	4.5 cc	4.5 cc
<u>CARBON TYPE:</u>		
a. Biovest (Dentsply)	8.0 cc	3.0 cc
b. Deguvest HFG (Degussa)	7.0 cc	2.0 cc

NOTE: A carbon-containing investment may be used with this alloy, but all carbon must be eliminated during burnout.

2. GYPSUM-BONDED INVESTMENTS: Not suitable for this alloy.

B. RECOMMENDED METHOD OF INVESTMENT: HIGH HEAT.

C. MANUFACTURER'S RECOMMENDED ASBESTOS SUBSTITUTE: KAOLINER (Dentsply), DRY.

You may also use one WET layer of NON-ASBESTOS ring liner (Whip-Mix) or NOBESTOS (Jelenko). Place the ring liner flush with the top of the casting ring, but leave at least 1/8-in. clearance at the bottom of the ring. The 1/8-in. clearance will help lock the investment in the ring when it expands (Fig. 4-2). If additional expansion is needed, use two layers of asbestos substitute and/or more special liquid and less distilled water.

D. BURNOUT TECHNIQUE:

PHOSPHATE-BONDED INVESTMENT: Start with a cold or room temperature oven, and raise to 1600 °F (871 °C) at the rate of 20 °F/min; then HEAT SOAK as follows:

- a. Single ring - 1-1/2 hr
- b. Three units in a single ring - 1-1/2 hr
- c. Multiple units, 2-3 rings - 1-1/2 hr, add 10 min for each additional casting ring.

—SECTION 7: ATTACHMENT 2—

VI. MELTING AND CASTING INSTRUCTIONS—SUPRA-AP

A. CASTING EQUIPMENT:

1. CASTING MACHINE (DO NOT USE A THERMATROL 2500 WITH CARBON CRUCIBLES):
 - a. Manufacturer's preferred casting equipment - Torch and centrifuge or Induction casting
 - b. Alternative systems include - Centrifuge.
2. CASTING TORCH - Harris 16-S with #1390 H multi-orifice torch tip.
3. CASTING CRUCIBLES - Quartz or alumina.

B. QUANTITY OF ALLOY NEEDED:

1. VOLUME OF METAL NEEDED - Refer to conversion chart (Table 1).*
2. PREFERRED RATIO OF NEW METAL TO RECAST METAL - 50/50% by weight
3. MINIMUM RATIO OF NEW METAL TO RECAST METAL - 30/70%.

C. MELTING AND CASTING TECHNIQUE: (PROPANE preferred, NATURAL GAS adequate)

1. OXYGEN-GAS RATIO - 20 psi OXYGEN to NATURAL GAS, or 3-5 psi PROPANE.
2. SETTING CASTING MACHINE - Add one additional turn to casting machine to compensate for the lower density of the alloy.
3. FLAME ADJUSTMENT - Adjust torch to produce inner blue cones 1/2 in. in length for the multi-orifice torch tip.
4. APPEARANCE OF THE MELT - Place the alloy in a preheated crucible, and keep the torch moving in a rotating motion to heat all the metal evenly. The individual ingots or buttons will pool together like high-gold content alloys, but they will also retain a thin OXIDE FILM.
5. CASTING FLUX - Fused borax may be used, if deemed necessary.
6. WHEN TO CAST - When literally ROLLING around in the crucible from the pressure of the torch flame, the alloy is READY to cast. DO NOT ATTEMPT TO BREAK THE OXIDE SKIN.
7. RECOVERY OF CASTING - BENCH COOL - DO NOT QUENCH - DO NOT PICKLE.

D. INDUCTION CASTING (Start with a preheated crucible):

1. Set ARM SPEED to 450 rpm.
2. Set POWER to 50%.
3. Set TEMPERATURE to 2450 OF (1343 °C).
4. HEAT SOAK for 5 sec.
5. Appearance of melt when ready to cast is the same with torch casting.
6. Use Jeneric's PD Flux to minimize overheating and crucible melting.

* At close of text.

—SECTION 7: ATTACHMENT 2—

VII. ADJUSTING AND FINISHING—SUPRA-AP

A. REMOVING THE SPRUE:

1. SEPARATING DISC - Use any thin separating disc of your choice.
2. COLLECT GRINDINGS - This is a precious alloy, and its grindings have scrap value. Vacuum your clothing and work area.

B. FITTING THE CASTING:

1. REMOVE INTERNAL NODULES - Carefully inspect the inside of each casting under magnification, and remove any irregularities.
2. EVALUATE THE FIT - Verify an acceptable level of occlusal/incisal seat and marginal seal, before proceeding to any additional finishing steps.
3. QUALITY CONTROL CHECK - Unsatisfactory castings (poor fit, overheated alloy, porosity) should be remade.
4. INITIAL OCCLUSAL ADJUSTMENT - Articulate the casting and refine the occlusion, as necessary.

C. FINISHING THE CASTING:

1. STONES AND WHEELS - Use the same materials you have on hand to finish gold-base PFM alloys, i.e. uncontaminated aluminum oxide stones, diamond points, etc.
2. AVOID METAL CONTAMINATION - Set aside a set of finishing stones for this particular alloy to prevent contamination of the metal.
3. ADJUSTMENT TECHNIQUE - Use the uncontaminated aluminum oxide abrasives to produce a smooth, even textured surface for all porcelain-bearing areas. Finish the metal surface in one direction, and use light pressure.

—SECTION 7: ATTACHMENT 2—

VIII. PREPARATION OF THE METAL FOR PORCELAIN--SUPRA-AP

A. PREPARATION OF THE METAL SUBSTRATE:

1. NON-PORCELAIN BEARING SURFACES - Rubber wheel all non-porcelain bearing areas (lingual/occlusal surface, interproximal struts, and metal collars) to remove all scratches prior to the application of porcelain.
2. PORCELAIN BEARING SURFACES - Air-abrade the finished metal surfaces with a 50- μ m non-recycled, uncontaminated aluminum oxide (white) abrasive under 60-70 psi.
3. CLEANING - Steam clean the metal substrate, or place in distilled water in an ultrasonic unit for 10 min, after rubber wheeling and air-abrading.

B. OXIDATION (DEGASSING) OF THE METAL SUBSTRATE:

1. LOW temperature setting - 1200 °F (649 °C)
2. HIGH temperature setting - 1850 °F (1010 °C)
3. Rate of rise - 90-100 °F (50-55 °C)/min
4. Atmosphere - Air (NO VACUUM)
5. HOLD time at HIGH temperature - None
6. Appearance of the oxide layer:
 - a. A PROPERLY oxidized layer - DEEP BLUE color
 - b. An OVERoxidized layer - NOT APPARENT
 - c. An UNDERoxidized layer - NOT APPARENT

C. POST-OXIDATION TREATMENT: The manufacturer has indicated that two options are available in the management of the oxidized casting.

1. REMOVE THE OXIDE LAYER - You may remove the bulk of the oxide layer by lightly air-abrading with 50- μ m aluminum oxide.
2. CLEANING - Steam clean or place casting in distilled water in an ultrasonic unit for 10 min, if you air-abraded the casting. Proceed with the application of opaque porcelain after this cleaning step.
3. RETAIN THE OXIDE LAYER - You may apply opaque porcelain directly over the oxide layer.

--SECTION 7: ATTACHMENT 2--

IX. PORCELAIN COMPATIBILITY--SUPRA-AP

A. PORCELAIN SYSTEM COMPATIBILITY CHART: The following information has been provided by the alloy manufacturer (X):

<u>DENTAL PORCELAIN</u>	<u>PORCELAIN COMPATIBILITY</u>			
	YES	NO	MARGINAL	UNKNOWN
1. ARTIS-TECH (Jeneric) -	X			
2. BIOBOND (Dentsply) -				X
3. CERAMCO (Johnson & Johnson) -	X			
4. CRYSTAR (Unitek) -	X			
5. JELENKO (Jelenko) -				X
6. (BIOBOND) SHADEMATE (Dentsply) Low-Reg-				X
7. VITA (Vident) -	X			
8. WILL-CERAM (Williams) -				X

B. KNOWN OR SUSPECTED PORCELAIN-METAL INCOMPATIBILITIES: None

C. SPECIAL HANDLING INSTRUCTIONS: None

--SECTION 7: ATTACHMENT 2--

X. PRE-SOLDERING INSTRUCTIONS—SUPRA-AP

A. RECOMMENDED MATERIALS:

1. SOLDER - WCG Solder (flows at approximately 2150 °F/1177 °C)
2. FLUX - Use of flux is optional.
3. INVESTMENT - Use any conventional soldering investment or a high-heat phosphate-bonded casting investment with distilled water.

B. PRE-SOLDERING TECHNIQUE: Use the MAGIC WAND Torch (Williams) with its #248 tip, or the HARRIS torch with a 2N tip for precise heating.

1. Grind, with aluminum oxide stones, all surfaces to be soldered. This process will remove any oxides or contaminants which might impede pre-soldering.
2. Create a GAP DISTANCE of approximately 0.3 mm.
3. Mix investment so it is thick; turn fixed partial denture upside down; fill the inside of the casting with the mix; add a little extra on top; and invert onto a patty of investment. Do not let it settle. Keep the investment patty as small as possible.
4. Trim the investment patty, and form a "v" groove underneath each joint.
5. Allow the investment to reach final set; then boil out the wax; and preheat the assembly to 1050 °F (566 °C) for about 20 min. If acrylic resin (Duralay) is used, be sure to remove all traces of the resin before initiating the soldering process.
6. Wear #5 welding glasses as protective eye wear.
7. Use 5 psi OXYGEN and 2 psi NATURAL GAS (or 2 psi PROPANE). Adjust the inner blue cone of the flame until it is defined and has no feathered edge at its tip.
8. Place the invested units on a soldering block so the length of the assembly is perpendicular to your body. In other words, the lingual side of the units is to your right, and the facial to your left.
9. Apply the flux to the joint area, using the solder strip as a carrier. It is imperative that the flux be liquified and made to flow into the joint by brushing with the flame. Repeat this step for each joint area.
10. Position the flame so it is directed at an angle of about 80 degrees from the lingual side, goes diagonally through the joint, and heats both sides of the joint evenly.

—SECTION 7: ATTACHMENT 2—

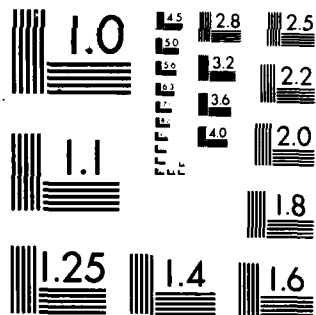
X. PRE-SOLDERING INSTRUCTIONS—SUPRA-AP (Cont'd)

11. The tip of the inner blue cone should be 1/4 in. - 1/2 in. from the joint.
 12. As the surfaces to be joined turn ORANGE-WHITE, feed the fluxed end of the solder into the lower third of the connector on the lingual (the same side where the flame is entering at the occlusal third). Continue to feed the joint until it is filled.
 13. Once the joint is filled, keep the joint area red for 4-5 sec, remove the flame, and allow to cool to ROOM TEMPERATURE.
 14. Remove traces of flux with stones, or blast with aluminum oxide abrasives.
 15. Finish the metal and prepare for porcelain application.
- C. OXIDATION OF PRE-SOLDERED UNITS: Castings which have been pre-soldered should be oxidized differently from non-soldered, single unit substructures. Rather than removing the fixed partial denture immediately after it reaches maximum temperature, HOLD the work at 1800 °F (982 °C) for 10 min in air; then remove it from the furnace.

--SECTION 7: ATTACHMENT 2--

XI. POST-SOLDERING INSTRUCTIONS--SUPRA-AP

- A. RECOMMENDED MATERIALS: It is presupposed that the porcelain units have been glazed and polished, and the metal substructures have been designed appropriately for the post-soldering procedure.
1. SOLDER - WLF Solder (flows between 1310 and 1370 °F/710 and 743 °C).
 2. FLUX - Use of LF flux is optional.
 3. INVESTMENT - Same as pre-soldering technique.
- B. POST-SOLDERING TECHNIQUE: Use a porcelain furnace for this step. It is especially helpful if the oven has a muffle view port (also referred to as a "sight window") to permit observation of the soldering process.
1. Grind joint surfaces with a fine vitrified aluminum oxide stone.
 2. Create a GAP DISTANCE of 0.3 mm.
 3. Place the units on the master cast, and seal the joint(s) with sticky wax.
 4. Added rigidity can be obtained by placing a metal rod across the occlusal or incisal surfaces, and sealing it with sticky wax.
 5. Once the sticky wax has cooled, remove the work from the master cast; and cover, with white wax, all the porcelain to be embedded in the investment. This step will prevent discoloration of the glazed porcelain.
 6. Invest the castings in a soldering investment (or equivalent), and allow the mix to set for 20 min.
 7. Trim the patty to a 3/8 in. thickness with 1/4 in. borders, and remove all the wax with boiling water.
 8. Shape the WLF solder strip to fit the joint area in such a fashion that it fills the joint and protrudes 1/8 in. from it.
 9. While the work is still warm (from wax boil-out procedure), paint the joint area with LF flux. Also dip the WLF solder strip in flux before placing it in the joint itself.
 10. Dry the invested work thoroughly, and slowly introduce it into a porcelain furnace set at 1000 °F (540 °C); then heat soak it for 2 min.
 11. With a full vacuum, raise the temperature to 1575 °F (857 °C) at the rate of 75 °F/min, and the solder should flow accordingly.
 12. Remove the work; allow it to cool; and repolish the metal.



MICROCOPY RESOLUTION TEST CHART
NATIONAL BUREAU OF STANDARDS-1963-A

SECTION 8:

THE PALLADIUM-SILVER ALLOYS

8-1. GENERAL DESCRIPTION

Of the many dental casting alloy systems for the PFM restoration, the palladium-silver alloys may be the least appreciated and the most maligned. Several misconceptions about these alloys have been perpetuated over the years, inadvertently transforming myths into perceived facts.

The first generalization regarding the palladium-silver alloys pertains to the description of the basic compositions of these metals. They most frequently are depicted as being composed of 60% palladium, with the balance being silver, plus trace amounts of additives like indium and tin.¹ Other assessments might include a range of 50-60% for the palladium, and mention that silver makes up the balance,² or limit the silver content to 30-40%, omitting any listing of the remaining elements in the alloy.³ Actually, the description of the palladium-silver alloys can be a great deal more specific. There are many different metals on the market, but two rather distinct trends in formulation. One group of alloys has a palladium content approximating 60% (57-60% range), with roughly 30% silver (28-32% range), plus indium and tin and other trace elements added to make up the balance. A second group had a palladium content closer to 50% (50-55%), a silver content approaching 40% (35-40%), plus tin and other trace elements, but NO indium. The difference in the make-up of these metals does have an influence on the alloys. The higher palladium content metals, containing both indium and tin, produce a bluish-violet oxide.⁴ The lower palladium and higher silver content alloys containing tin, but no indium, produce a light gray oxide. The oxide is so light that it has also been described as a transparent tin oxide (Fig. 8-1). One study suggested that the oxidation occurs internally and not externally at all.⁵ Whether that observation accurately portrays the behavior of these alloys is not clear; for the alloy samples in the study were not finished in the customary manner, but were given a metallurgical polish prior to oxidation. Nonetheless, the fact remains that the level of oxidation for the palladium-silver alloys reportedly does not interfere with pre-solder.

Figure 8-1. The oxides produced by this palladium-silver alloy (Will-Ceram W-1*) are light gray in color, and appear almost transparent.



* Williams Gold Refining Company, Buffalo, NY.

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More importantly, some believe that the tin oxide (SnO_2) improves chemical bonding and wettability.⁶ Yamamoto has even suggested acid-treating precious PFM alloys to remove selectively all the unfavorable dark oxides, and leave only the white tin oxide (SnO_2) on the alloy surface.⁶ What is often overlooked is the fact that the palladium-silver alloys, which contain tin but no indium, naturally produce the white tin oxides (SnO_2). One can use these alloys and avoid the potential dangers to the technician and the parent alloy which are associated with handling acids.

It has also been said that palladium-silver alloys do not cast very well.^{1,7} Unfortunately, this statement is based on a 1976 study using the silver-palladium crown and bridge alloys, NOT palladium-silver PFM alloys, and is analogous to describing the castability of Olympia* using the results of a study on Type III gold. The palladium-silver alloys DO cast well, but they require careful heating and melting. Palladium does have an affinity for hydrogen (hydrogen acceptor) and other gases, while silver is prone to oxygen absorption.¹ Careful torch adjustment and proper melting (reducing zone) can compensate for these weaknesses. The palladium-silver alloys cast margins completely and there was no observable interference with bonding due to the high silver content as suggested by McLean.¹ In fact, the palladium-silver alloys melt and cast as easily as gold-base PFM alloys (Figs. 8-2 to 8-5). However, subsurface porosity due to alloy overheating during induction casting has been reported.⁸ As with the palladium base alloy, in general, the zircon-aluminum or quartz casting crucibles are recommended. Carbon crucibles should not be used in this alloy system.



Figure 8-2. To control the amount of alloy used and to eliminate a button, the wax patterns were weighed before investing.

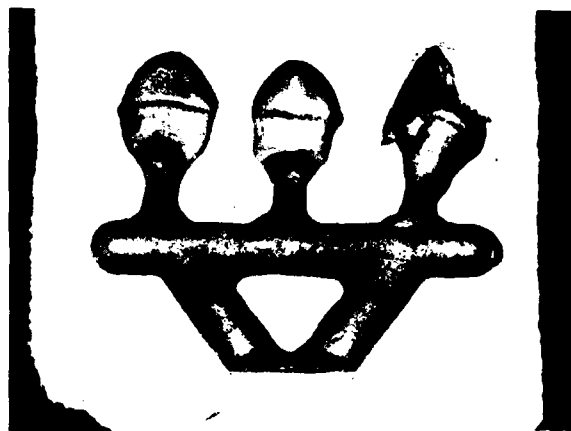


Figure 8-3. By controlling the amount of metal used, the reservoir bar is the largest mass of metal and can be positioned in the heat center of the investment.

* J. F. Jelenko & Co., Buffalo, NY.

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Figure 8-4. The location of the casting porosity can be controlled by properly estimating the amount of palladium-silver alloy (Will-Ceram W-1*) that is needed and following the Laws of Casting. Note that the porosity is on the underside of the reservoir bar, away from the restorations.



Figure 8-5. The castings, as well as the top portion of the reservoir bar, are dense and cast completely, with no porosity being detectable. (The marginal irregularities, in the unit on the right for the porcelain margin substructure, were present in the wax-up.)

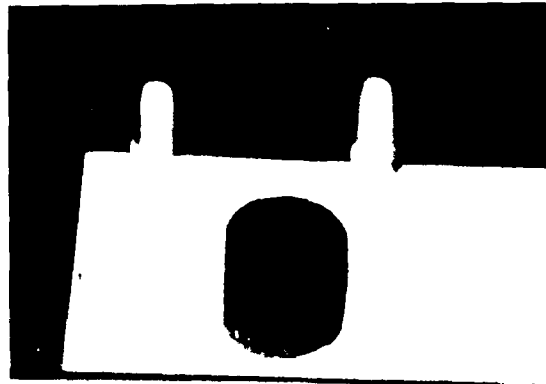
Perhaps the most unqualified statement frequently made regarding the palladium-silver alloys is that the "principle" or "major" problem with these alloys is the porcelain discoloration or color change due to a high silver content.^{1,2} The most typical description is a "green" discoloration, especially with the lighter shades and most often at the porcelain metal junction.³ It is more important to note that although these color changes may occur, they do not necessarily take place with every dental porcelain.^{2,9} Two dental porcelains are available today which reportedly are resistant to porcelain discoloration: Will-Ceram* and Artis-Tech.**⁹ Both porcelain systems were used with the palladium-silver alloys, and no discoloration of the porcelain was observed. This phenomenon, which has been discussed in greater detail in Section 3, is not repeated here. However, it is important to understand that, if the major disadvantage of the routine use of palladium-silver alloys is the potential discoloration of the dental porcelain, the problem can be readily overcome simply by using one of the (chemically) compatible dental porcelains.

* Williams Gold Refining Co., Buffalo, NY.
** Rx Jeneric Gold Co., Wallingford, CT.

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Silver contamination of sagger trays and the porcelain furnace can be controlled by firing with carbon pellets and regularly purging the furnace muffle to remove accumulated silver (Fig. 8-6). Poor technique in this regard can lead to silver build-up and color changes in dental porcelains less resistant to interaction with silver particles.

Figure 8-6. A piece of carbon should be placed on the sagger tray and fired with each palladium-silver unit to reduce the likelihood of porcelain discoloration by silver.



Since most of the attention is focused on the negative aspects of the palladium-silver alloys (porcelain discoloration, muffle contamination), not everyone is aware of the positive features of this alloy system. For instance, the palladium-silver metals possess a high yield strength and modulus of elasticity,^{1,2} thus making them suitable for long-span fixed partial dentures as well as single units (Table 3).¹ In fact, since the elastic modulus is the most favorable of all the precious metal alloys, the castings are the least flexible.² Because the nobility of the system ranges from 50 to 60%, the level of tarnish and corrosion resistance is quite high.² Likewise, these alloys do not contain any elements with questionable biological ramifications, and are regarded as non-toxic.¹ Some assessments describe the palladium-silver alloys as possessing mechanical properties superior even to the most costly noble metal alloys.² Their clinical working characteristics are also good, and bond strength is excellent.² Moreover, both the bluish-violet oxide of indium and tin metals and the transparent tin oxide of the tin only alloys are less likely to influence porcelain shade development, particularly when used with porcelain systems like Will-Ceram* and Artis-Tech** (Figs. 8-7 and 8-8). The palladium-silver alloys are very easy to adjust and produce a very high shine, thus making finishing both quick and easy.

The palladium-silver system has been available for approximately 10 years, and two alloys are A.D.A. Acceptable: Will-Ceram W-1* and Jelstar.*** The Will-Ceram W-1 is a lower palladium, higher silver alloy containing tin and no indium, and produces a transparent tin oxide layer. Although we did not test Jelstar, it is the high palladium, lower silver type of alloy which contains both indium and tin, thus resulting in a slightly darker oxide.

* Williams Gold Refining Co., Buffalo, NY.

** Rx Jeneric Gold Co., Buffalo, NY.

*** J. F. Jelenko & Co., Armonk, NY.

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Figure 8-7. The palladium-silver alloy (Will-Ceram W-1^{*}) on the right has a much lighter oxide layer than the high palladium-copper alloy (Naturelle^{**}) on the left. Not only is the color itself lighter with the palladium-silver alloy, but the actual amount of surface oxides appears less than with the high palladium-copper casting.



Figure 8-8. When compared with a gold-palladium alloy (Olympia^{***}) on the left and a high palladium-copper alloy (Naturelle^{**}) in the middle, the palladium-silver alloy (Will-Ceram W-1^{*}) on the right has an obviously lighter and more discreet oxide.

8-2. ECONOMIC CONSIDERATIONS

Interestingly enough, the cost of the palladium-silver alloys is often 40% of the gold-palladium metals, such as Olympia,^{***} and less than many of the high palladium alloys. When the government cost of Olympia^{***} is \$296.20/oz, an ounce of Will-Ceram W-1^{*} and Jelstar^{***} can be purchased for as little as \$86.80 and \$118.00, respectively (February 1985 price).

Alloys in this system possess scrap value, and their buttons can be reused just like gold-base metals. Grindings and flash should be collected regularly for turn-in with other precious metals.

8-3. TARNISH RESISTANCE

Since these alloys have a high noble metal content (>50% palladium), they are very tarnish and corrosion resistant.² We did not observe any evidence of tarnish or corrosion.

* Williams Gold Refining Co., Buffalo, NY.
** Ix Jeneric Gold Co., Wallingford, CT.
*** J. F. Jelenko & Co., Armonk, NY.

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8-4. ADVANTAGES:

Are PRECIOUS alloys.
Have a substantial NOBLE metal content.
At least 2 alloys are A.D.A. "ACCEPTABLE".
Are available in 2-dwt ingots.
Melt and cast like gold-base PFM alloys.
Are less dense than gold-base alloys, thus resulting in more castings per ounce.
Are suitable for long span fixed partial dentures, as well as single units.
Are burnishable.
Produce either a light or transparent oxide layer.
Are reportedly easy to pre-solder, since they do not oxidize heavily.
Are easy to adjust and finish.
Can be readily polished to a high shine.
Are MUCH less expensive than gold-palladium alloys.
Are even less expensive than the newer high palladium alloys.
Are reportedly easy to pre-solder.
Their buttons are reusable.
Have scrap value.

8-5. DISADVANTAGES:

Are not A.D.A. CERTIFIED.
Should not be cast in carbon crucibles.
A non-carbon containing phosphate-bonded investment is preferred.
Are prone to gaseous absorption (hydrogen, oxygen, etc.).
May not be best suited for induction casting.
May discolor some dental porcelains.
Are most predictable with dental porcelains which are resistant to silver interaction and porcelain discoloration (Will-Ceram and Artis-Tech).
May have to consider adding a metal conditioner to prevent discoloration if a non-resistant porcelain is used.
May have to consider acid treatment of the oxidized casting to reduce surface silver if a non-resistant porcelain is used.
Should fire each case with a carbon pellet to retard silver oxidation.
Must purge the porcelain furnace muffle correctly and on a routine basis.
Silver build-up in the furnace muffle may even contaminate restorations made of non-silver containing alloys.

—SECTION 8—

8-6. REFERENCES

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EDITOR'S NOTE: The following Attachments provide comprehensive information on four examples of the palladium-silver alloy system, specifically; BAK-ON SP, JEL-5, PORS-ON, and WILL-CERAM W-1.

—SECTION 8: ATTACHMENT 1—

BAK-ON SP

I. GENERAL INFORMATION

ALLOY TYPE: "PRECIOUS"

ALLOY SYSTEM: Palladium-Silver

ALLOY CONTENT: 53% Palladium, 31% Silver, 6% Tin, 4% Indium and 1% Zinc

MANUFACTURER:

Johnson & Johnson
Dental Products Company
20 Lake Drive, CN 7060
East Windsor, N.J. 08520

TOLL-FREE PHONE NUMBER: NONE

COMMERCIAL PHONE NUMBERS:

1-(201) 494-7311 (Eastern)
1-(404) 233-5444 (Southern)
1-(312) 654-0990 (Midwestern)
1-(805) 497-4424 (Western)

TELEPHONE CONTACTS:

Mr. John C. Subelka
Metals Research & Development
1-(609) 443-3300

REGIONAL SALES REPRESENTATIVES:

Area Technical Directors

ALLOY INTRODUCED IN: 1981

F.D.A. LISTED: YES

A.D.A. ACCEPTANCE OR PROVISIONAL ACCEPTANCE: NO

II. PHYSICAL DESCRIPTION

Ingot color - Platinum
Ingot weight - 2 dw'
Ingot identification - "Bak-On
SP"

Ingot Shape - Square
Ingots Per Ounce - 10 per oz
Alloy Packaging - 1 oz only

III. PHYSICAL AND MECHANICAL PROPERTIES

Specific gravity (density) - 10.7 g/cc
Brinell hardness number - 220
Vickers hardness number - 240
Percentage elongation (in 1 in.) - 15%
Ultimate tensile strength - 96,000 psi
Yield strength (0.2 % offset) - 69,000 psi
Bond strength - 15,200 psi
Coefficient of thermal expansion - 14.3×10^{-6} in/in/C (between 40-500 °C)

MELTING RANGE - 2320-2410 °F
(1271-1331 °C)

CASTING TEMPERATURE - 2450 °F
(1343 °C)

—SECTION 8: ATTACHMENT 1—

IV. WAXING AND SPRUING INSTRUCTIONS--BAK-ON SP

A. MINIMUM RECOMMENDED WAX THICKNESS:

1. SINGLE UNITS - 0.5 mm
2. THREE-UNITS FIXED PARTIAL DENTURES - 0.5 mm
3. FIXED PARTIAL DENTURES GREATER THAN 3 UNITS - 0.7 mm.

B. RECOMMENDED SPRUING TECHNIQUE:

1. SINGLE UNITS - Use either the DIRECT or INDIRECT Method.

DIRECT Method: Attach a 10-GAUGE sprue 8-10 mm in length directly to the thickest portion of the wax pattern (Fig. 4-1).

RESERVOIR SPRUES: According to the manufacturer, reservoir sprues may also be used for direct spruing.

2. MULTIPLE SINGLE UNITS - Use the INDIRECT Method only.

INDIRECT Method: Attach 12-GAUGE sprues 5-8 mm in length to the wax patterns. Join these sprues to an 8-GAUGE runner bar which extends just beyond the length of the end patterns. Use offset 8-GAUGE sprue leads from the runner bar to the sprue former (Fig. 4-2).

3. FIXED PARTIAL DENTURES - Use the INDIRECT Method with 12-GAUGE sprues 5-8 mm in length to the wax patterns. Join these sprues to an 8-GAUGE runner bar which extends just beyond the length of the end patterns. Use several offset 8-GAUGE sprue leads from the runner bar to the crucible former (Fig. 4-2).

(NOTE: Adjust the runner bar to conform to the contour of the fixed partial denture. Be sure to cut the bar and re wax it to eliminate any wax memory.)

4. VENTING - Use an 18-GAUGE wax wire vent for each crown to assist gas exhaustion.
5. WAX PATTERN POSITIONING - If the wax pattern is seated too low in the casting ring, build up the sprue former with wax, and raise the pattern to within 1/4 in. of the top of the ring. This procedure will facilitate wax elimination and the escape of gases. Design the spruing system so that any reservoir is in the HEAT CENTER of the casting ring, with the wax patterns in a "COLD ZONE" (Fig. 4-2).

--SECTION 8: ATTACHMENT 1--

V. INVESTMENT AND BURNOUT TECHNIQUE--BAK-ON SP

A. RECOMMENDED INVESTMENTS:

1. PHOSPHATE-BONDED INVESTMENTS: Use either a NON-CARBON investment (white color), or a CARBON-containing investment.

<u>NON-CARBON TYPE:</u>	<u>SPECIAL LIQUID</u>	<u>DISTILLED WATER</u>
Vestra-fine (Unitek) -	8.0 cc	7.5 cc
<u>CARBON TYPE:</u>		
Deguvest HFG (Degussa) -	7.0 cc	2.0 cc

2. GYPSUM-BONDED INVESTMENTS: NOT suitable for this alloy.

B. RECOMMENDED METHOD OF INVESTMENT: HIGH-HEAT rather than hygroscopic.

C. MANUFACTURER'S RECOMMENDED ASBESTOS SUBSTITUTE: Unspecified

We routinely use one WET layer of NON-ASBESTOS LINER (Whip-Mix). You may also use KAOLINER (Dentsply) or NOBESTOS (Jelenko). Place the liner flush with the top of the casting ring, but leave at least 1/8-in. clearance at the bottom of the ring. The 1/8-in. clearance will help lock the investment in the ring when the investment expands (Fig. 4-2). If additional expansion is needed, use two layers of ring liner or more of the special liquid.

D. BURNOUT TECHNIQUE:

PHOSPHATE-BONDED INVESTMENT: Start with a cold oven and raise to a temperature of 1450 °F (788 °C), and HEAT SOAK as follows:

- a. Single ring - 1 hr
- b. Three units in a single ring - 1 hr
- c. Multiple units, 2-3 rings - 1 hr and 20 min. (Add 10 min for each additional ring.)

—SECTION 8: ATTACHMENT 1—

VI. MELTING AND CASTING INSTRUCTIONS—BAK-ON SP

A. CASTING EQUIPMENT:

1. CASTING MACHINE: (You may use a THERMATROL 2500 with CARBON crucibles.)
 - a. Manufacturer's Preferred Casting Equipment - Induction casting.
 - b. Alternative Systems Include - Broken arm casting machine, centrifuge.
2. CASTING TORCH - Harris 16-S with #1390H multi-orifice tip.
3. CASTING CRUCIBLES - An alumina crucible is preferred, but a quartz crucible may also be used. DO NOT USE a clay crucible.

B. QUANTITY OF ALLOY NEEDED:

1. VOLUME OF METAL NEEDED - Refer to conversion chart (TABLE 1).*
2. PREFERRED RATIO OF NEW METAL TO RECAST METAL - 70/30% by weight
3. MINIMUM RATIO OF NEW METAL TO RECAST METAL - 50/50% by weight.

C. MELTING AND CASTING TECHNIQUE (PROPANE preferred, NATURAL GAS adequate):

1. OXYGEN-GAS RATIO - 20 psi OXYGEN and 15-20 psi PROPANE.
2. SETTING CASTING MACHINE - add one turn to casting machine to compensate for the lower density of the alloy.
3. FLAME ADJUSTMENT - Set inner blue cones to a length of 3/4 in. with an overall length of 2 in. Place torch tip approximately 1/2 in. from alloy. Move in a rotating motion.
4. APPEARANCE OF THE "MELT" - The metal will roll with fluidity. When a clear surface appears, place ring in the cradle.
5. CASTING FLUX - Is not necessary since there is little slag.
6. WHEN TO CAST - Heat alloy for 5 sec after alloy "clears."
7. RECOVERY OF CASTING - BENCH COOL; DO NOT QUENCH; and DO NOT PICKLE.

D. INDUCTION CASTING:

1. Set ARM SPEED to 4000-4500 rpm.
2. Set TEMPERATURE to 2560 °F (1404 °C).
3. HOLD at temperature for 30-60 sec, then CAST.

* At close of text.

--SECTION 8: ATTACHMENT 1--

VII. ADJUSTING AND FINISHING--BAK-ON SP

A. REMOVING THE SPRUE:

1. SEPARATING DISC - Use any thin separating disc of your choice.
2. COLLECT GRINDINGS - This is a precious alloy, and its grindings have scrap value. Vacuum your clothing and work area.

B. FITTING THE CASTING:

1. REMOVE INTERNAL NODULES - Carefully inspect the inside of each casting under magnification, and remove any irregularities.
2. EVALUATE THE FIT - Verify an acceptable level of occlusal/incisal seat and marginal seal, before proceeding to any additional finishing steps.
3. QUALITY CONTROL CHECK - Unsatisfactory castings (poor fit, overheated alloy, porosity) should be remade.
4. INITIAL OCCLUSAL ADJUSTMENT - Articulate the casting and refine the occlusion, as necessary.

C. FINISHING THE CASTING:

1. STONES AND WHEELS - Use the same materials you have on hand to finish precious PFM alloys; i.e., uncontaminated aluminum oxide stones, diamond points, etc.
2. AVOID METAL CONTAMINATION - Set aside a set of finishing stone for this particular alloy to prevent contamination of the metal.
3. ADJUSTMENT TECHNIQUE - Use the uncontaminated aluminum oxide abrasives to produce a smooth, even textured surface for all porcelain-bearing areas. Finish the metal surface in one direction, using light pressure.

--SECTION 8: ATTACHMENT 1--

VIII. PREPARATION OF THE METAL FOR PORCELAIN--BAK-ON SP

A. PREPARATION OF THE METAL SUBSTRATE:

1. NON-PORCELAIN BEARING SURFACES - Rubber wheel all non-porcelain bearing areas (lingual/occlusal surfaces, interproximal struts and metal collars) to remove all scratches prior to the application of porcelain.
2. PORCELAIN BEARING SURFACES - Air-abrade the finished metal surfaces with a 50- μ m non-recycled, uncontaminated aluminum oxide (white) abrasive under 90-100 psi.
3. CLEANING - Steam clean the metal substrate, or place in distilled water in an ultrasonic unit for 10 min.

B. OXIDATION (DEGASSING) OF THE METAL SUBSTRATE:

1. LOW temperature settings - 1200 °F (649 °C)
2. HIGH temperature setting - 1900 °F (1038 °C)
3. Rate of rise - 80-90 °F/min (27-50 °C)
4. Atmosphere - FULL VACUUM TO 1900 °F (1038 °C), then release vacuum and hold.
5. HOLD time at HIGH temperature - 2 min of AIR firing.
6. Appearance of the oxide layer:
 - a. A properly oxidized layer - BLUE-GRAY color
 - b. An OVERoxidized layer - GRAY-BLACK color (refinish and reoxidize 25-50 °F lower)
 - c. An UNDERoxidized layer - SILVER color (reoxidize 25-50 °F higher)

C. POST-OXIDATION TREATMENT:

1. PICKLE THE CASTING - Place the oxidized casting in a 190 °F (88 °C) hydrochloric acid (HCl) bath for 15 min, using a sealed glass jar (to contain fumes); then rinse under tap water. This process removes silver oxides and reduces the likelihood of porcelain discoloration ("greening").

(NOTE: An alternative to the use of acids is simply to air-abrade the casting with 50- μ m, non-recycled aluminum oxide).

2. CLEANING - Place in distilled water in an ultrasonic unit for 5 min; then apply the opaque porcelain.

--SECTION 8: ATTACHMENT 1--

IX. PORCELAIN COMPATIBILITY--BAK-ON SP

A. PORCELAIN SYSTEM COMPATIBILITY CHART: The following information has been provided by the alloy manufacturer (X):

<u>DENTAL PORCELAIN</u>	<u>PORCELAIN COMPATIBILITY</u>			
	<u>YES</u>	<u>NO</u>	<u>MARGINAL</u>	<u>UNKNOWN</u>
1. ARTIS-TECH (Jeneric)	X*			
2. BIOBOND (Dentsply)			X	
3. CERAMCO (Johnson & Johnson)	X			
4. CRYSTAR (Unitek)		X		
5. JELENKO (Jelenko)		X		
6. (BIOBOND) SHADEMATE (Dentsply)	Low - Reg-			X X
7. VITA (Vident)		X		
8. WILL-CERAM (Williams)	X*			

B. KNOWN OR SUSPECTED PORCELAIN-METAL INCOMPATIBILITIES: Since this alloy contains silver, certain additional precautionary steps are recommended to reduce the likelihood of porcelain discoloration and furnace contamination.

1. Use of Metal Conditioners - Is ADVISABLE, but OPTIONAL.
2. Use of Carbon Pellets - Place a carbon pellet on the sagger tray each time a casting is fired in the porcelain furnace.
3. Purging the Porcelain Furnace - If silver-containing alloys are used routinely, it is advisable to purge the furnace of silver contamination several times per week. Place 1 or 2 carbon pellets in the furnace at 1200 °F(649 °C), draw a full vacuum, and raise the temperature to 2200 °F (1204 °C). Leave the furnace at temperature under full vacuum for 20-30 min.
- 4.* Non-Greening Porcelains - Will-Ceram and Artis-Tech porcelains are reportedly resistant to porcelain discoloration (greening), when used with silver-containing alloys. Therefore, acid treatments (pickling) and metal conditioners are not required with these two dental porcelain systems.
5. Extend the first application of opaque over the metal collar area, and do not remove this overextension until the final glaze. This procedure will prevent an exposed collar from yellowing the body porcelain.

—SECTION 8: ATTACHMENT 1—

X. PRE-SOLDERING INSTRUCTIONS—BAK-ON SP

A. RECOMMENDED MATERIALS:

1. SOLDER - Use BAK-ON Yellow Solder (flows at 2010 °F/1099 °C)
2. FLUX - BAK-ON High Temp Flux
3. SOLDERING INVESTMENT - Use a soldering investment and NOT a high-heat phosphate-bonded casting investment.

B. SOLDERING TECHNIQUE: Use the Williams Magic Wand torch with the #248 torch tip or the Harris 16-S torch and a 2N tip.

1. Smooth the surfaces which are to be joined using either a rubber wheel or fine sandpaper disc.
2. Create a GAP DISTANCE of 0.3 to 0.5 mm. Clean in distilled water.
3. Join the units to be pre-soldered with quick cure acrylic resin (Duralay) or sticky wax.
4. Mix the soldering investment according to manufacturer's instructions. Allow to set for 30 minutes then trim away corners and sharp angles; wash with boiling water; and allow to dry thoroughly.
5. Preheat the dried investment in an electric furnace at room temperature and run it up to 1800-1850 °F (982-1010 °C). At temperature, remove, and place on a soldering block. (Torch and Bunsen burner preheating may also be used.)
6. A properly preheated investment block should appear lighter in color as a result of the burnout of carbon. Be sure no carbon is present.
7. Apply flux to the solder joint areas to control oxidation.
8. Use a gas-oxygen torch, a soldering torch tip, and 5 psi OXYGEN.
9. Adjust the inner blue cones to about 1/2- to 3/4-in. in length. If a hissing sound occurs, reduce oxygen flow to a quiet flame.
10. Heat the area to be soldered with the REDUCING flame which begins about 1/2-in. beyond the inner blue cones.
11. Play the soft flame over the invested case to maintain even heat.
12. Move the end of the solder across the joint with a wiping motion, until a small amount of solder is deposited.
13. Maintain the heat while the flux turns dark; continue heating until the dark effect dissipates and the solder flows. Do NOT attempt to remelt the solder.
14. BENCH COOL, divest, and finish with non-contaminated abrasives.

—SECTION 8: ATTACHMENT 1—

XI. POST-SOLDERING INSTRUCTIONS--BAK-ON SP

A. RECOMMENDED MATERIALS:

1. SOLDER - Use MASTERCASE 650 Solder (flows at 1470 °F/799 °C);
MASTERCASE 615 Solder (flows at 1400 °F/760 °C); or
Regular White Low Fusing Solder (flows at 1325 °F/718°C)
2. FLUX - BAK-ON Low Temperature Flux
3. SOLDERING INVESTMENT - Use a soldering investment, and NOT a high-heat phosphate-bonded casting investment.

B. SOLDERING TECHNIQUE: Use the Williams Magic Wand torch with the #248 torch tip; a Harris 2N torch tip; or a National OX-1 or OX-2 tip.

1. Lightly grind all surfaces to be soldered to remove any oxides, polishing agents or other contaminants.
2. Create a GAP DISTANCE of 0.3 - 0.5 mm between the units to be joined.
3. Join the units with acrylic resin (Duralay) or sticky wax. It is helpful to provide the dental laboratory with a soldering index should it be necessary to separate the units.
4. Invest in a soldering investment; do NOT use a high heat casting investment. Use wax to protect the porcelain.
5. Allow the investment to set for at least 30 min.
6. Boil out the stick wax. Remove any acrylic resin with a Robinson brush and isopropanol.
7. Dry excess water and lightly apply flux to the joint areas.
8. Preheat the investment in the muffle entrance and introduce the units into a porcelain furnace set at 1000 °F (538 °C) over a 5-min period.
9. Raise the porcelain oven to 1550 °F (843 °C) at the rate of 80-100 °F (27-38 °C) per min for MASTERCASE White Low Fusing Solder, and to 1650 °F (899 °C) for MASTERCASE 650 and 615.
10. Once solder has flowed, position the units in the muffle entrance and begin a 5-min cool down. Allow the invested units to cool slowly; do not rush the cast at this stage to avoid porcelain cracking.
11. Once at room temperature, remove the investment, finish and polish the metal.

—SECTION 8: ATTACHMENT 2—

IV. WAXING AND SPRUING INSTRUCTIONS—JEL-5

A. MINIMUM RECOMMENDED WAX THICKNESS:

1. SINGLE UNITS - 0.5 mm
2. THREE-UNITS FIXED PARTIAL DENTURES - 0.5 mm
3. FIXED PARTIAL DENTURES GREATER THAN 3 UNITS - 0.5 mm.

B. RECOMMENDED SPRUING TECHNIQUE:

1. SINGLE UNITS - Use the INDIRECT METHOD, with 8- or 10-GAUGE sprues 5 mm long, attached to the thickest part of the wax pattern, a 6- or 8-GAUGE runner bar, and offset 8-GAUGE leads connecting the sprue former to the runner bar (Fig. 4-2).
2. MULTIPLE SINGLE UNITS - Use the INDIRECT METHOD, with 8- or 10-GAUGE sprues 5 mm long, attached to the thickest part of the wax pattern, a 6- or 8-GAUGE runner bar, and offset 8-GAUGE leads connecting the sprue former to the runner bar.
3. FIXED PARTIAL DENTURES - Use the INDIRECT METHOD, with 8- or 10-GAUGE sprues 5 mm long, attached to the thickest part of the wax pattern, a 6- or 8-GAUGE runner bar, and offset 8-GAUGE leads connecting the sprue former to the runner bar.

NOTE: Adjust the runner bar to conform to the contour of the fixed partial denture. If the bar must be bent, then cut and re wax it at each cut in order to destroy any memory in the wax (Fig. 4-2).

4. VENTING - Is not considered necessary
5. WAX PATTERN POSITIONING - If the wax pattern is seated too low in the casting ring, build up the sprue former with wax, and raise the patterns to within 1/4 in. of the top of the ring. This technique will facilitate wax elimination and the escape of gases during investment burnout. Arrange the spruing system so the reservoir portion is in the HEAT CENTER of the casting ring with the wax patterns in a COLD ZONE (Fig. 4-2).

--SECTION 8: ATTACHMENT 2--

V. INVESTMENT AND BURNOUT TECHNIQUE--JEL-5

A. RECOMMENDED INVESTMENTS:

1. PHOSPHATE-BONDED INVESTMENTS: The following proportions of special liquid and distilled water are recommended starting points.

<u>NON-CARBON TYPE:</u>	<u>SPECIAL LIQUID</u>	<u>DISTILLED WATER</u>
a. Vestra-fine (Unitek) -	9.0 cc	6.5 cc
b. Hi-Temp (Whip-Mix) -	4.5 cc	4.5 cc
c. Hi-Span (Jelenko) - (Suggested by alloy manufacturer)	Not tested with this alloy.	

CARBON-TYPE: Not tested

NOTE: A carbon-containing investment may be used with this alloy, but all carbon must be eliminated during burnout.

2. GYPSUM-BONDED INVESTMENTS: NOT suitable for this alloy.

B. RECOMMENDED METHOD OF INVESTMENT: HIGH-HEAT rather than hygroscopic

C. MANUFACTURER'S RECOMMENDED ASBESTOS SUBSTITUTE: NOBESTOS (Jelenko)

You may use one WET layer of NON-ASBESTOS ring liner (Whip-Mix) or similar material. Place the ring liner flush with the top of the casting ring, but leave at least a 1/8-in. clearance at the bottom of the ring. The 1/8-in. clearance will help lock the investment in the ring when it expands (Fig. 4-2). If additional expansion is needed, use two layers of asbestos substitute and/or more special liquid and less distilled water.

D. BURNOUT TECHNIQUE:

PHOSPHATE-BONDED INVESTMENT: Start with a cold oven and raise to a temperature of 1400 °F (760 °C) at the rate of 25-30 °F/min, then HEAT SOAK as follows:

- a. Single ring - 1 hr
- b. Three units in a single ring - 1 hr
- c. Multiple units, 2-3 rings - 1 hr, 20 min; add 10 min for each additional ring.

—SECTION 8: ATTACHMENT 2—

VI. MELTING AND CASTING INSTRUCTIONS--JEL-5

A. CASTING EQUIPMENT:

1. CASTING MACHINE (DO NOT USE A THERMATROL 2500 WITH CARBON CRUCIBLES):
 - a. Manufacturer's Preferred Casting Equipment - Torch/centrifuge or Procaster
 - b. Alternative Systems Include - Centrifuge.
2. CASTING TORCH - Harris 16-S with #1390 H multi-orifice tip.
3. CASTING CRUCIBLES - Alumina or quartz; DO NOT USE CLAY OR CARBON TYPE.

B. QUANTITY OF ALLOY NEEDED:

1. VOLUME OF METAL NEEDED - Refer to conversion chart (Table 1)*
2. PREFERRED RATIO OF NEW TO RECAST METAL - 50/50% by weight or NEW metal
3. MINIMUM RATIO OF NEW METAL TO RECAST METAL - 50/50% by weight.

C. MELTING AND CASTING TECHNIQUE (PROPANE preferred, NATURAL GAS adequate):

1. OXYGEN-GAS RATIO - 10 psi OXYGEN to natural gas, or 10 psi PROPANE.
2. SETTING CASTING MACHINE - Add one additional turn to casting machine to compensate for the alloy's lower density.
3. FLAME ADJUSTMENT - Adjust torch to produce inner blue cones 1/4 in. in length for the multi-orifice torch tip.
4. APPEARANCE OF THE MELT - Place the alloy in a preheated crucible, and keep the torch moving in a rotating motion to heat all the metal evenly. The individual ingots or the buttons will pool together like high-gold content alloys.
5. CASTING FLUX - Not necessary.
6. WHEN TO CAST - When the cloudiness disappears (oxide layer) and the alloys clears, it is READY to CAST.
7. RECOVERY OF CASTING - BENCH COOL; DO NOT QUENCH; DO NOT PICKLE.

D. INDUCTION CASTING (Start with a preheated crucible):

Jelenko Procaster

1. Set ARM SPEED to 3-4.
2. Set POWER to 3-4.

* At close of text.

—SECTION 8: ATTACHMENT 2—

VII. ADJUSTING AND FINISHING—JEL-5

A. REMOVING THE SPRUE:

1. SEPARATING DISC - Use Jelenko High-Speed separating discs or similar disc.
2. COLLECT GRINDINGS - This is a precious alloy, and its grindings have scrap value. Vacuum your clothing and work area.

B. FITTING THE CASTING:

1. REMOVE INTERNAL NODULES - Carefully inspect the inside of each casting under magnification, and remove any irregularities.
2. EVALUATE THE FIT - Verify an acceptable level of occlusal/incisal seat and marginal seal before proceeding to any additional finishing steps.
3. QUALITY CONTROL CHECK - Unsatisfactory castings (poor fit, overheated alloy, extensive porosity) should be remade.
4. INITIAL OCCLUSAL ADJUSTMENT - Articulate the casting and refine the occlusion, as necessary.

C. FINISHING THE CASTING:

1. STONES AND WHEELS - Use the same materials you have on hand to finish gold-base PFM alloys; i.e., Jelenko Brown Mounted Points, uncontaminated aluminum oxide stones, diamond points, etc.
2. AVOID METAL CONTAMINATION - Set aside a set of finishing stones for this particular alloy to prevent contamination of the metal.
3. ADJUSTMENT TECHNIQUE - Use the uncontaminated aluminum oxide abrasives to produce a smooth, even textured surface for all porcelain-bearing areas. Finish the metal surface in one direction, using light pressure.

—SECTION 8: ATTACHMENT 2—

VIII. PREPARATION OF THE METAL FOR PORCELAIN--JEL-5

A. PREPARATION OF THE METAL SUBSTRATE:

1. NON-PORCELAIN BEARING SURFACES - Rubber wheel all non-porcelain bearing areas (lingual/occlusal surfaces, interproximal struts and metal collars) to remove all scratches prior to the application of porcelain.
2. PORCELAIN BEARING SURFACES - Air-abrade the finished metal surfaces with a 50- μ m non-recycled, uncontaminated aluminum oxide (white) abrasive under 90-100 psi.
3. CLEANING - Steam clean the metal substrate, or place in distilled water in an ultrasonic unit for 10 min.

B. OXIDATION (DEGASSING) OF THE METAL SUBSTRATE:

1. LOW temperature setting - 1200 °F (649 °C)
2. HIGH temperature setting - 1900 °F (1038 °C)
3. Rate of rise - 90-100 °F (50-55 °C)/min
4. Atmosphere - Air (NO VACUUM)
5. HOLD time at HIGH temperature - None
6. Appearance of the oxide layer:
 - a. A PROPERLY oxidized layer - GRAY color, rough surface
 - b. An OVERoxidized layer - DARK GRAY to BLACK color
 - c. An UNDERoxidized layer - LIGHT GRAY, smooth surface.

C. POST-OXIDATION TREATMENT: To minimize the potential for discoloration of dental porcelain, this alloy does not necessarily have to be oxidized.

1. APPLY A METAL CONDITIONER - Place a metal conditioner, such as Jelenko's Color Prep, on all porcelain-bearing surfaces if the casting is not oxidized (optional).
2. **RETAIN THE OXIDE LAYER** - You may apply opaque porcelain directly over the oxide layer for those porcelains resistant to discoloration by silver (Will-Ceram and Artis-Tech).

--SECTION 8: ATTACHMENT 2--

IX. PORCELAIN COMPATIBILITY--JEL-5

A. PORCELAIN SYSTEM COMPATIBILITY CHART: The following information has been provided by the alloy manufacturer (X) or represents the opinions of the author (O) for single unit castings:

<u>DENTAL PORCELAIN</u>	<u>PORCELAIN COMPATIBILITY</u>			
	<u>YES</u>	<u>NO</u>	<u>MARGINAL</u>	<u>UNKNOWN</u>
1. ARTIS-TECH (Jeneric) -	O			X
2. BIOBOND (Dentsply) -				X
3. CERAMCO (Johnson & Johnson) -				X
4. CRYSTAR (Unitek) -				X
5. JELENKO (Jelenko) -				X
6. (BIOBOND) SHADEMATE (Dentsply) -	Low- Reg- X			
7. VITA (Vident) -		X		
8. WILL-CERAM (Williams) -	X*,O			

B. KNOWN OR SUSPECTED PORCELAIN-METAL INCOMPATIBILITIES:

- *1. This alloy, like the general group of silver-containing metals, has the potential to discolor certain dental porcelains. However, both Will-Ceram and Artis-Tech porcelain are reportedly resistant to this discoloration problem. Refer to Section 2 for more information.

C. SPECIAL HANDLING INSTRUCTIONS:

1. It is advisable to place a carbon pellet on the sagger tray whenever firing a silver-containing alloy.
2. Porcelain furnaces should be purged regularly (3 times/week), if silver-containing alloys are used regularly. More frequent purges should be performed if Jel-5 is used exclusively.

—SECTION 8: ATTACHMENT 2—

X. PRE-SOLDERING INSTRUCTIONS—JEL-5

A. RECOMMENDED MATERIALS:

1. SOLDER - Jelstar Presolder (flows between 2030 and 2060 °F/
1110 and 1127 °C).
2. FLUX - Is NOT recommended. Flux may contaminate the porcelain.
3. INVESTMENT - Use any conventional soldering investment or a high-heat phosphate-bonded casting investment with distilled water.

B. PRE-SOLDERING TECHNIQUE: Use the MAGIC WAND Torch (Williams) with its #248 tip, or the HARRIS torch with a 2N tip for precise heating.

1. Grind, with aluminum oxide stones, all surfaces to be soldered. This process will remove any oxides or contaminants which might impede pre-soldering.
2. Create a GAP DISTANCE of approximately 0.5 mm.
3. Mix investment so it is thick; turn fixed partial denture upside down; fill the inside of the casting with the mix; add a little extra on top; and invert onto a patty of investment. Do not let it settle. Keep the investment patty as small and as thin as possible.
4. Trim the investment patty and form a "v" groove underneath each joint.
5. Allow the investment to reach final set; then boil out the wax; and preheat the assembly to 1050 °F (566 °C) for about 20 min. If acrylic resin (Duralay) is used, be sure to remove all traces of the resin before initiating the solder process.
6. Use 10 psi OXYGEN and 1/4 psi NATURAL GAS (or 10 psi PROPANE). Adjust the inner blue cone(s) until a feathered edge is produced at each tip.
7. Place the invested units on a soldering block so the length of the assembly is perpendicular to your body. In other words, the lingual side of the units is to your right and the facial to your left.
8. Begin soldering.

--SECTION 8: ATTACHMENT 2--

XI. POST-SOLDERING INSTRUCTIONS--JEL-5

- A. RECOMMENDED MATERIALS: It is presupposed that the PFM units have been glazed and polished, and the metal substructures have been designed appropriately for the post-soldering procedure.
1. SOLDER - Jelstar Post-Solder (flows between 1310 and 1370 °F/
710 and 743 °C).
 2. FLUX - Use of flux is optional.
 3. INVESTMENT - Same as pre-soldering technique.
- B. POST-SOLDERING TECHNIQUE: Use a porcelain furnace for this step. It is especially helpful if the oven has a muffle view port (also referred to as a "sight window") to permit observation of the soldering process.
1. Grind joint surfaces with a fine vitrified aluminum oxide stone.
 2. Create a GAP DISTANCE of 0.5 mm.
 3. Place units on the master cast and seal the joint(s) with sticky wax.
 4. Once the sticky wax has cooled, remove the work from the master cast, and cover all the porcelain to be embedded in the investment with white wax. This step will prevent discoloration of the glazed porcelain.
 5. Invest the castings in a soldering investment (or equivalent), and allow the mix to set.
 6. Trim the patty to remove sharp corners and to increase access to the joint area(s).
 7. Remove all the wax with boiling water.
 8. Shape the Jelstar Post-Solder to fit the joint area(s) in such a fashion that it fills the joint(s).
 9. Dry the invested work thoroughly, and slowly introduce it into a porcelain furnace set at 1000 °F (540 °C); then heat soak it for several minutes.
 10. A full vacuum may be drawn to reduce oxide build-up.
 11. Raise the temperature to 1470 °F (700 °C), at the rate of 75 °F/min (24 °C/min). The solder should flow accordingly.
 12. Remove the work, allow it to cool, and repolish the metal.

—SECTION 8: ATTACHMENT 3—

PORS-ON

I. GENERAL INFORMATION

ALLOY TYPE: "PRECIOUS"

ALLOY SYSTEM: Palladium-Silver

ALLOY CONTENT: 58% Palladium, 30% Silver, with 12% Tin, Indium, and Zinc
(exact formulation is proprietary information)

MANUFACTURER:

Degussa Dental Inc.
21-25 44th Avenue
Long Island City, New York 11101

TOLL-FREE PHONE NUMBER:
1-(800) 221-0168, ext. 43 or 46

COMMERCIAL PHONE NUMBER:
1-(212) 392-7272

TELEPHONE CONTACTS:

Laboratory - Susan Denton, ext. 43
Research - Dr. Manohar Lal Malhotra

REGIONAL SALES REPRESENTATIVES:

No; Call for assistance

ALLOY INTRODUCED IN: 1975

F.D.A. LISTED: Yes

A.D.A. ACCEPTANCE OR PROVISIONAL ACCEPTANCE: No

II. PHYSICAL DESCRIPTION

Ingot color - Platinum

Ingot shape - Rectangle

Ingot weight - 2 dwt

Ingots per ounce - 10 per oz

Ingot identification - "Pors-On White"

Alloy packaging - 1 oz only

III. PHYSICAL AND MECHANICAL PROPERTIES

Specific gravity (density) - 11.0 g/cc

Brinell hardness number - 220

Vickers hardness number - 240

Percentage elongation (in 1/2 in.) - 15%

Ultimate tensile strength - 96,000 psi

Yield strength (0.2% offset) - Not specified

Proportional limit - 69,000 psi

Bond strength - No value available

Coefficient of thermal expansion - $(15.0 \pm 0.3) \times 10^{-6}$ in/in/°C .

MELTING RANGE - 2261-2318 °F
(1238-1270 °C)

CASTING TEMPERATURE - 2500 °F
(1371 °C)

--SECTION 8: ATTACHMENT 3--

IV. WAXING AND SPRUING INSTRUCTIONS--PORS-ON

A. MINIMUM RECOMMENDED WAX THICKNESS:

1. SINGLE UNITS - 0.3 mm
2. THREE-UNITS FIXED PARTIAL DENTURES - 0.5 mm
3. FIXED PARTIAL DENTURES GREATER THAN 3 UNITS - 0.5 mm.

B. RECOMMENDED SPRUING TECHNIQUE:

1. SINGLE UNITS - Use either the DIRECT or INDIRECT METHOD (Figs. 4-1 and 4-2).
 - a. DIRECT METHOD: Attach 8- or 6-GAUGE sprues, 10-15 mm in length, directly to the thickest portion of the wax pattern.
 - b. INDIRECT METHOD: Refer to Section 2 (next).
2. MULTIPLE SINGLE UNITS - Use the INDIRECT METHOD, with 5-7 mm, 8- or 6-GAUGE sprues, attached to the wax patterns. Join these sprues to a 6-GAUGE (4 mm diameter) runner bar, which extends just beyond the width of the patterns at each end. Use 8- or 6-GAUGE sprue leads offset from the runner bar to the crucible former cone.
3. FIXED PARTIAL DENTURES - Use the INDIRECT METHOD, with 5-7 mm, 8- or 6-GAUGE sprues, attached to the thickest portion of each wax pattern. Join these sprues to a 6-GAUGE runner bar which extends just beyond the width of each end pattern. Use several offset 6- or 8- GAUGE sprue leads from the runner bar to the crucible former cone.

NOTE: The runner bar should be shaped to conform to the contour of the fixed partial denture. If the bar must be bent, then cut and re wax it at each cut in order to destroy any memory in the wax (Fig. 4-2).

4. VENTING - Attach 18-GAUGE wire wax to the interproximal areas to serve as chill vents.
5. WAX PATTERN POSITIONING - If the wax pattern is seated too low in the casting ring, build up the sprue former with wax, and raise the pattern to within 1/4 in. of the top of the ring. This technique will facilitate wax elimination and the escape of gases. Design the spruing system so any reservoir is in the HEAT CENTER of the casting ring, with the wax patterns in a COLD ZONE (Fig. 4-2).

—SECTION 8: ATTACHMENT 3—

V. INVESTMENT AND BURNOUT TECHNIQUE—PORS-ON

A. RECOMMENDED INVESTMENTS:

1. PHOSPHATE-BONDED INVESTMENTS: Use either a NON-CARBON investment (white color), or a CARBON-containing investment.

<u>NON-CARBON TYPE:</u>	<u>SPECIAL LIQUID</u>	<u>DISTILLED WATER</u>
Vestra-fine (Unitek) -	10.0 cc	5.5 cc
<u>CARBON TYPE:</u>		
Deguvest HFG (Degussa) -	7.0 cc	2.0 cc

2. GYPSUM-BONDED INVESTMENTS: NOT suitable for this alloy.

B. RECOMMENDED METHOD OF INVESTMENT: HIGH-HEAT rather than hygroscopic.

C. MANUFACTURER'S RECOMMENDED ASBESTOS SUBSTITUTE: Degussa Asbestos Free Ring Liner. Use WET.

You may also use one WET layer of NON-ASBESTOS LINER (Whip-Mix).

D. BURNOUT TECHNIQUE:

PHOSPHATE-BONDED INVESTMENT: Start with a cold oven and raise to a temperature of 600 °F (316 °C) until all wax has been eliminated, then raise a temperature of 1560 °F (849 °C) and HEAT SOAK as follows:

<u>Ring Size</u>	<u>Wax Elimination Time</u>	<u>Heat Soaking Time</u>
1x Ring	30 min	35 min
3x Ring	40 min	45 min
6x Ring	50 min	60 min
9x Ring	60 min	60 min

- b. Three units in a single ring - 40 min for 3x rings

- c. Multiple units, 2-3 rings - 60 min for 9x rings

NOTE: A longer soaking time, and/or burnout temperature, may be required to ensure complete carbon elimination when using plastic sprues.

—SECTION 8: ATTACHMENT 3—

VI. MELTING AND CASTING INSTRUCTIONS--PORS-ON

A. CASTING EQUIPMENT:

1. CASTING MACHINE (You may use a THERMATROL 2500 with CARBON crucibles):
 - a. Manufacturer's preferred casting equipment - Not specified.
 - b. Alternative systems include - Broken-arm casting machine, centrifuge.
2. CASTING TORCH - Harris 16-S with a #1390H multi-orifice tip.
3. CASTING CRUCIBLES - Use either a quartz or alumina crucible.
DO NOT USE a clay crucible.

B. QUANTITY OF ALLOY NEEDED:

1. VOLUME OF METAL NEEDED - Refer to conversion chart (Table 1).*
2. PREFERRED RATIO OF NEW METAL TO RECAST METAL - 50/50% by weight.
3. MINIMUM RATIO OF NEW METAL TO RECAST METAL - 50/50% by weight.

C. MELTING AND CASTING TECHNIQUE (PROPANE preferred, NATURAL GAS adequate):

1. OXYGEN-GAS RATIO - 10 psi OXYGEN or 5 psi PROPANE (for natural gas, open valve all the way).
2. SETTING CASTING MACHINE - Add one turn to casting machine to compensate for the lower density of the alloy.
3. FLAME ADJUSTMENT - Set inner blue cones to a length of 1/2 in. or less.
4. APPEARANCE OF THE MELT - Alloy will melt rapidly, and the ingots will pool, like gold-base PFM alloys.
5. CASTING FLUX - Not specified.
6. WHEN TO CAST - When a brilliant, clean surface appears.
7. RECOVERY OF CASTING - BENCH COOL to room temperature.
8. DO NOT PICKLE.

* At close of text.

--SECTION 8: ATTACHMENT 3--

VII. ADJUSTING AND FINISHING--PORS-ON

A. REMOVING THE SPRUE:

1. SEPARATING DISC - Use any thin separating disc of your choice.
2. COLLECT GRINDINGS - This is a precious alloy and its grindings have scrap value. Vacuum your clothing and work area.

B. FITTING THE CASTING:

1. REMOVE INTERNAL NODULES - Carefully inspect the inside of each casting under magnification, and remove any irregularities.
2. EVALUATE THE FIT - Verify an acceptable level of occlusal/incisal seat and marginal seal, before proceeding to any additional finishing steps.
3. QUALITY CONTROL CHECK - Unsatisfactory castings (poor fit, overheated alloy, porosity) should be remade.
4. INITIAL OCCLUSAL ADJUSTMENT - Articulate the casting and refine the occlusion, as necessary.

C. FINISHING THE CASTING:

1. STONES AND WHEELS - Use the same materials you have on hand to finish precious PFM alloys; i.e., uncontaminated aluminum oxide stones, diamond points, etc.
2. AVOID METAL CONTAMINATION - Set aside a set of finishing stones for this particular alloy to prevent contamination of the metal.
3. ADJUSTMENT TECHNIQUE - Use the uncontaminated aluminum oxide abrasives to produce a smooth, even textured surface for all porcelain-bearing areas. Finish the metal surface in one direction, using light pressure.

—SECTION 8: ATTACHMENT 3—

VIII. PREPARATION OF THE METAL FOR PORCELAIN—PORS-ON

A. PREPARATION OF THE METAL SUBSTRATE:

1. NON-PORCELAIN BEARING SURFACES - Rubber wheel all non-porcelain bearing areas (lingual/occlusal surfaces, interproximal struts and metal collars) to remove all scratches prior to the application of porcelain.
2. PORCELAIN BEARING SURFACES - Air-abrade the finished metal surfaces with a 50- μ m non-recycled, uncontaminated aluminum oxide (white) abrasive under 90-100 psi.
3. CLEANING - Steam clean the metal substrate, or place in distilled water in an ultrasonic unit for 10 min.

B. OXIDATION (DEGASSING) OF THE METAL SUBSTRATE:

1. LOW temperature setting - 1200 °F (649 °C)
2. HIGH temperature setting - 1900 °F (1038 °C)
3. Rate of rise - Not specified.
4. Atmosphere - Air (NO VACUUM)
5. HOLD time at HIGH temperature - 0
6. Appearance of the oxide layer: No visible thick oxide will appear.
 - a. A properly oxidized layer - LIGHT GRAY color
 - b. An OVERoxidized layer - Can not be recognized
 - c. An UNDERoxidized layer - Can not be recognized.

C. POST-OXIDATION TREATMENT: Procedure #1 is applicable to all compatible dental porcelains, while procedure #2 should be limited to the processing of Will-Ceram and Artis-Tech porcelain.

1. **REMOVE THE SILVER OXIDE** - Pickle in preheated (150-200 °F/66-93 °C) hydrochloric acid (35%) for 15 min; use a metal conditioner according to supplier's instructions, and lightly blast with nonrecycled aluminous oxide.
2. **RETAIN THE OXIDE LAYER** - Do not air-abrade the casting or otherwise attempt to remove/reduce the oxide layer. Apply opaque porcelain DIRECTLY to the oxidized casting.

—SECTION 8: ATTACHMENT 3—

IX. PORCELAIN COMPATIBILITY—PORS-ON

A. PORCELAIN SYSTEM COMPATIBILITY CHART: The following information has been provided by the alloy manufacturer (X):

<u>DENTAL PORCELAIN</u>	<u>PORCELAIN COMPATIBILITY</u>			
	<u>YES</u>	<u>NO</u>	<u>MARGINAL</u>	<u>UNKNOWN</u>
1. ARTIS-TECH (Jeneric)	X*			
2. BIOBOND (Dentsply)	X			
3. CERAMCO (Johnson & Johnson)	X			
4. CRYSTAR (Unitek)	X			
5. JELENKO (Jelenko)	X			
6. (BIOBOND) SHADEMATE (Dentsply)	Low - X Reg- X	X		
7. VITA (Vident)	X			
8. WILL-CERAM (Williams)	X*			

B. KNOWN OR SUSPECTED PORCELAIN-METAL INCOMPATIBILITIES: Since this alloy contains silver, certain additional precautionary steps are recommended to minimize any porcelain discoloration and furnace contamination.

1. Pickling - Place castings in hydrochloric acid (HCl) pre-heated to a temperature of 190 °F (88 °C) for approximately 15 min. Remove from the acid bath and rinse under tap water for 2 min, followed by a 5-min soaking in distilled water in an ultrasonic cleaner.
2. Use of metal conditioners - A metal conditioner (such as Aderer Ceramic Alloy conditioner) is **ADVISABLE**, except when using either Will-Ceram or Artis-Tech porcelain.
3. Use of carbon pellets - Place a carbon pellet on the sagger tray each time a casting is fired in the porcelain furnace.
4. Purging the porcelain furnace - If silver-containing alloys are used routinely, it is advisable to purge the furnace of silver contamination several times per week. Place 1 or 2 carbon pellets in a 1200 °F (649 °C) furnace, draw a full vacuum, raise the temperature to 2200 °F (1204 °C), and hold at temperature under full vacuum for 20-30 min.
- * 5. Non-greening porcelains - Only Will-Ceram and Artis-Tech porcelains are reportedly free of porcelain discoloration (greening), when used with silver-containing alloys. Pickling and metal conditioners are reportedly unnecessary with these two porcelain systems.

—SECTION 8: ATTACHMENT 3—

X. PRE-SOLDERING INSTRUCTIONS—PORS-ON

A. RECOMMENDED MATERIALS:

1. SOLDER - Use Pors-On HF Solder or Ceramco White Solder (both flow at approximately 2075 °F or 1135 °C)
Or use Degudent U1 Solder (2048 °F or 1120 °C)
2. FLUX - Use Degussa Anoxsan flux.
3. INVESTMENT - A soldering investment (such as Deguvest L) is the IDEAL material to use, but a casting investment with all distilled water may be substituted.

B. SOLDERING TECHNIQUE: For precise heating, use the Magic Wand torch (Williams) with a #248 tip, the Harris 16-S torch and a 2N tip, or the Degussa Gas/Oxygen torch with #2 tip.

1. Propane-oxygen is the preferred heat source, although natural gas-oxygen is an acceptable alternative.
2. Be certain the surfaces to be soldered are large enough to provide adequate strength to the joint.
3. Prepare a uniform GAP DISTANCE of no more than 0.05-0.1 mm.
4. The surfaces to be soldered must have a rough finish and be clean.
5. Invest the units to be soldered in a soldering investment.
6. Trim the investment patty to a uniform but stable thickness.
7. After boiling the sticky wax out of the joint(s), clean the joint area(s), and apply Degussa Anoxan Flux. This procedure will prevent the build-up of oxides which might interfere with the soldering process.
8. Preheat the investment block in an electric furnace at 1150 °F (621 °C).
9. Use 5 psi OXYGEN with NATURAL GAS or PROPANE.
10. Heat the solder connections(s) until they reach the working temperature of the solder.
11. Once soldering is complete, allow the investment block to cool slowly to room temperature before divesting.
12. Grind the joint(s) with uncontaminated stones; air-abrade; and clean in an ultrasonic unit to remove all traces of flux and investments.
13. Remove the cleaned castings, and proceed with the OXIDATION process.

--SECTION 8: ATTACHMENT 3--

XI. POST-SOLDERING INSTRUCTIONS--PORS-ON

A. RECOMMENDED MATERIALS:

1. SOLDER - Regular White Solder (working temperature 1360 °F/738 °C)
2. FLUX - Degussa T-Flux (DO NOT APPLY FLUX TO THE PORCELAIN)
3. INVESTMENT - A soldering investment (such as DEGUVEST L) is the IDEAL material, but a casting investment with distilled water may be used.

B. SOLDERING TECHNIQUE: Use a porcelain furnace with a view port to monitor the soldering process.

1. Prepare a uniform GAP DISTANCE of no more than 0.05-0.1 mm.
2. Position the units to be joined on a cast, and join them with sticky wax. Alternatively, the units may be united with the resin directly in the mouth with an index for reassembly, if necessary.
3. The surfaces to be soldered should be rough finished and clean.
4. Cover all the porcelain surfaces with wax, to prevent direct contact with the soldering investment, and possible porcelain discoloration.
5. Invest and trim the investment block to a minimum but stable thickness.
6. Boil out the sticky wax, and coat the joints to be soldered with T-Flux. DO NOT APPLY THE FLUX TO THE PORCELAIN.
7. Carefully melt the solder strip over a Bunsen burner until a small ball is formed. Cut the ball off the strip, thus leaving a small tail.
8. Use the tail to seat each solder piece in the soldering investment. Apply T-Flux to each solder ball.
9. Preheat the assembly in front of the furnace muffle for 10-15 min.
10. Set the furnace maximum temperature to the solder working temperature.
11. Slowly insert the invested castings into the muffle to permit uniform heat absorption.
12. Leave the unit in the furnace for 2-3 min, depending on the size of the soldering work. If necessary, the temperature may be increased in 10 °F increments until the solder flows.
13. Carefully remove the work and inspect the solder joints. Allow the metal to cool uniformly before divesting and repolishing.

—SECTION 8: ATTACHMENT 4—

WILL-CERAM W-1

I. GENERAL INFORMATION

ALLOY TYPE: "PRECIOUS"

ALLOY SYSTEM: Palladium-Silver

ALLOY CONTENT: 53.5% Palladium, 37.5% Silver, 8.5% Tin, and 0.5% of unspecified grain refiners and deoxidizers

MANUFACTURER:

Williams Gold Refining Co.
2978 Main Street
Buffalo, New York 14214

TOLL-FREE PHONE NUMBER:

1-(800) 828-1003
1-(800) 462-7688 (in New York State)
1-(800) 852-7066 (in California)
1-(800) 824-7925 (west of the Rocky Mountains)

COMMERCIAL PHONE NUMBER:

1-(716) 837-1000

TELEPHONE CONTACTS:

Education Department
1-(800) 828-1538

REGIONAL SALES REPRESENTATIVES:

Yes

ALLOY INTRODUCED IN: 1975

F.D.A. LISTED: Yes

A.D.A. ACCEPTANCE OR PROVISIONAL ACCEPTANCE: "ACCEPTABLE" (1980)

II. PHYSICAL DESCRIPTION

Ingot color - Platinum

Ingot shape - Rectangle

Ingot weight - 2 dwt

Ingots per ounce - 10 per oz

Ingot Identification - "Williams W-1"

Alloy Packaging - 1- and 5-oz

III. PHYSICAL AND MECHANICAL PROPERTIES

Specific gravity (density) - 11.06 g/cc

Brinell hardness number - Not determined

Vickers hardness number - 242 (after porcelain application)

Percentage elongation (in 1 in.) - 11%

Ultimate tensile strength - 94,100 psi (after porcelain application)

Yield strength (0.1% offset) - 68,100 psi (after porcelain application)

Bond strength - No value available

Coefficient of thermal expansion - $15.20 \times 10^{-6}/^{\circ}\text{C}$ from 600-20 °C

MELTING RANGE - 2165-2320 °F
(1185-1271 °C)

CASTING TEMPERATURE - 2420 °F
(1327 °C)

—SECTION 8: ATTACHMENT 4—

IV. WAXING AND SPRUING INSTRUCTIONS—WILL-CERAM W-1

A. MINIMUM RECOMMENDED WAX THICKNESS:

1. SINGLE UNITS - 0.3 mm
2. THREE-UNITS FIXED PARTIAL DENTURES - 0.5 mm
3. FIXED PARTIAL DENTURES GREATER THAN 3 UNITS - 0.5 mm.

B. RECOMMENDED SPRUING TECHNIQUE:

1. SINGLE UNITS - Use an INDIRECT spruing technique, with 8-GAUGE connector sprues, 2-3 mm in length, to each pattern; and attach them to a 6-GAUGE runner bar (distribution channel). Attach the runner bar to the sprue former with two offset 6-GAUGE lead sprues (Fig. 4-2).
2. MULTIPLE SINGLE UNITS - Use an INDIRECT spruing technique, with 8-GAUGE connector sprues, 2-3 mm in length, to each pattern; and attach them to a 6-GAUGE runner bar (distribution channel). Attach the runner bar to the sprue former with two offset 6-GAUGE lead sprues (Fig. 4-2).
3. FIXED PARTIAL DENTURES - Use an INDIRECT spruing technique, with 8-GAUGE connector sprues, 2-3 mm in length, to each wax pattern. Attach them to a 6-GAUGE runner bar (distribution channel) which extends slightly beyond the ends of the patterns.

NOTE: Adjust the connector or runner bar to conform to the contour of the fixed partial denture; cut the bar; and re wax it to eliminate wax memory. Design any INDIRECT spruing system so the runner bar is in the heat center of the casting ring (Fig. 4-2).

4. VENTING - You may include a blind vent, attached to the thickest portion of each wax pattern, to help cool the restoration first. However, this step is not required.
5. WAX PATTERN POSITIONING - If the wax pattern is seated too low in the casting ring, build up the sprue former with wax and raise the pattern to within 1/4 in. of the top of the ring. This technique facilitates casting solidification and the escape of gases (Fig. 4-2).

--SECTION 8: ATTACHMENT 4--

V. INVESTMENT AND BURNOUT TECHNIQUE--WILL-CERAM W-1

A. RECOMMENDED INVESTMENTS:

1. PHOSPHATE-BONDED INVESTMENTS: A NON-CARBON-containing investment (white color) is preferred. Increase burnout time if a CARBON-containing investment (black color) is used.

<u>NON-CARBON TYPE:</u>	<u>SPECIAL LIQUID</u>	<u>DISTILLED WATER</u>
-------------------------	-----------------------	------------------------

Vestra-fine (Unitek) -	10.0 cc	5.5 cc
------------------------	---------	--------

CARBON TYPE: Not used with this alloy.

2. GYPSUM-BONDED INVESTMENTS: Not recommended for this alloy.

B. RECOMMENDED METHOD OF INVESTMENT: HIGH-HEAT

C. MANUFACTURER'S RECOMMENDED ASBESTOS SUBSTITUTE: Unspecified.

We prefer to use one WET layer of NON-ASBESTOS ring liner (Whip-Mix), rather than ASBESTOS FREE LINER (Degussa), NOBESTOS (Jelenko), or KAOLINER (Dentsply). Place the liner flush with the top of the casting ring, with at least 1/8-in. clearance at the bottom of the ring. The 1/8-in. clearance will lock the investment in the ring when the investment expands.

D. BURNOUT TECHNIQUE:

PHOSPHATE-BONDED INVESTMENT: Start with a COLD oven; raise temperature to 1500 °F (816 °C) at the rate of 25 °F/min; and HEAT SOAK as follows:

- a. Single units - 1 hr
- b. Three units in a single ring - 1 hr
- c. Multiple units, 2-3 rings - 1 hr and 20 min (add 10 min for each additional ring).

—SECTION 8: ATTACHMENT 4—

VI. MELTING AND CASTING INSTRUCTIONS—WILL-CERAM W-1

A. CASTING EQUIPMENT:

1. CASTING MACHINE (DO NOT USE THERMATROL 2500 WITH CARBON CRUCIBLE):
 - a. Manufacturer's recommendation - Williams Inductocast Machine
 - b. Alternative systems include - Centrifuge
2. CASTING TORCH - Harris 16-S with a #1390 H multi-orifice tip.
(Williams recommends their MAGIC WAND Torch.)
3. CASTING CRUCIBLES - Quartz or alumina. Do NOT use clay.

B. QUANTITY OF ALLOY NEEDED:

1. VOLUME OF METAL NEEDED - Refer to conversion chart (Table 1). *
2. PREFERRED RATIO OF NEW METAL TO RECAST METAL - 50/50% by weight
3. MINIMUM RATIO OF NEW METAL TO RECAST METAL - 33/67% by weight.

C. MELTING AND CASTING TECHNIQUE:

1. OXYGEN-GAS RATIO - Use 10 psi OXYGEN and 5 psi natural GAS.
2. SETTING CASTING MACHINE - Add 1 extra turn for the alloy's lower density.
3. FLAME ADJUSTMENT - The multiple light blue inner cones should be set to 1/8- to 1/2-in. lengths with a maximum flame length of 8- to 10-in. (Fig. 4-12). Hold the torch tip 2-in. above the metal with the flame perpendicular to the alloy. Guide the flame in a slight circular motion, with the alloy in the REDUCING ZONE of the flame.
4. APPEARANCE OF THE MELT - The alloy will melt readily, "pool," and then "clear," like gold-based ceramic alloys.
5. CASTING FLUX - Do NOT use casting flux or attempt to remove oxides.
6. WHEN TO CAST - When the molten alloy "clears" and "spins."
7. RECOVERY OF CASTING - BENCH COOL; DO NOT QUENCH; DO NOT PICKLE.

D. INDUCTION CASTING:

1. Set speed between 400 and 500 RPM.
2. Set temperature to 2420 °F (1327 °C).
3. CAST at temperature.

* At close of text.

--SECTION 8: ATTACHMENT 4--

VII. ADJUSTING AND FINISHING--WILL-CERAM W-1

A. REMOVING THE CERAM:

1. SEPARATING DISC - Use any thin separating disc of your choice.
2. GRINDING - This is a precious alloy, so its grindings have scrap value. Vacuum your clothing and work area.

B. FITTING THE CASTING:

1. QUALITY CONTROL CHECK - Unsatisfactory castings (poor fit, overheated alloy, porosity) should be remade.
2. REMOVE INTERNAL NODULES - Carefully inspect the inside of each casting under magnification, and remove any irregularities.
3. EVALUATE THE FIT - Verify an acceptable level of occlusal/incisal seat and marginal seal, before proceeding to any additional finishing steps.
4. INITIAL OCCLUSAL ADJUSTMENT - Articulate the casting and refine the occlusion, as necessary.

C. FINISHING THE CASTING:

1. STONES AND WHEELS - Use stones, carbide burs, and burlew wheels.
2. POLISHING - Use the same compounds employed to polish gold-base PFM alloys, such as Buffing Bar Compound (BBC) and rouge.
3. AVOID METAL CONTAMINATION - Set aside a set of finishing stones for this particular alloy to prevent metal contamination.
4. ADJUSTMENT TECHNIQUE - Use uncontaminated aluminum oxide abrasives to produce a smooth, even textured surface for all porcelain bearing areas. Finish the metal surface in one direction.

--SECTION 8: ATTACHMENT 4--

VIII. PREPARATION OF THE METAL FOR PORCELAIN--WILL-CERAM W-1

A. PREPARATION OF THE METAL SUBSTRATE:

1. NON-PORCELAIN BEARING SURFACES - Rubber wheel all non-porcelain bearing areas (lingual/occlusal surfaces, interproximal struts, and metal collars) to remove all scratches prior to the application of porcelain.
2. PORCELAIN BEARING SURFACES - Air-abrade the finished metal surfaces with a 50- μ m non-recycled, uncontaminated aluminum oxide (white) abrasive under 90-100 psi.
3. CLEANING - Steam clean the metal substrate, or place in distilled water in an ultrasonic unit for 10 min, after rubber-wheeling and air-abrading.

B. OXIDATION (DEGASSING) OF THE METAL SUBSTRATE:

1. LOW temperature setting - 1200 °F (649 °C)
2. HIGH temperature setting - 1850 °F (1010 °C)
3. Rate of rise - 100 °F (55 °C)
4. Atmosphere - FULL VACUUM (26-28 in. of Hg)
5. HOLD time at HIGH temperature - 5 min, under VACUUM
6. Appearance of the oxide layer:
 - a. A PROPERLY oxidized layer - LIGHT GRAY color
(surface finish will influence the appearance of the oxide)
 - b. An OVERoxidized layer - DARK GRAY or BLACK color
(air-abrade; clean; and reoxidize at a lower temperature)
 - c. An UNDERoxidized layer - NO READILY DISCERNIBLE color.
(reoxidize at a higher temperature)

C. POST-OXIDATION APPEARANCE:

1. RETAIN THE OXIDE LAYER - apply the opaque porcelain directly over the oxide layer.
2. REMOVE THE OXIDE LAYER -

--SECTION 8: ATTACHMENT 4--

IX. PORCELAIN COMPATIBILITY--WILL-CERAM W-1

A. PORCELAIN SYSTEM COMPATIBILITY CHART. The following information has been provided by the alloy manufacturer (X):

<u>DENTAL PORCELAIN</u>	<u>PORCELAIN COMPATIBILITY</u>			
	<u>YES</u>	<u>NO</u>	<u>MARGINAL</u>	<u>UNKNOWN</u>
1. ARTIS-TECH (Jeneric) -	X*			
2. BIOBOND (Dentsply) -	X			
3. CERAMCO (Johnson & Johnson) -	X			
4. CRYSTAR (Unitek) -	X			
5. JELENKO (Jelenko) -	X			
6. (BIOBOND) SHADEMATE (Dentsply) Reg-	X	Low-	X	
7. VITA (Vident) -	X			
8. WILL-CERAM (Williams) -	X*			

B. KNOWN OR SUSPECTED PORCELAIN-METAL INCOMPATIBILITIES: Since this alloy contains silver, certain additional precautionary steps are recommended to diminish the likelihood of any porcelain discoloration and furnace contamination.

1. Use of carbon pellets - Place a carbon pellet on the sagger tray each time a casting is fired in the porcelain furnace.
2. Purging the porcelain furnace - If silver-containing alloys are used routinely, it is advisable to purge the furnace of silver contamination on a daily basis. Place 1 or 2 carbon pellets in a 1200 °F (649 °C) furnace, draw a full vacuum, and raise the temperature to 2200 °F (1204 °C). Leave the furnace at temperature under full vacuum for 20-30 min with the vacuum pump running.
- * 3. Non-greening porcelains - Only Will-Ceram and Artis-Tech porcelains are reportedly free of porcelain discoloration (greening), when used with silver-containing alloys. Pickling and metal conditioners are reportedly unnecessary with these two porcelain systems.

--SECTION 8: ATTACHMENT 4--

X. PRE-SOLDERING INSTRUCTIONS--WILL-CERAM W-1

A. RECOMMENDED MATERIALS:

1. SOLDER - Use Will-Ceram Super Solder (flows around 2075 °F/1135 °C)
2. FLUX - Williams High Fusing Bondal Flux
3. INVESTMENT - Use Hi-Heat Soldering Investment (Whip-Mix), or a high-heat casting investment with distilled water (no special liquid).

B. SOLDERING TECHNIQUE: Use the MAGIC WAND Torch (Williams) with its #248 torch tip or the HARRIS 16-S torch with a 2N tip, for precise heating. (Use 5 psi OXYGEN and 2 psi natural GAS.)

1. Grind, with aluminum oxide stones, all surfaces to be soldered. This process will remove any oxides or contaminants which would impede soldering.
2. Create a GAP DISTANCE of approximately 0.3 mm.
3. Mix investment so it is thick; turn the fixed partial denture upside down; fill the inside of the castings with the mix; and invert onto a patty of investment. Do not let the castings settle into the investment. Keep investment patty as small as possible.
4. Allow the investment to reach final set, trim, smooth to remove sharp angles, and allow to dry thoroughly.
5. Apply heat in excess of 800 °F (427 °C) to eliminate the wax or acrylic resin joint (Duralay); dry thoroughly; remove from furnace; cool to room temperature. (Carbon will burn off at 800 °F (427 °C), and a dry investment will draw less heat from the parent metal.)
6. Blast THROUGH, not down into, the connector (joint) area with uncontaminated 50- μ m aluminum oxide to remove the oxides. (Oxides will impede, if not prevent, the solder-parent metal union.)
7. You now want to GLAZE your solder rod. First, heat the rod to a DULL ORANGE color; dip the rod in the flux, and you should hear it sizzle. (A GLAZED solder rod will act to retain the flux on the outside of the connector, and prevents its incorporation into the soldered joint.)
9. WEAR DARK GLASSES IN ORDER TO SEE AT THESE PRE-SOLDER TEMPERATURES, AS WELL AS TO PROTECT YOUR EYES FROM INJURY.
10. Heat the parent metal with the REDUCING atmosphere at the end of the inner blue cone(s) to prevent OXIDE FORMATION, and introduce the GLAZED solder rod to the connector area from the occlusal.
11. Solder should flow on contact, but ensure joint is filled before removing the reducing flame. REMOVE SOLDER, FINISH and polish.

--SECTION 8: ATTACHMENT 4--

XI. POST-SOLDERING INSTRUCTIONS--WILL-CERAM W-1

A. RECOMMENDED MATERIALS: The porcelain units are assumed to have been glazed, polished, and the metal substructures designed appropriately for the post-soldering procedure.

1. SOLDER - Williams Low Fusing Solder (flows at 1350 °F/732 °C)
2. FLUX - Williams Bondal Flux
3. INVESTMENT - Use High-Heat Soldering Investment (Whip-Mix) or a high-heat, non-carbon casting investment with distilled water (no special liquid).

B. POST-SOLDERING TECHNIQUE: Use a porcelain furnace for this procedure. It is especially helpful if the oven has a muffle view port (also referred to as a "sight window") to permit observation of the soldering process.

1. Invest in the normal manner for oven soldering (protect all glazed porcelain surfaces by covering them with colorless wax.)
2. Once the investment has set, heat the invested work to 800 °F (427 °C) to remove the wax or acrylic resin uniting the units.
3. Air-abrade the joints with 50- μ m aluminum oxide to clean them.
4. Flux each joint LIGHTLY.
5. Dip the solder in #7 Flux (Williams), and place in a Bunsen burner flame at the tip of the inner blue cone. The solder will immediately ball up. Remove the ball from the flame, and allow to cool.
6. Cut the solder approximately 1/4 in. from the ball, thus leaving a small tail. Place one ball (tail first) in small joints, and two balls in larger connector areas.
7. Vacuum-fire the case to approximately 1400 °F (760 °C).
8. Hold at 1400 °F (760 °C) for 2-3 min.
9. The solder should flow readily and fill the joint space(s).
10. Withdraw the soldered work to the muffle door and cool the work slowly.
11. Remove the investment and polish the joint areas.

SECTION 9:

THE NICKEL-CHROMIUM-BERYLLIUM ALLOYS

9-1. GENERAL DESCRIPTION

Due to the unprecedented increase in the cost of gold and the fact that the precious metals market is prone to sudden price swings, the non-precious metals, particularly nickel-chromium-beryllium alloys, have become popular.¹ The exact composition of the alloys within this group may vary markedly. However, it is not uncommon for an alloy to contain between 70 and 80% nickel, 13 and 20% chromium, and up to 2% beryllium.¹ Low density (less than one-half that of gold-base alloys), high strength, low thermal conductivity, and low cost have made this system particularly attractive for single unit PFM units, as well as for long span fixed partial dentures.²

With handling characteristics vastly different from those of gold-base metals, these non-precious alloys require a "learned" skill for investing, spruing, casting, finishing, and polishing. Historically, the failure to process these alloys properly may have been due to the misconception that techniques used for gold-base metals could be employed for these newer, lower density alloys. For example, on heating, the molten alloy develops an oxide film which separates ingots and buttons and prevents the metal from "pooling" into a single fluid mass, like precious alloys.

In addition, these alloys have a high casting shrinkage (approximately 2.3%) which must be accommodated for by the investment.³ Improved phosphate-bonded investments have been developed, and attention has been drawn to the need to evaluate the influence of casting investments on the castability of alloys.^{4,5} Also, better technical processing instructions for the non-precious alloys have been more widely available. Moreover, many alloy manufacturers have also improved the older formulations of nickel-chromium-beryllium alloys. Consequently, when referring to the results of castability studies done some years ago, one must consider the type of investment used, the casting techniques employed, and whether or not the alloys studied are still on the market today (Figs. 9-1 to 9-3).

The addition of beryllium to this nickel-base system increases the fluidity, improves the castability of the alloy, helps control surface oxidation,³ and enhances polishability. The presence of beryllium in an alloy is significant for several other reasons. If beryllium accounts for 1.8%-2.0% of the alloy's composition on a weight basis, the actual atomic volume of beryllium exceeds 10%.⁶ Beryllium's atomic size is relatively small (1.12 angstroms) and its atomic weight is 9.0122 as compared with gold's atomic weight of 196.967.⁷ Therefore, many atoms are needed to reach that 2.0% weight level. Research has also indicated that beryllium might display migratory behavior far below its melting point.⁸ Covington et al. observed surface beryllium concentrations ranging from 14 atom % for an ingot (uncast) of nickel-chromium-beryllium alloy, to as much as 39% for cast alloy incubated for 120 days in an acidic salivary solution.⁹ All this information indicates that more beryllium is "available" in the nickel-chromium-beryllium (Ni-Cr-Be)

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alloys than one might realize; the beryllium may concentrate along the alloy surface, and beryllium may leave the alloy.

Figure 9-1. Dense castings with sharp, distinct margins can be produced with Ni-Cr-Be alloys (Litecast B* shown). Eliminating a button on the casting is often difficult because of the size of many non-precious ingots.



Figure 9-2. The casting produced from this Ni-Cr-Be alloy (Biobond II**) is complete, with no porosity noted in the restorations or the reservoir bar. The margins are sharp, and the casting appears complete.

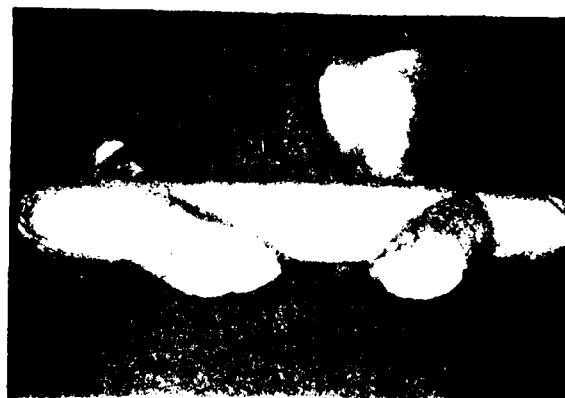


Figure 9-2. The bar, the reservoir bar should be the largest mass of metal, and the button should be cast. Note how the button is on the casting in Fig. 9-1. It is joined to the underside of the reservoir bar, away from the margins.

* Williams Gold Refining Co., Buffalo, NY.
** Dentsply International, Inc., York, PA.

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A particular concern with the nickel-chromium-beryllium alloys is their inherent tendency to oxidize. Laboratory and clinical bond failures, attributed to excessive oxidation, have been known to occur (Figs. 9-4 and 9-5). As a result, the permanency of the porcelain-metal bond has come under questions.² In fact, both the nickel- and cobalt-base alloys are considered to have a potential for porcelain delamination, due to separation of a poorly adherent oxide layer from the metal substrate.¹⁰

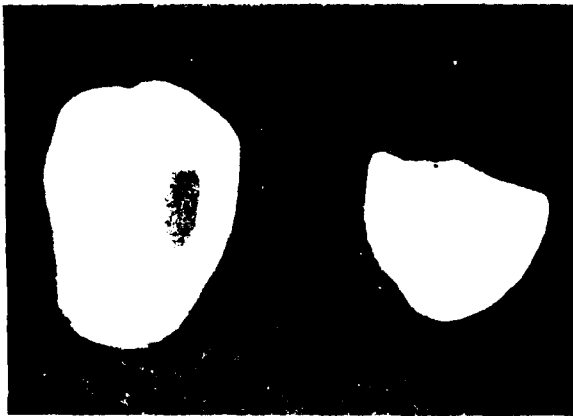


Figure 9-4. The bond between this Ni-Cr-Be alloy (Rexillum III*) and Vita** porcelain failed during the fabrication process. Note the oxide layer still bonded to the piece of dental porcelain on the right.



Figure 9-5. The porcelain fractures during cooling (left) and extensive delamination of the porcelain veneer from the metal substructure (right) are examples of some of the types of porcelain-metal failures observed.

Despite many of the improvements made in the processing of non-precious alloys in general, processing is one procedure still plagued by problems (Figs. 9-4 and 9-5).² The alloys are extremely hard,³ may wear an opposing natural dentition, cannot be burnished like gold-base alloys, and are difficult to section for repair. Nonetheless, the nickel-chromium alloys are used extensively, within the Air Force, for single unit PFM restorations as well as for fixed partial dentures.¹

All the above considerations aside, consumers should be aware that very serious health risks have been expressed for the potential health risks associated with the use of nickel-containing alloys. Contact dermatitis, hypersensitivity, and possible suppression of the immune response system have all been associated with the use of non-precious alloys. Physical protection and proper ventilation should be utilized to protect dental technicians from the hazard of nickel fumes.¹¹

* Rexillum III, Rexin Dental, Inc., St. Louis, Mo.

** Vita, Vita Zahnfabrik, Bad Soden, Germany.

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Figure 9-6. This early attempt to presolder a Ni-Cr-Be alloy looked successful. (Too much solder was applied to the connector area as a result of the photography.)

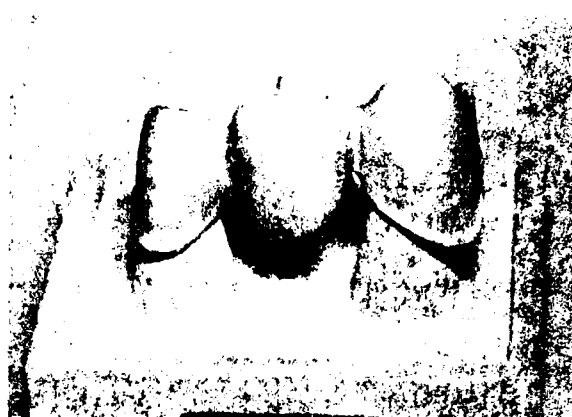


Figure 9-7. The soldered area was refined and air-abraded with non-recycled aluminum oxide to prepare the casting for oxidation.



Figure 9-8. After oxidizing, the solder appeared to release contaminants from the connector area and surrounding region. No separation between the pontic and the anterior retainer was observable.

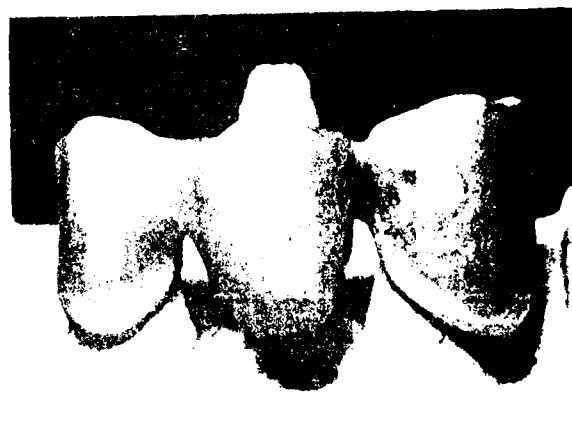


Figure 9-9. After the porcelain was applied and fired, the fixed partial denture became distorted and failed to seat on the master dies. When the porcelain veneer was removed, the joint failure was detected.

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9-2. ECONOMIC CONSIDERATIONS

Since none of their major constituents are either noble or precious metals, these alloys are very inexpensive. Small orders of less than five ounces may cost up to \$20.00/oz, while purchases of larger quantities can reduce that price to between \$8.00 and \$15.00/oz. However, the individual ingots vary in weight between 2 dwt 15 grs and 3 dwt 15 grs, and represent the minimum quantity which may be cast at any one time. For small single units, more metal may be expended than is necessary, and large buttons can accumulate. To maintain the recommended 50/50% ratio of new metal to recast metal, single unit castings become less economical. If recast metal is not enriched with new metal, an elevation in the casting temperature and hardness of the alloy may occur, since the minor alloying elements are not replenished.

Many manufacturers also now recommend the use of all new metal (ingots) when casting the substructure for a cast metal, resin-bonded retainer (Maryland Bridge). The justification is simply to prevent changes to the microstructure and ensure consistency in the properties of the alloy. An overheated alloy or an alloy with a depleted beryllium content will simply not etch well.

As a result of lapses in techniques for spruing, investing, and casting, miscasts may be more numerous with non-precious than with precious alloys.² Overheating the metal is common when first using these alloys, since time is needed for one to appreciate the particular melting behavior of each individual alloy. Induction casting not only reduces such variables and improves castability, but also represents a tremendous increase in the startup cost for this system. Miscasts, the accumulation of large buttons, and increased adjusting and finishing times are economic considerations frequently overlooked in cost estimates. The assessment of an alloy system solely on the basis of material costs is misleading, and is not indicative of the accumulated expense which a new system might entail.

9-3. ADVANTAGES:

Some alloys in this system are A.D.A. "ACCEPTABLE."

Low density permits up to 30% more castings per ounce than gold-base alloys.

Are low cost.

Are poor thermal conductors.

Produce lightweight castings.

High modulus of elasticity and yield strength provide rigidity for thin castings.

Thin castings permit maximum porcelain coverage

Sharp margins can be produced with proper technique.

Do not have to be secured like precious alloys.

Afford high sag resistance--an advantage when used for long-span fixed partial dentures.

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9-4. **DISADVANTAGES:**

Are not A.D.A. CERTIFIED.

Not all alloys are A.D.A. "ACCEPTABLE" or "PROVISIONALLY ACCEPTABLE."

Are much harder than gold- and palladium-base alloys.

Nickel is toxic, and may pose a health threat to patients.

Beryllium is toxic; inhalation or ingestion may pose a threat to dental laboratory technicians.

The surface of these alloys may be enriched with beryllium.

Should not be used for patients with known or suspected nickel sensitivity.

Require a high-heat investment (i.e., phosphate-bonded).

Ingots do not pool like precious alloys.

Are more difficult to melt and cast with consistent accuracy.

Are more amenable to induction casting than torch casting.

Are more prone to miscasts than precious alloys.

Propane-oxygen is preferred to natural gas-oxygen.

Require central air evacuation for nickel and beryllium dust.

Necessitate environmental monitoring for Ni and Be levels.

Large ingots tend to produce large buttons in smaller laboratories.

Possess a platinum or white color, rather than traditional yellow hue.

Excessive oxidation may lead to either immediate or delayed porcelain-metal bond failure.

Are not BURNISHABLE.

Are difficult to solder satisfactorily due to the thick oxidation.

Are more time consuming to finish and polish.

Are more difficult to adjust.

More difficult to section and remove these castings from the mouth.

Some alloys have NO ingot identification.

Are more prone to crevice corrosion than the nickel-chromium beryllium-free alloys.

9-5. **BIOCOMPATIBILITY**

The subject of the biocompatibility of dental casting alloys is addressed separately in Section 12. The reader is also referred to the statements and recommendations on nickel- and beryllium-containing alloys released by the USAF Special Consultants for Prosthodontics and Laboratory Services.

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EDITOR'S NOTE: The following Attachments provide comprehensive information on four examples of the nickel-chromium-beryllium group; specifically, BAK-ON NP, BIOBOND II, LITECAST B, and REXILLIUM III.

--SECTION 9: ATTACHMENT 1--

BAK-ON NP

I. GENERAL INFORMATION

ALLOY TYPE: "NON-PRECIOUS" ALLOY SYSTEM: Nickel-Chromium-Beryllium

ALLOY CONTENT: 77% Nickel, 13% Chromium, 5% Molybdenum, 1.8% Beryllium,
1.8% Titanium, and 1.4% Aluminum

MANUFACTURER: TOLL-FREE PHONE NUMBER: NONE

Johnson & Johnson
Dental Products Company
Ceramco, Inc.
20 Lake Drive, CN 7060
East Windsor, New Jersey 08520

COMMERCIAL PHONE NUMBER:
1-(201) 494-7311 Eastern
1-(404) 233-5455 Southern
1-(312) 654-0990 Midwestern
1-(805) 497-4424 Western

TELEPHONE CONTACTS: REGIONAL SALES REPRESENTATIVES:

Metals Research and Development
1-(609) 443-3300

Area Technical Directors

ALLOY INTRODUCED IN: Unspecified F.D.A. LISTED: Yes, 1981

A.D.A. ACCEPTANCE OR PROVISIONAL ACCEPTANCE: "PROVISIONALLY ACCEPTABLE" (1981)

II. PHYSICAL DESCRIPTION

Ingot color - Platinum Ingot shape - Cube
Ingot weight - 2 dwt 15 grs - 2 dwt 19 grs Ingots per ounce - 8 per oz
Ingot identification - "BAK-ON" Alloy packaging- 1 or 10 troy oz

III. PHYSICAL AND MECHANICAL PROPERTIES

Specific gravity (density) - 7.8 g/cc
Brinell hardness number - 240
Vickers hardness number - 260
Percentage elongation (in 1 in.) - 9%
Ultimate tensile strength - 155,000 psi
Yield strength (0.2% Offset) - 74,000 psi
Bond strength - 15,500 psi
Coefficient of thermal expansion - $13.5-14.8 \times 10^{-6}$ in/in °C (20-600 °C)

MELTING RANGE - 2250-2350 °F CASTING TEMPERATURE - 2500 °F
(1232-1288 °C) (1371 °C)

—SECTION 9: ATTACHMENT 1—

IV. WAXING AND SPRUING INSTRUCTIONS--BAK-ON NP

A. MINIMUM RECOMMENDED WAX THICKNESS:

1. SINGLE UNITS - 0.3 mm
2. THREE-UNITS FIXED PARTIAL DENTURES - 0.3 mm
3. FIXED PARTIAL DENTURES GREATER THAN 3 UNITS - 0.3 mm.

B. RECOMMENDED SPRUING TECHNIQUE:

1. SINGLE UNITS - Use DIRECT SPRUING. Attach a 6- or 8-GAUGE RESERVOIR sprue, 3/8-in.- 5/8-in. long, to your wax pattern; and lute it to the sprue former (Fig. 4-1).
2. MULTIPLE SINGLE UNITS - Use INDIRECT SPRUING. Attach an 8- or 10-GAUGE sprue, 1/4 in. long, to the wax patterns; join these to a 6- or 8-GAUGE connector, or runner bar; and use 6- or 8-GAUGE offset sprues to join the sprue former to the runner bar (Fig. 4-2).
3. FIXED PARTIAL DENTURES - Use INDIRECT SPRUING; same as above, but contour the runner bar to the configuration of the fixed partial denture; cut; and re wax the bar to eliminate wax memory (Fig. 4-2).

NOTE: The runner bar should be shaped to conform to the contour of the fixed partial denture. If the bar must be bent, then cut and re wax it at each cut in order to destroy any memory in the wax (Fig. 4-2).

4. VENTING - You may use an 18-GAUGE vent, attached to the labial surface of the wax pattern and at least 1 mm from the gingival edge.
5. WAX PATTERN POSITIONING - If the wax pattern is seated too low in the casting ring, build up the sprue former with wax and raise the pattern to within 1/4 in. of the top of the ring. This technique will facilitate wax elimination and the escape of gases (Fig. 4-3). Design the spruing system so that any reservoir is in the HEAT CENTER of the casting ring, with the wax patterns in a "COLD ZONE" (Fig. 4-3).

--SECTION 9: ATTACHMENT 1--

V. INVESTMENT AND BURNOUT TECHNIQUE--BAK-ON NP

A. RECOMMENDED INVESTMENTS:

1. PHOSPHATE-BONDED INVESTMENTS: A NON-CARBON-containing phosphate-bonded investment (white color) is preferred. Increase burnout time if a CARBON-containing investment (black color) is used.

<u>NON-CARBON TYPE:</u>	<u>SPECIAL LIQUID</u>	<u>DISTILLED WATER</u>
Hi-Temp (Whip-Mix) -	7.5 cc	2.0 cc
<u>CARBON TYPE:</u>		
1. Biovest (Dentsply) -	11.0 cc	0
2. Deguvest HFG (Degussa) -	9.5 cc	0
3. Complete (Jelenko) -	5.25 cc	5.25

2. GYPSUM-BONDED INVESTMENTS: Not recommended for this alloy.

B. RECOMMENDED METHOD OF INVESTMENT: Manufacturer prefers the HYGROSCOPIC technique, but we routinely use the HIGH-HEAT method.

C. MANUFACTURER'S RECOMMENDED ASBESTOS SUBSTITUTE: Ceramic type. WET.

We recommend one WET layer of NON-ASBESTOS ring liner (Whip-Mix). You may also use the Degussa Asbestos Free Liner or NOBESTOS (Jelenko). Place the liner flush with the top of the casting ring, but leave at least 1/8-in. clearance at the bottom of the ring. The 1/8-in. clearance will help lock the investment in the ring when the investment expands (Fig.4-2). If additional expansion is needed, use two layers of ring liner or more of the special liquid.

D. BURNOUT TECHNIQUE:

PHOSPHATE-BONDED INVESTMENT: Start with a COLD oven (or an oven no warmer than 200 °F(93 °C) and raise the temperature to 1450 °F (788°C) at the rate of 20 °F/min.

HEAT SOAK the ring(s) at 1450 °F (788°C), as follows:

- Single ring - 1 hr
- Three units in a single ring - 1 hr and 15 min
- Multiple units, 2-3 rings - 1 hr plus 10 min for each additional ring.

—SECTION 9: ATTACHMENT 1—

VI. MELTING AND CASTING INSTRUCTIONS—BAK-ON NP

A. CASTING EQUIPMENT:

1. CASTING MACHINE (DO NOT USE A THERMATROL 2500 WITH CARBON CRUCIBLE):
 - a. Manufacturer's preferred casting equipment - Induction system
 - b. Alternative systems include- Centrifuge
2. CASTING TORCH - HARRIS 16-S with #1390 H multi-orifice tip, or a single orifice tip (National OX-5) adjusted to maximum length.
3. CASTING CRUCIBLES - Quartz or alumina, DO NOT USE CLAY OR CARBON.

B. QUANTITY OF ALLOY NEEDED:

1. VOLUME OF METAL NEEDED - Refer to conversion chart (Table 1).*
2. PREFERRED RATIO OF NEW METAL TO RECAST METAL - 50/50% by weight
3. MINIMUM RATIO OF NEW METAL TO RECAST METAL - 30/70% by weight.

C. MELTING AND CASTING TECHNIQUE (PROPANE preferred, NATURAL GAS adequate):

1. OXYGEN-GAS RATIO - 15-20 psi (OXYGEN) or 5-10 psi (PROPANE)
2. SETTING CASTING MACHINE - Add one turn to casting machine to compensate for the alloy's lower density.
3. FLAME ADJUSTMENT - Adjust torch to produce 1/4-in. inner blue cones, and to create a distinct hissing sound. The actual cone length depends on the flow and the regulated pressure of both the oxygen and the gas (Fig. 4-12).
4. APPEARANCE OF THE MELT - Place the alloy in a preheated crucible, and heat the metal with the tip of the reducing flame. Move the torch in a circular motion to distribute the heat evenly.
5. CASTING FLUX - Not recommended; do not disturb the oxide layer.
6. WHEN TO CAST - The alloy will start to SLUMP, but ingots or buttons will not pool. When the ingots lose their dark appearance and RIPPLE under the oxide layer from the pressure of the flame, transfer the ring to the casting cradle and CAST IMMEDIATELY.
7. RECOVERY OF CASTING - BENCH COOL; DO NOT QUENCH; DO NOT PICKLE.

D. INDUCTION CASTING (Start with a preheated crucible):

1. Set ARM SPEED between 475 and 500 rpm.
2. Set AMPS to 1.1.
3. Set TEMPERATURE to 2550 °F/1399 °C.
4. HEAT SOAK for 20-30 sec.

* At close of text.

—SECTION 9: ATTACHMENT 1—

VII. ADJUSTING AND FINISHING—BAK-ON NP

A. REMOVING THE SPRUE:

1. SEPARATING DISC - Use any thin separating disc to cut off the sprue.
2. GRINDINGS - Use suction to remove grindings, and try to avoid mixing non-precious with precious grindings.

B. FITTING THE CASTING:

1. REMOVE INTERNAL NODULES - Carefully inspect the inside of each casting under magnification, and remove any irregularities.
2. EVALUATE THE FIT - Verify an acceptable level of occlusal/incisal seat and marginal seal, before proceeding to any additional finishing steps.
3. QUALITY CONTROL CHECK - Unsatisfactory castings (poor fit, overheated alloy, porosity) should be remade.
4. INITIAL OCCLUSAL ADJUSTMENT - Articulate the casting and refine the occlusion, as necessary.

C. FINISHING THE CASTING:

1. STONES AND WHEELS - Use Ceramco Diamond Sintered Instruments or other non-contaminated abrasives. All metal surfaces should be dressed with a hard rubber wheel (Dedeco, or equivalent) until all scratches are removed.
2. POLISHING - Use removable partial denture polishing compounds, such as Ti-Cor and Ti-Hi (Ticonium).

NOTE: Non-precious alloys are more difficult to adjust, polish, and finish than their precious alloy counterparts. Therefore, allow additional time for these steps. This alloy also contains NICKEL and BERYLLIUM, so special handling is recommended: use central evacuation (suction); limit grinding to as few areas as possible; and wear protective eyewear, mask, and laboratory coat.

3. AVOID METAL CONTAMINATION - Set aside a set of finishing stones for this particular alloy to prevent contamination of the metal.
4. ADJUSTMENT TECHNIQUE - Use the uncontaminated aluminum oxide abrasives to produce a smooth, even textured surface for all porcelain-bearing areas. Finish the metal surface in one direction, using light pressure.

—SECTION 9: ATTACHMENT 1—

VIII. PREPARATION OF THE METAL FOR PORCELAIN—BAK-ON NP

A. PREPARATION OF THE METAL SUBSTRATE:

1. NON-PORCELAIN BEARING SURFACES - Rubber wheel all non-porcelain bearing areas (lingual/occlusal surfaces, interproximal struts, and metal collars), to remove all scratches prior to the application of porcelain.
2. PORCELAIN-BEARING SURFACES - Air-abrade the finished metal surfaces with a 50- μ m non-recycled, uncontaminated aluminum oxide (white) abrasive under 75 psi.
3. CLEANING - Steam clean the metal substrate, or place in distilled water in an ultrasonic unit for 10 min, after rubber-wheeling and air-abrading.

B. OXIDATION (DEGASSING) OF THE METAL SUBSTRATE:

1. LOW temperature setting - Preheat oven to 1200 °F (649 °C)
2. HIGH temperature setting - 1800 °F (982 °C)
3. Rate of rise - 70-80 °F/min (21-27 °C/min)
4. Atmosphere - FULL VACUUM (26-28 in. of Hg)
5. HOLD time at HIGH temperature - 0
6. Appearance of the oxide layer:
 - a. A PROPERLY oxidized layer - STRAW color (gray-yellow to gray-brown)
 - b. An OVERoxidized layer - REDDISH BROWN color
(air-abrade; clean; and reoxidize at a lower temperature)
 - c. An UNDERoxidized layer - BLUISH color
(reoxidize at a higher temperature)

C. POST-OXIDATION TREATMENT:

- RETAIN THE OXIDE LAYER - You may apply opaque porcelain directly over the oxide layer.

—SECTION 9: ATTACHMENT 1—

IX. PORCELAIN COMPATIBILITY PROFILE—BAK-ON NP

A. PORCELAIN SYSTEM COMPATIBILITY CHART: The following information has been provided by the alloy manufacturer (X):

<u>DENTAL PORCELAIN</u>	<u>PORCELAIN COMPATIBILITY</u>			
	YES	NO	MARGINAL	UNKNOWN
1. ARTIS-TECH (Jeneric)	X			
2. BIOBOND (Dentsply)			X	
3. CERAMCO (Johnson & Johnson)	X			
4. CRYSTAR (Unitek)		X		
5. JELENKO (Jelenko)		X		
6. (BIOBOND) SHADEMATE (Dentsply) Low-Reg-				X
7. VITA (Vident)		X		
8. WILL-CERAM (Williams)	X			

B. KNOWN OR SUSPECTED PORCELAIN-METAL INCOMPATIBILITIES:

The coefficient of thermal expansion of Bak-On NP does not match that of Crystar, Jelenko, or Vita porcelain; and porcelain fracture may occur with multiple unit castings.

C. SPECIAL HANDLING INSTRUCTIONS: None

--SECTION 9: ATTACHMENT 1--

X. PRE-SOLDERING INSTRUCTIONS--BAK-ON NP

A. RECOMMENDED MATERIALS:

1. **SOLDERS** - Use BAK-ON High Fusing Solder (flows at 1840 °F/1004 °C)
2. **FLUX** - BAK-ON High Temp Flux (contains fluoride)
3. **INVESTMENT** - Manufacturer recommends a **SOLDERING** investment.
(Do NOT use casting investments, since they have excessive permanent expansion which could result in improper fit.)

B. SOLDERING TECHNIQUE: For precise heating, use the Magic Wand torch (Williams) with its #248 soldering tip, the HARRIS 16-S torch and the 2N tip, or a NATIONAL OX-1 or OX-2 tip.

1. Lightly grind all surfaces to be soldered to remove surface oxides.
2. Create a GAP DISTANCE of 0.3 to 0.4 mm.
3. Join units to be pre-soldered, with quick cure acrylic resin (Duralay) or sticky wax and invest in a soldering investment.
4. Remove wax; thoroughly clean the areas to be soldered.
5. Preheat the invested casting to 600 °F (316 °C).
6. Place soldering flux (mixed with distilled water) on the areas to be soldered and on the soldering rod.
7. Use a gas and oxygen soldering torch and 3-5 psi OXYGEN.
8. Using the REDUCING flame, heat the area to be soldered. Introduce the fluxed solder rod, and solder should flow into joint.
9. Remove flame AS SOON AS the solder flows (thus minimizing excess solder).
10. BENCH COOL; divest, and finish with non-contaminating abrasives.

—SECTION 9: ATTACHMENT 1—

XI. POST-SOLDERING INSTRUCTIONS—BAK-ON NP

A. RECOMMENDED MATERIALS:

1. SOLDERS - MASTERCAST White Low Fusing Solder (flows at 1325 °F/718 °C);
MASTERCAS T 650 Solder (liquidus is 1470 °F/799 °C); or
MASTERCAS T 615 Solder (liquidus is 1500 °F/816 °C)
2. FLUX - BAK-ON Low Fusing Solder
3. INVESTMENT - Manufacturer recommends a SOLDERING investment.
(Do NOT use casting investments, since they have excessive permanent expansion which could result in improper fit.)

B. SOLDERING TECHINQUE: Use a porcelain furnace with a muffle view port to monitor the soldering process.

1. Lightly grind all surfaces to be soldered to remove any oxides, polishing agents, or other contaminants.
2. Create a GAP DISTANCE of 0.3 to 0.5 mm.
3. Join the units with quick cure acrylic resin (Duralay) or sticky wax. (It is helpful to provide the dental laboratory with a soldering index, in case it becomes necessary to separate the units.)
4. Invest in a SOLDERING investment. Do NOT use a high-heat casting investment. Be sure to protect the porcelain by covering it with a thin layer of wax.
5. Allow the investment to set for at least 30 min.
6. Boil out the sticky wax; and remove any acrylic resin with a Robinson brush and isopropanol.
7. Dry excess water, and lightly apply flux to the joint areas.
8. Preheat the investment in the muffle entrance; and introduce the units into a furnace set at 1000 °F (538 °C) over a 5-min period.
9. Raise the temperature of the porcelain furnace to 1550 °F (843 °C) at the rate up to 100 °F (55 °C) per minute for MASTERCAS T White Solder and to 1650 °F (899 °C) for MASTERCAS T 650 or 615.
10. Once the solder has flowed, position the units in the muffle entrance.
11. Begin a 5-min cool down to allow the invested units to cool slowly. (To avoid porcelain cracking--do not rush the case at this stage.)
12. Once at room temperature, remove the investment, finish, and polish the metal.

—SECTION 9: ATTACHMENT 2—

BIOBOND II

I. GENERAL INFORMATION

ALLOY TYPE: "NON-PRECIOUS" ALLOY SYSTEM: Nickel-Chromium-Beryllium

ALLOY CONTENT: 80.7% Nickel, 13.5% Chromium, 4% Vanadium, and 1.8% Beryllium

MANUFACTURER:

Dentsply International, Inc.
570 West College Avenue
P.O. BOX 872
York, Pennsylvania 17405

TOLL-FREE PHONE NUMBER:
1-(800) 233-9454, ext.511

COMMERCIAL PHONE NUMBER:
1-(717) 845-7511, ext. 511

TELEPHONE CONTACTS:

Mr. John Appelbaum

REGIONAL SALES REPRESENTATIVES:

Yes

ALLOY INTRODUCED IN: September 1982

F.D.A. LISTED: Yes

A.D.A. ACCEPTANCE OR PROVISIONAL ACCEPTANCE: "PROVISIONALLY ACCEPTABLE"
February 1984

II. PHYSICAL DESCRIPTION

Ingot color - Platinum	Ingot shape - Raised rectangle
Ingot weight - 3 dwt 1 gr to 3 dwt 9 gr	Ingot per package - Thirteen per 2-oz package
Ingot Identification - Roman numeral II appears on second tier	Alloy packaging - 2-troy-oz packages

III. PHYSICAL AND MECHANICAL PROPERTIES

Specific gravity (density) - 7.81 g/cc
Brinell hardness number - 294
Vickers hardness number - 310
Percentage elongation (in 1 in.) - 9%
Ultimate tensile strength - 130,000 psi
Yield strength (0.2% offset) - 85,000 psi
Bond strength - No value available
Coefficient of thermal expansion - Proprietary information

MELTING RANGE - 2140-2250 °F
(1170-1230 °C)

CASTING TEMPERATURE - 2650 °F (1452 °C)
(Induction casting only)

—SECTION 9: ATTACHMENT 2—

IV. WAXING AND SPRUING INSTRUCTIONS—BIOBOND II

A. MINIMUM RECOMMENDED WAX THICKNESS:

1. SINGLE UNITS - 0.3 mm
2. THREE-UNITS FIXED PARTIAL DENTURES - 0.3 to 0.5 mm
3. FIXED PARTIAL DENTURES GREATER THAN 3 UNITS - 0.3 to 0.5 mm.

B. RECOMMENDED SPRUING TECHNIQUE:

1. SINGLE UNITS - DIRECT SPRUING: Use an 8- or 10-GAUGE reservoir sprue, attached to the thickest part of the wax pattern. If you elect to fashion your own reservoir, make sure it is equal in diameter to the thickest part of the wax pattern, and is positioned 1.5 mm from the pattern. Allow about 1/4-in. (6-mm) space between the top of the wax pattern and the top of the casting ring (Fig. 4-1).
2. MULTIPLE SINGLE UNITS - INDIRECT SPRUING is recommended for multiple units with 10-GAUGE 1/4-in. length sprues to each unit connected to an 8-GAUGE runner bar, which is attached to the sprue former by offset 8-GAUGE sprue leads. Extend the length of the runner bar slightly beyond the width of the units at each end. Leave 1/4-in. space between the top of the wax pattern and the top of the casting ring (Fig. 4-2).
3. FIXED PARTIAL DENTURES - INDIRECT SPRUING is also recommended for fixed partial dentures with 10-GAUGE 1/4-in. length sprues attached to each unit connected to an 8-GAUGE runner bar, which is joined to the sprue former by offset 8-GAUGE sprue leads. Extend the length of the runner bar slightly beyond the width of the units at each end (Fig. 4-2).

NOTE: The runner bar should be shaped to conform to the contour of the fixed partial denture. If the bar must be bent, then cut and re wax it at each cut in order to destroy any memory in the wax (Fig. 4-2).

4. VENTING - Is not required.
5. WAX PATTERN POSITIONING - If the wax pattern is seated too low in the casting ring, build up the sprue former with wax and raise the pattern to within 1/4 in. of the top of the ring. This technique will facilitate wax elimination and the escape of gases.

--SECTION 9: ATTACHMENT 2--

V. INVESTMENT AND BURNOUT TECHNIQUE--BIOBOND II

A. RECOMMENDED INVESTMENTS:

1. PHOSPHATE-BONDED INVESTMENTS: The manufacturer does not market a NON-CARBON containing casting investment, and does NOT require the use of such investments with this nickel-base alloy.

<u>NON-CARBON TYPE:</u>	<u>SPECIAL LIQUID</u>	<u>DISTILLED WATER</u>
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Not tested with this alloy.

CARBON TYPE:

Biovest (Dentsply) -	11.0 cc	0
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2. GYPSUM-BONDED INVESTMENTS: Not recommended for this alloy.

B. RECOMMENDED METHOD OF INVESTMENT: HIGH-HEAT rather than Hygroscopic

C. MANUFACTURER'S RECOMMENDED ASBESTOS SUBSTITUTE: KAOLINER (Dentsply), DRY

We recommend one WET layer of NON-ASBESTOS ring liner (Whip-Mix) or other asbestos substitute. Place liner flush with the top of the casting ring, but leave at least a 1/8-in. clearance at the bottom of the ring. The 1/8-in. clearance will help lock the investment in the ring when the investment expands (Fig. 4-2). If additional expansion is needed, use two layers of an asbestos substitute, or more of the undiluted special liquid.

D. BURNOUT TECHNIQUE:

PHOSPHATE-BONDED INVESTMENT: Start with a ROOM TEMPERATURE oven, raise the temperature to 1550 °F/843 °C at the rate of 25 °F per min, and HEAT SOAK as follows:

- a. Single ring - 1 hr
- b. Three units in a single ring - 1 hr
- c. Multiple units, 2-3 rings - 1 hr plus 10 min for each additional ring.

—SECTION 9: ATTACHMENT 2—

VI. MELTING AND CASTING INSTRUCTIONS—BIOBOND II

A. CASTING EQUIPMENT:

1. CASTING MACHINE (DO NOT USE A THERMATROL 2500 WITH A CARBON CRUCIBLE):
 - a. Manufacturer's preferred casting equipment - Centrifuge
 - b. Alternative systems include - Induction system
2. CASTING TORCH - Harris 16-S Torch with #1390 H multi-orifice tip
3. CASTING CRUCIBLES - Quartz, alumina, or clay. DO NOT USE GRAPHITE.

B. QUANTITY OF ALLOY NEEDED:

1. VOLUME OF METAL NEEDED - Refer to conversion chart (Table 1).*
2. PREFERRED RATIO OF NEW METAL TO RECAST METAL - 50/50% by weight
3. MINIMUM RATIO OF NEW METAL TO RECAST METAL - 50/50% by weight.

C. MELTING AND CASTING TECHNIQUE:

1. OXYGEN-GAS RATIO - 15 psi OXYGEN with natural gas or 5 psi PROPANE.
2. SETTING CASTING MACHINE - 3-1/2 or 4 turns are ample.
3. FLAME ADJUSTMENT - Adjust the multiple light blue inner cones to 1/4-in. lengths. The REDUCING ZONE should be an additional 2-1/2-in., with the OXIDIZING ZONE beyond that for a maximal flame length of approximately 8 in. A distinct hissing sound should be noted when the flame has been adjusted correctly.
4. APPEARANCE OF THE MELT - Position the inner blue cone tips 1-1/2 to 2 in. from the alloy to be melted, and rotate the torch in circular motion to distribute the heat evenly. As the alloy begins to SLUMP, an oxide layer will develop and the individual ingots will NOT flow together.
5. CASTING FLUX - Not recommended.
6. WHEN TO CAST - When the molten alloy under the oxide surface ROLLS and MOVES with the motion of the torch and SMALL SEPARATIONS of the oxide occur, you are READY TO CAST.
7. RECOVERY OF CASTING - ALLOW TO BENCH COOL; DO NOT QUENCH; DO NOT PICKLE.

D. INDUCTION CASTING (Start with a preheated crucible):

1. Set ARM SPEED between 425 and 450 rpm.
2. Set POWER CONTROL (amperage) to HIGH.
3. Set TEMPERATURE to 2650 °F/1454 °C with a maximum of 5-sec HEAT SOAK.
4. When alloy is PULSATING, you may CAST.

* At close of text.

--SECTION 9: ATTACHMENT 2--

VII. ADJUSTING AND FINISHING--BIOBOND II

A. REMOVING THE SPRUE:

1. SEPARATING DISC - Use a Faskut #8 metal cut-off disc (Dentsply) or other similar separating disc to cut off the sprue.
2. GRINDINGS - Use suction to remove grindings, and try to avoid mixing non-precious with precious grindings.

B. FITTING THE CASTING:

1. REMOVE INTERNAL NODULES - Carefully inspect the inside of each casting under magnification, and remove any irregularities.
2. EVALUATE THE FIT - Verify an acceptable level of occlusal/incisal seat and marginal seal, before proceeding to any additional finishing steps.
3. QUALITY CONTROL CHECK - Unsatisfactory castings (poor fit, overheated alloy, porosity) should be remade.
4. INITIAL OCCLUSAL ADJUSTMENT - Articulate the casting and refine the occlusion, as necessary.

C. FINISHING THE CASTING:

1. STONES AND WHEELS - For bulk metal removal, use Faskut #10 wheel (Dentsply), Faskut Bornide Mounted Points, or other similar materials.
2. POLISHING - Use removable partial denture polishing compounds, such as Ti-Cor and Ti-Hi (ticonium).

NOTE: Non-precious alloys are more difficult to adjust, polish, and finish than their precious alloy counterparts. Therefore, allow more time for these steps. This alloy also contains NICKEL and BERYLLIUM, so special handling is recommended: use central evacuation (suction); limit grinding to as few areas as possible; and wear protective eyewear, mask, and a laboratory coat.

3. AVOID METAL CONTAMINATION - Put aside a set of finishing stones for this particular alloy, to prevent contamination of the metal.
4. ADJUSTMENT TECHNIQUE - Use the uncontaminated aluminum oxide abrasives to produce a smooth, even textured surface for all porcelain-bearing areas. Finish the metal surface in one direction, using light pressure.

--SECTION 9: ATTACHMENT 2--

VIII. PREPARATION OF THE METAL FOR PORCELAIN--BIOBOND II

A. PREPARATION OF THE METAL SUBSTRATE:

1. NON-PORCELAIN BEARING SURFACES - Rubber wheel all non-porcelain bearing areas (lingual/occlusal surfaces, interproximal struts, and metal collars) to remove all scratches prior to the application of porcelain.
2. PORCELAIN-BEARING SURFACES - Air-abrade the finished metal surfaces with a 50- μ m non-recycled, uncontaminated aluminum oxide (white) abrasive under a minimum of 75 psi.
3. CLEANING - Steam clean the metal substrate, or place in distilled water in an ultrasonic unit for 10 min, after rubber wheeling and air-abrading.

B. OXIDATION (DEGASSING) OF THE METAL SUBSTRATE:

1. LOW temperature setting - Preheat oven to 1740 °F (950 °C)
2. HIGH temperature setting - 1740 °F (950 °C)
3. Rate of rise - 0
4. Atmosphere - FULL VACUUM (26-28 in. of Hg)
5. HOLD time at HIGH temperature - 10 min (release vacuum slowly and remove casting)
6. Appearance of the oxide layer:
 - a. A PROPERLY oxidized layer - LIGHT BLUE color (new metal) (Slightly darker if 50% remelt is used)
 - b. An OVERoxidized layer, and
 - c. An UNDERoxidized layer - Both would have a BLUE hue. The only possible change would be in the chroma, or depth of the blue.

NOTE: The overoxidized unit would have a deep blue oxide, and the underoxidized oxide would have a lighter blue oxide layer.

C. POST-OXIDATION TREATMENT:

RETAIN THE OXIDE LAYER - You may apply opaque porcelain directly over the oxide layer. (If the casting has been pre-soldered, then AIR-ABRADE the metal to remove the oxide, prior to the application of opaque.)

—SECTION 9: ATTACHMENT 2—

IX. PORCELAIN COMPATIBILITY PROFILE--BIOBOND II

A. PORCELAIN SYSTEM COMPATIBILITY CHART: The following information has been provided by the alloy manufacturer (X):

<u>DENTAL PORCELAIN</u>	<u>PORCELAIN COMPATIBILITY</u>			
	YES	NO	MARGINAL	UNKNOWN
1. ARTIS-TECH (Jeneric)	X			
2. BIOBOND (Dentsply)	X			
3. CERAMCO (Johnson & Johnson)	X			
4. CRYSTAR (Unitek)	X			
5. JELENKO (Jelenko)	X			
6. (BIOBOND) SHADEMATE (Dentsply) Low- Reg-	X	X		
7. VITA (Vident)	X			
8. WILL-CERAM (Williams)	X			

B. KNOWN OR SUSPECTED PORCELAIN-METAL INCOMPATIBILITIES:

Do not use Shademate Low build-up porcelain.

C. SPECIAL HANDLING INSTRUCTIONS: None

—SECTION 9: ATTACHMENT 2—

X. PRE-SOLDERING INSTRUCTIONS—BIOBOND II

A. RECOMMENDED MATERIALS:

1. SOLDER - BIOBOND NC High-Fusing Non-Precious Presolder
(flows 2100 °F/1149 °C)
2. FLUX - BIOBOND NC Flux
3. INVESTMENT - BIOVEST Soldering Investment (Dentsply), mixed with
12 cc water per 100 grs powder.

B. SOLDERING TECHNIQUE: For precise heating, use the MAGIC WAND torch
(Williams) with its #248 soldering tips, or the HARRIS 16-S torch
with a 2N tip.

1. Grind, with fine aluminum oxide stones, all surfaces to be soldered.
This process will remove debris and oxide contaminants.
2. Create a GAP DISTANCE of approximately 0.25 mm.
3. Invest in BIOVEST soldering investment; allow to set for 30 min;
then fashion access to the solder joint before final set.
4. Boil out wax and pieces of investment to clean the joint area. (If
Duralay is used to join the units, heat to 900 °F/482 °C and clean.)
5. Apply BIOBOND C&B Fluoride Soldering Flux, and let dry for 15 min.
6. Transfer patty to a room temperature burnout furnace; increase the
temperature to 800 °F (427 °C); and IMMEDIATELY PROCEED WITH SOLDERING
when you reach 800 °F. DO NOT HEAT SOAK.
7. USE 5 psi (OXYGEN) with NATURAL gas or 5 psi PROPANE.
8. Establish fine blue inner cone flame(s), extending 3/4 in. in length.
Apply even heat to joint, until alloy becomes a DULL RED color.
9. Keep torch on the joint, and position a fluxed solder rod on the joint.
IMPORTANT: Place the inner blue tip of the flame (hottest part) to the
joint and fluxed solder rod. PUSH the ball of molten solder directly
into the joint gap. Remove the solder rod by breaking it away.
10. Move inner blue cone tip back 1 in. (REDUCING ZONE), and maintain heat
until solder has flowed completely. Use only the REDUCING ZONE to
prevent GAS CONTAMINATION.
11. Remove torch; BENCH COOL; adjust and clean in an ultrasonic unit, for
5-10 min, to remove all traces of flux and investment.
12. Total elapsed time for soldering should be approximately 30 sec.

—SECTION 9: ATTACHMENT 2—

XI. POST-SOLDERING INSTRUCTIONS—BIOBOND II

A. RECOMMENDED MATERIALS:

1. SOLDER - Use 615 Solder (flows at 1350 °F/732 °C)
2. FLUX - BIOBOND C&B Fluoride Flux
3. INVESTMENT - Use BIOVEST Soldering Investment rather than a high-heat phosphate-bonded casting investment.

B. SOLDERING TECHNIQUE: We recommend a porcelain furnace with a view port to monitor the soldering process. The manufacturer considers the use of a view port to be optional.

1. Remove any edges, debris, or porcelain covering the metal surfaces to be soldered.
2. Create a GAP DISTANCE of 0.25 mm.
3. Cover all porcelain with sticky wax to prevent possible investment contamination or discoloration of the glazed porcelain.
4. Invest the units in BIOVEST Soldering Investment.
5. Boil out wax and pieces of investment to clean the joint area. (If Duralay is used to join the units, heat to 900 °F/482 °C and clean.)
6. Flux the areas to be soldered.
7. Cut several 1/8-in. to 1/4-in. pieces of 615 solder, and place them in the joints to be soldered.
8. Place the invested units in the front of an opened porcelain furnace muffle, and preset to a temperature of 600 °F (316°C) (manual oven with horizontal muffle). The preset temperature may be as high as 900 °F (842°C) for automatic ovens, or variations in the horizontal muffle.
9. Hold at the muffle entrance for 15 min. HEAT THE WORK SLOWLY AND CAREFULLY TO PREVENT PORCELAIN CHECKING AND CRACKING.
10. Gradually introduce the investment block into the muffle, and increase the temperature to 1550 °F (843 °C).
11. You may proceed with or without vacuum.
12. Once 1550 °F (843 °C) has been reached, HOLD for 1 min.
13. Inspect the soldered units, and BENCH COOL before deinvesting.
14. Finish the soldered joints with stones, rubber wheels; and polish to a high shine.

--SECTION 9: ATTACHMENT 3--

LITECAST B

I. GENERAL INFORMATION

ALLOY TYPE: "NON-PRECIOUS" ALLOY SYSTEM: Nickel-Chromium-Beryllium

ALLOY CONTENT: 77.5% Nickel, 12.5% Chromium, 4% Molybdenum, and 1.7% Beryllium
with 4.3% Aluminum, Iron and Silicon

<u>MANUFACTURER:</u>	<u>TOLL-FREE PHONE NUMBER:</u>
Williams Gold Refining Co.	1-(800) 828-1003
2978 Main Street	1-(800) 462-7688 (in New York State)
Buffalo, New York 14214	1-(800) 852-7066 (in California)
	1-(800) 824-7925 (west of the Rocky Mountains)

COMMERCIAL PHONE NUMBER:
1-(716) 837-1000

<u>TELEPHONE CONTACTS:</u>	<u>REGIONAL SALES REPRESENTATIVES:</u>
Education Department	Yes
1-(800) 828-1538	

ALLOY INTRODUCED IN: February 1980 F.D.A. LISTED: Yes

A.D.A. ACCEPTANCE OR PROVISIONAL ACCEPTANCE: "ACCEPTABLE" (1983)

II. PHYSICAL DESCRIPTION

Ingot color - Platinum	Ingot shape - Cylinder
Ingot weight - VARIES, 2 dwt 14 gr to 3 dwt	Ingots per ounce - 8 per oz
Ingot Identification - " W	Alloy Packaging- 1-, 2- or 5-troy-oz packages
L C	
B "	

III. PHYSICAL AND MECHANICAL PROPERTIES

Specific gravity (density) - 7.4 g/cc
Brinell hardness number - Not determined
Vickers hardness number - 335 (after porcelain application)
Percentage elongation (in 1 in.) - 12%
Ultimate tensile strength - 172,000 psi (after porcelain application)
Yield strength (0.1% offset) - 112,000 psi (after porcelain application)
Bond strength - No value available
Coefficient of thermal expansion - No value available.

MELTING RANGE - 2120-2330 °F CASTING TEMPERATURE - 2450 °F
(1161-1277 °C) (1343 °C)

—SECTION 9: ATTACHMENT 3—

IV. WAXING AND SPRUING INSTRUCTIONS--LITECAST B

A. MINIMUM RECOMMENDED WAX THICKNESS:

1. SINGLE UNITS - 0.3 mm
2. THREE-UNITS FIXED PARTIAL DENTURES - 0.5 mm
3. FIXED PARTIAL DENTURES GREATER THAN 3 UNITS - 0.5 mm.

B. RECOMMENDED SPRUING TECHNIQUE:

1. SINGLE UNITS - Use an INDIRECT technique, with 8-GAUGE connector sprues, 2-3 mm in length, to each pattern; and attach them to a 6-GAUGE runner bar (distribution channel). Attach the runner bar to the sprue former with two offset 6-GAUGE lead sprues (Fig. 4-2).
2. MULTIPLE SINGLE UNITS - Use INDIRECT spruing technique, with 8-GAUGE connector sprues, 2-3 mm in length, to each pattern; and attach them to a runner bar (distribution channel). Attach the runner bar to the sprue former with two offset 6-GAUGE lead sprues.
3. FIXED PARTIAL DENTURES - Use INDIRECT spruing technique, with 8-GAUGE connector sprues, 2-3 mm in length, to each wax pattern. Attach them to a runner bar (distribution channel) which extends slightly beyond the ends of the patterns.

NOTE: Adjust the connector or runner bar to conform to the contour of the fixed partial denture; cut the bar; and re wax it to eliminate wax memory. Design any INDIRECT spruing system so the runner bar is in the heat center of the casting ring (Fig. 4-2).

4. VENTING - You may include a blind vent, attached to the thickest portion of each wax pattern, to help cool the restoration first. However, this step is not required.
5. WAX PATTERN POSITIONING - If the wax pattern is seated too low in the casting ring, build up the sprue former with wax and raise the pattern to within 1/4 in. of the top of the ring. This technique facilitates casting solidification and the escape of gases. Design the spruing system so that any reservoir is in the HEAT CENTER of the casting ring, with the wax patterns in a "COLD ZONE" (Fig. 4-2).

—SECTION 9: ATTACHMENT 3—

V. INVESTMENT AND BURNOUT TECHNIQUE—LITECAST B

A. RECOMMENDED INVESTMENTS:

1. PHOSPHATE-BONDED INVESTMENTS: A NON-CARBON-containing investment (white color) is preferred. Increase burnout time if a CARBON-containing investment (black color) is used.

<u>NON-CARBON TYPE:</u>	<u>SPECIAL LIQUID</u>	<u>DISTILLED WATER</u>
a. Vestra-fine (Unitek) -	7.75 cc	7.75 cc
b. Hi-Temp (Whip-Mix) -	4.5 cc	4.5 cc

CARBON TYPE:

Not used with this alloy.

2. GYPSUM-BONDED INVESTMENTS: Not recommended for this alloy.

B. RECOMMENDED METHOD OF INVESTMENT: HIGH-HEAT

C. MANUFACTURER'S RECOMMENDED ASBESTOS SUBSTITUTE: Unspecified.

We prefer to use one WET layer of NON-ASBESTOS ring liner (Whip-Mix), rather than ASBESTOS FREE LINER (Degussa), NOBESTOS (Jelenko), or KAOLINER (Dentsply). Place the liner flush with the top of the casting ring, with at least 1/8-in. clearance at the bottom of the ring. The 1/8-in. clearance will lock the investment in the ring when the investment expands.

D. BURNOUT TECHNIQUE:

PHOSPHATE-BONDED INVESTMENT: Use a TWO-STAGE BURNOUT TECHNIQUE; start with a COLD oven; raise temperature to 500 °F (260 °C) at the rate of 25 °F/min.; HEAT SOAK at Stage One; raise the temperature to 1500 °F (815 °C) at the rate of 25 °F/min; and HEAT SOAK again, as indicated:

	<u>Time at 500 °F(260 °C)</u>	<u>Time at 1500 °F(815 °C)</u>
a. Single units -	30 min	45 min
b. Three units in a single ring -	30 min	45 min
c. Multiple units, 2-3 rings -	30 min	45 min

VI. MELTING AND CASTING INSTRUCTIONS—LITECAST B

A. CASTING EQUIPMENT:

1. CASTING MACHINE (DO NOT USE THERMATROL 2500 WITH CARBON CRUCIBLE):
 - a. Manufacturer's recommendation - Williams Inductocast Machine
 - b. Alternative systems include - Centrifuge
2. CASTING TORCH - Harris 16-S with a #1390 H multi-orifice tip.
(Williams recommends their MAGIC WAND Torch.)
3. CASTING CRUCIBLES - Quartz or alumina.

B. QUANTITY OF ALLOY NEEDED:

1. VOLUME OF METAL NEEDED - Refer to conversion chart (Table 1).*
2. PREFERRED RATIO OF NEW METAL TO RECAST METAL - 50/50% by weight.
3. MINIMUM RATIO OF NEW METAL TO RECAST METAL - 50/50% by weight.

C. MELTING AND CASTING TECHNIQUE:

1. OXYGEN-GAS RATIO - Use 10 psi OXYGEN and 5 psi NATURAL GAS.
2. SETTING CASTING MACHINE - Add 1 extra turn for the alloy's lower density.
3. FLAME ADJUSTMENT - The multiple light blue inner cones should be set to 1/2- to 3/4-in. lengths with a maximum flame length of 10-1/2 to 10-3/4 in.(Fig. 4-12).
4. APPEARANCE OF THE MELT - Place ingots in the crucible on their rounded edge, and direct the flame to the larger flat surface. Put recast alloy (buttons) on the BOTTOM, and ingots on TOP; but ensure TIGHT CONTACT. Hold the torch tip 2 in. above the metal, with the flame perpendicular to the alloy. Guide the flame in a slight circular motion, with alloy in the REDUCING ZONE of the flame.
5. CASTING FLUX - Do NOT use casting flux or attempt to remove oxides.
6. WHEN TO CAST - When the ingots are RED HOT, reduce the rotation, but maintain in the REDUCING ZONE. The tops of the ingots will turn WHITE HOT; the WHITE HEAT will spread throughout the ingots; the tops will begin to SLUMP; and the WHITE HEAT will spread to the bottom of the ingots. When the ingots COLLAPSE, they are ready to cast. THE FORMATION OF AN OXIDE LAYER IS NORMAL.
7. RECOVERY OF CASTING - BENCH COOL; DO NOT QUENCH; DO NOT PICKLE.

D. INDUCTION CASTING:

1. Set speed between 400 and 500 RPM.
2. Set temperature to 2450 °F (1345 °C).
3. CAST at temperature.

* At close of text.

--SECTION 9: ATTACHMENT 3--

VII. ADJUSTING AND FINISHING--LITECAST B

A. REMOVING THE SPRUE:

1. SEPARATING DISC - Use any thin separating disc of your choice.
2. GRINDINGS - Use central air evacuation to remove grindings, and avoid mixing non-precious with precious materials.

B. FITTING THE CASTING:

1. QUALITY CONTROL CHECK - Unsatisfactory castings (poor fit, overheated alloy, porosity) should be remade. A THICK CASTING OXIDE is the best evidence of overheating, prolonged heating, or improper spruing. When the investment is difficult to remove from the casting and literally adheres to the surface, the alloy was overheated.
2. REMOVE INTERNAL NODULES - Carefully inspect the inside of each casting under magnification, and remove any irregularities.
3. EVALUATE THE FIT - Verify an acceptable level of occlusal/incisal seat and marginal seal, before proceeding to any additional finishing steps.
4. INITIAL OCCLUSAL ADJUSTMENT - Articulate the casting and refine the occlusion, as necessary.

C. FINISHING THE CASTING:

1. STONES AND WHEELS - Use stones, carbide burs, and burlew wheels.
2. POLISHING - Use removable partial denture polishing compounds, such as Ti-Cor and Ti-Hi (Ticonium), rather than Buffing Bar Compound (BBC).

NOTE: Non-precious alloys are more difficult to adjust, polish, and finish than their precious alloy counterparts. Therefore, allow additional time for these steps. Litecast B also contains NICKEL and BERYLLIUM, so special handling is recommended: use central evacuation (suction); limit grinding to as few areas as possible; and wear protective eyewear, a mask, and a laboratory coat.

3. AVOID METAL CONTAMINATION - Set aside a set of finishing stones for this particular alloy, to prevent metal contamination.
4. ADJUSTMENT TECHNIQUE - Use the uncontaminated aluminum oxide abrasives to produce a smooth, even textured surface for all porcelain-bearing areas. Finish the metal surface in one direction.

--SECTION 9: ATTACHMENT 3--

VIII. PREPARATION OF THE METAL FOR PORCELAIN--LITECAST B

A. PREPARATION OF THE METAL SUBSTRATE:

1. NON-PORCELAIN BEARING SURFACES - Rubber wheel all non-porcelain bearing areas (lingual/occlusal surfaces, interproximal struts, and metal collars) to remove all scratches prior to the application of porcelain.
2. PORCELAIN BEARING SURFACES - Air-abrade the finished metal surfaces with a 50- μ m non-recycled, uncontaminated aluminum oxide (white) abrasive under 90-100 psi.
3. CLEANING - Steam clean the metal substrate; or place in distilled water in an ultrasonic unit for 10 min, after rubber wheeling and air-abrading.

B. OXIDATION (DEGASSING) OF THE METAL SUBSTRATE:

1. LOW temperature setting - 1200 °F (649 °C)
2. HIGH temperature setting - 1850 °F (1010 °C)
3. Rate of rise - 100 °F (55 °C)
4. Atmosphere - FULL VACUUM (26-28 in. of Hg)
5. HOLD time at HIGH temperature - 5 min, under VACUUM
6. Appearance of the oxide layer:
 - a. A PROPERLY oxidized layer - MULTI-HUED TO LIGHT GRAY color
(surface finish will influence the appearance of the oxide)
 - b. An OVERoxidized layer - DARK GRAY or GREEN color
(air-abrade; clean; and reoxidize at a lower temperature)
 - c. An UNDERoxidized layer - NO READILY DISCERNIBLE color
(reoxidize at a higher temperature)

C. POST-OXIDATION TREATMENT:

1. **RETAIN THE OXIDE LAYER** - You may apply opaque porcelain directly over the oxide layer.
2. DO NOT AIR-ABRADE.

--SECTION 9: ATTACHMENT 3--

IX. PORCELAIN COMPATIBILITY--LITECAST B

A. PORCELAIN SYSTEM COMPATIBILITY CHART. The following information has been provided by the alloy manufacturer (X):

<u>DENTAL PORCELAIN</u>	<u>PORCELAIN COMPATIBILITY</u>			
	<u>YES</u>	<u>NO</u>	<u>MARGINAL</u>	<u>UNKNOWN</u>
1. ARTIS-TECH (Jeneric) -	X			
2. BIOBOND (Dentsply) -	X			
3. CERAMCO (Johnson & Johnson) -	X			
4. CRYSTAR (Unitek) -	X			
5. JELENKO (Jelenko) -	X			
6. (BIOBOND) SHADEMATE (Dentsply) Reg- Low-	X	X		
7. VITA (Vident) -	X			
8. WILL-CERAM (Williams) -	X			

B. KNOWN OR SUSPECTED PORCELAIN-METAL INCOMPATIBILITIES: None

C. SPECIAL HANDLING INSTRUCTIONS: None

—SECTION 9: ATTACHMENT 3—

X. PRE-SOLDERING INSTRUCTIONS—LITECAST B

A. RECOMMENDED MATERIALS:

1. SOLDER - Use Will-Ceram Super Solder (flows at about 2075 °F/1135 °C)
2. FLUX - Williams High Fusing Bondal Flux
3. INVESTMENT - Use Hi-Heat Soldering Investment (Whip-Mix), or a high-heat casting investment with distilled water (no special liquid).

B. SOLDERING TECHNIQUE: Use the MAGIC WAND Torch (Williams) with its #248 torch tip or the HARRIS 16-S torch with a 2N tip, for precise heating. (Use 5 psi OXYGEN and 2 psi NATURAL GAS.)

1. Grind, with aluminum oxide stones, all surfaces to be soldered. This process removes oxides or contaminants which would impede pre-soldering.
2. Create a GAP DISTANCE of approximately 0.3 mm.
3. Mix investment so it is thick; turn the fixed partial denture upside down; fill the inside of the castings with the mix; and invert onto a patty of investment. Do not let the castings settle into the investment. Keep investment patty as small as possible.
4. Allow the investment to reach final set; trim; smooth to remove sharp angles; and allow to dry thoroughly.
5. Apply heat in excess of 800 °F (427 °C) to eliminate the wax or acrylic resin joint (Duralay); dry thoroughly; remove from furnace; cool to room temperature. (Carbon will burn off at 800 °F / 427 °C , and a dry investment will draw less heat from the parent metal.)
6. Blast THROUGH, not down into, the connector (joint) area with uncontaminated 50- μ m alumina oxide to remove the oxides. (Oxides will impede, if not prevent, the solder-parent metal union.)
7. You now want to GLAZE your solder rod. First, heat the rod to a DULL ORANGE color; dip the rod in the flux, and you should hear it sizzle. (A GLAZED solder rod will act to retain the flux on the outside of the connector, and prevents its incorporation into the soldered joint. Only a thin glaze is necessary.)
8. WEAR DARK GLASSES IN ORDER TO SEE AT THESE PRE-SOLDER TEMPERATURES, AS WELL AS TO PROTECT YOUR EYES FROM INJURY.
9. Heat the parent metal with the REDUCING atmosphere at the end of the inner blue cones to prevent OXIDE FORMATION, and introduce the GLAZED solder rod to the connector area from the occlusal.
10. Solder should flow on contact, but ensure joint is filled before removing the reducing flame. BENCH COOL. Finish and polish.

—SECTION 9: ATTACHMENT 3—

XI. POST-SOLDERING INSTRUCTIONS—LITECAST B

A. RECOMMENDED MATERIALS: The PFM units are assumed to have been glazed and polished; and the metal substructures have been designed appropriately for the post-soldering procedure.

1. SOLDER - Williams Low Fusing Solder (flows at 1350 °F/732 °C)
2. FLUX - Williams Bondal Flux
3. INVESTMENT - Use High-Heat Soldering Investment (Whip-Mix) or a high-heat, non-carbon casting investment with distilled water (no special liquid).

B. POST-SOLDERING TECHNIQUE: Use a porcelain furnace for this procedure. It is especially helpful if the oven has a muffle view port (also referred to as a "sight window") to permit observation of the soldering process.

1. Invest in the normal manner for oven soldering. (Protect all glazed porcelain surfaces by covering them with colorless wax.)
2. Once the investment has set, heat the invested work to 800 °F (427 °C) to remove the wax or acrylic resin uniting the units.
3. Air-abrade the joints with 50- μ m aluminum oxide to clean them.
4. Flux each joint LIGHTLY.
5. Dip the solder in #7 Flux (Williams) and place it in a Bunsen burner flame at the tip of the inner blue cone. The solder will immediately ball up. Remove the ball from the flame, and allow to cool.
6. Cut the solder approximately 1/4 in. from the ball, thus leaving a small tail. Place one ball (tail first) in small joints, and two balls in larger connector areas.
7. Vacuum-fire the case to approximately 1400 °F (760 °C).
8. Hold at 1400 °F (760 °C) for 2-3 min.
9. The solder should flow readily and fill the joint space(s).
10. Withdraw the soldered work to the muffle door, and cool the work slowly.
11. Remove the investment and polish the joint areas.

—SECTION 9: ATTACHMENT 4—

REXILLIUM III

I. GENERAL INFORMATION

ALLOY TYPE: "NON-PRECIOUS" ALLOY SYSTEM: Nickel-Chromium-Beryllium

ALLOY CONTENT: 74-78% Nickel, 12-15% Chromium, 4-6% Molybdenum, and
1.8% (max.) Beryllium

MANUFACTURER:

Rx. Jeneric Gold Company
Jeneric Industries, Inc.
P.O. Box 724
Wallingford, Connecticut 06492

TOLL-FREE PHONE NUMBER:
1-(800) 243-3969, Ext. 212 or 310

COMMERCIAL PHONE NUMBER:
1-(203) 265-7397 (in Connecticut
and outside U.S., call "Collect")

TELEPHONE CONTACT:

REGIONAL SALES REPRESENTATIVES:

Laboratory: Mr. Grant Day
 Mr. Rick Tobe
Research: Dr. Arun Prasad

None

ALLOY INTRODUCED IN: 1975

F.D.A. LISTED: Yes

A.D.A. ACCEPTANCE OR PROVISIONAL ACCEPTANCE: "ACCEPTABLE" (1982)

II. PHYSICAL DESCRIPTION

Ingot color - Platinum
Ingot weight - Approximately 3.5 dwt
Ingot identification - NONE

Ingot shape - Cylinder
Ingots per ounce - 6 or 7
Alloy packaging - 1 or 5 oz

III. PHYSICAL AND MECHANICAL PROPERTIES

Specific gravity (density) - 7.75 g/cc
Brinell hardness - 240
Vickers hardness - 255
Percentage elongation (in 1 in.) - 9-12%
Tensile strength - 155,000 (1,090 kg/mm²)
Modulus of elasticity - 28 x 10⁶ psi (198,000 kg/mm²)
Yield strength (0.2% offset) - 74,000 psi (520 kg/mm²)
Bond strength - 13,000 psi
Coefficient of thermal expansion - 0.595% at 450 °C

MELTING RANGE - 2250-2350 °F
(1232-1238 °C)

CASTING TEMP - 2425-2650 °F
(1329-1454 °C)

—SECTION 9: ATTACHMENT 4—

IV. WAXING AND SPRUING INSTRUCTIONS—REXILLIUM III

A. MINIMUM RECOMMENDED WAX THICKNESS:

1. SINGLE UNITS - 0.2 mm
2. THREE-UNIT FIXED PARTIAL DENTURE - 0.3 mm
3. FIXED PARTIAL DENTURE GREATER THAN 3 UNITS - 0.3 mm.

B. RECOMMENDED SPRUING TECHNIQUE:

1. SINGLE UNITS - Use the DIRECT METHOD, with 1/4 in. long 10-GAUGE sprues for small units; and 6 or 8 GAUGE, 1/4 in. long sprues for larger ones (Fig. 4-1).
2. MULTIPLE SINGLE UNITS - INDIRECT SPRUING is recommended for multiple units with 1/4 in. long 8- or 10-GAUGE sprues (depending on the size of the crown, pontic, or coping) connected to a 6- or 8-GAUGE runner bar. Extend the length of the runner bar slightly beyond the width of the units at each end. Use 6- or 8-GAUGE offset sprue leads to join the runner bar to the sprue former (Fig. 4-2).
3. FIXED PARTIAL DENTURES - INDIRECT SPRUING is recommended for multiple units with 1/4 in. long, 8- or 10-GAUGE sprues (depending on the size of the crown, pontic, or coping) connected to a 6- or 8-GAUGE runner bar. Extend the length of the runner bar slightly beyond the width of the units at each end. Use 6- or 8-GAUGE offset sprue leads to join the runner bar to the sprue former.

NOTE: The runner bar should be shaped to conform to the contour of the fixed partial denture. If the bar must be bent, then cut and re wax it at each cut in order to destroy any memory in the wax (Fig. 4-2).

4. VENTING - Use 18-GAUGE wire wax approximately 1.0 mm from the gingival or marginal edge of the facial margin. Extend the vent down to the outer edge of the sprue former base. DO NOT CONNECT THE VENT TO THE SPRUE FORMER BASE.
5. WAX PATTERN POSITIONING - If the wax pattern is seated too low in the casting ring; build up the sprue former with wax. This technique will facilitate wax elimination and the escape of gases. Arrange the spruing system so the reservoir portion is in the HEAT CENTER of the casting ring, with the wax patterns in a COLD ZONE (Fig. 4-2).

--SECTION 9: ATTACHMENT 4--

V. INVESTMENT AND BURNOUT TECHNIQUE--REXILLIUM III

A. RECOMMENDED INVESTMENT:

1. PHOSPHATE-BONDED INVESTMENTS: Begin with undiluted special liquid and, if too much expansion results, dilute to 50% special liquid and 50% distilled water.

<u>NON-CARBON TYPE:</u>	<u>SPECIAL LIQUID</u>	<u>DISTILLED WATER</u>
a. Hi-Temp (Whip Mix) -	9.5 cc	0
b. Deguvest HFG (Degussa) -	9.5 cc	0

CARBON TYPE: Not tested with this alloy.

NOTE: A carbon-containing investment may be used with this alloy, but all carbon must be eliminated during burnout.

2. GYPSUM-BONDED INVESTMENTS: Not recommended by manufacturer.

B. INVESTMENTS NOT RECOMMENDED BY MANUFACTURER:

- 1) Complete; 2) Biovest; 3) Ceramigold II; and 4) ANY GYPSUM INVESTMENT

C. RECOMMENDED METHOD OF INVESTMENT: HIGH-HEAT rather than hygroscopic

D. MANUFACTURER'S RECOMMENDED ASBESTOS SUBSTITUTE: KAOLINER (Dentsply), DRY

You may also use one WET layer of NON-ASBESTOS ring liner (Whip-Mix) or NOBESTOS (Jelenko). Place liner flush with the top of the casting ring, but leave at least 1/8-in. clearance at the bottom of the ring. The 1/8-in. clearance will help lock the investment in the ring when the investment expands (Fig. 4-2). If additional expansion is needed, use two layers of asbestos substitute and more special liquid with less distilled water.

E. BURNOUT TECHNIQUE:

PHOSPHATE-BONDED INVESTMENTS: Start with a COLD oven and raise to 1600 °F(871 °C), then HEAT SOAK as follows:

- a. Single ring - 1 hr, add 10 min for each additional ring
b. Three units in a single ring - 1 hr and 15 min
c. Multiple units, 2-3 rings - 2 hr.

—SECTION 9: ATTACHMENT 4—

VI. MELTING AND CASTING INSTRUCTIONS—REXILLIUM III

A. CASTING EQUIPMENT:

1. CASTING MACHINE (DO NOT USE THERMATROL 2500 WITH CARBON CRUCIBLES):
 - a. Manufacturer preferred casting equipment: Induction System
 - b. Alternative systems include: Centrifugal, broken-arm casting machine
2. CASTING TORCH - Harris 16-S with #1390 H multi-orifice tip
3. CASTING CRUCIBLE - Quartz or alumina; DO NOT USE CLAY OR CARBON TYPE.

B. QUANTITY OF ALLOY NEEDED:

1. VOLUME OF METAL NEEDED - Refer to conversion chart (Table 1).*
2. PREFERRED RATIO OF NEW METAL TO RECAST METAL - 50/50% by weight
3. MINIMUM RATIO OF NEW METAL TO RECAST METAL - 30/70% by weight.

C. MELTING AND CASTING TECHNIQUE:

1. OXYGEN-GAS RATIO - 30 psi (OXYGEN), or 3-5 psi (PROPANE).
2. SETTING CASTING MACHINE - Add one turn to casting machine to compensate for the alloy's lower density.
3. FLAME ADJUSTMENT - Adjust torch to produce inner blue cones which are 1/4 in. in length and create a distinct hissing sound.

NOTE: The actual length of the inner blue cones in the neutral condition depends on the flow and the regulated pressure of both the oxygen and the gas (Fig. 4-12).

4. APPEARANCE OF THE MELT - Place the alloy in a preheated crucible, and keep the torch moving in a rotating motion to heat all the metal evenly. OXIDES will form around each ingot or button, and prevent their coalescence or pooling.
5. CASTING FLUX - Not recommended. Do not disturb oxide layer.
6. WHEN TO CAST - When the alloy starts to SLUMP or SAG, place the casting ring in position. CAST the metal after the dark shadow disappears, and the pressure of the flame causes molten alloy inside the oxide skin to move.
7. RECOVERY OF CASTING - Bench cool for at least 5 min; then quench.

D. INDUCTION CASTING (Start with a preheated crucible):

1. Set ARM SPEED between 400 and 450 RPM.
2. Set POWER to HIGH.
3. Make sure alloy is PULSATING and SLUMPING.
4. Automatic Casting Equipment - 2500 °F (1371 °C), with 5-sec HEAT SOAK.

* At close of text.

--SECTION 9: ATTACHMENT 4--

VII. ADJUSTING AND FINISHING--REXILLIUM III

A. REMOVING THE SPRUE:

1. SEPARATING DISC - Use any thin separating disc of your choice.
2. GRINDINGS - Use suction to remove grindings, and try to avoid mixing non-precious with precious grindings.

B. FITTING THE CASTING:

1. REMOVE INTERNAL NODULES - Carefully inspect the inside of each casting under magnification, and remove any irregularities.
2. EVALUATE THE FIT - Verify an acceptable level of occlusal/incisal seat and marginal seal, before proceeding to any additional finishing steps.
3. QUALITY CONTROL CHECK - Unsatisfactory castings (poor fit, overheated alloy, porosity) should be remade.
4. INITIAL OCCLUSAL ADJUSTMENT - Articulate the casting and refine the occlusion, as necessary.

C. FINISHING THE CASTING:

1. STONES AND WHEELS - Use stones, carbide burs, and burlew wheels.
2. POLISHING -
 - a. Use Rx NP Polishing Compounds # 1 and # 2, or similar materials;
 - b. or use removable partial denture polishing compounds, such as Ti-Cor and Ti-Hi (Ticonium), rather than BBC (Jelenko).

NOTE: Non-precious alloys are more difficult to adjust, polish, and finish than their precious alloy counterparts. Therefore, allow additional time for these steps. Rexillium III also contains NICKEL and BERYLLIUM, so special handling is recommended: use central evacuation (suction); limit grinding to as few areas as possible; and wear protective eyewear, mask, and a laboratory coat.

3. AVOID METAL CONTAMINATION - Set aside a set of finishing stones for this particular alloy, to prevent contamination of the metal.
4. ADJUSTMENT TECHNIQUE - Use the uncontaminated aluminum oxide abrasives to produce a smooth, even textured surface for all porcelain-bearing areas. Finish the metal surface in one direction, using light pressure.

--SECTION 9: ATTACHMENT 4--

VIII. PREPARATION OF THE METAL FOR PORCELAIN--REXILLIUM III

A. PREPARATION OF THE METAL SUBSTRATE:

1. NON-PORCELAIN BEARING SURFACES - Rubber wheel all non-porcelain bearing areas (lingual/occlusal surfaces, interproximal struts, and metal collars) to remove all scratches prior to the application of porcelain.
2. PORCELAIN-BEARING SURFACES - Air-abrade the finished metal surfaces with a 50- μ m non-recycled, uncontaminated aluminum oxide (white) abrasive under 90-100 psi.
3. CLEANING - Steam clean the metal substrate, or place in distilled water in an ultrasonic unit for 10 min, after rubber wheeling and air-abrading.

B. OXIDATION (DEGASSING) OF THE METAL SUBSTRATE:

1. LOW temperature setting - 1200 °F (649 °C)
2. HIGH temperature setting - 1775-1800 °F (968-982 °C)
3. Rate of rise - 90-100 °F (50-55 °C)
4. Atmosphere - FULL VACUUM (26-28 in. of Hg)
5. HOLD time at HIGH temperature - None
6. Appearance of the oxide layer:
 - a. A PROPERLY oxidized layer - YELLOWISH-BROWN (straw) color
 - b. An OVERoxidized layer - DARK REDDISH-BROWN color
(Air-abrade; clean; and reoxidize at a lower temperature.)
 - c. An UNDERoxidized layer - BLuish color
(Reoxidize at a higher temperature.)

C. POST-OXIDATION TREATMENT:

1. **RETAIN THE OXIDE LAYER** - You may apply opaque porcelain directly over the oxide layer.
2. DO NOT AIR-ABRADE.

--SECTION 9: ATTACHMENT 4--

IX. PORCELAIN COMPATIBILITY--REXILLIUM III

A. PORCELAIN SYSTEM COMPATIBILITY CHART. The following information has been provided by the alloy manufacturer (X) or represents the opinions of the author (0) for single unit castings:

<u>DENTAL PORCELAIN</u>	<u>PORCELAIN COMPATIBILITY</u>			
	YES	NO	MARGINAL	UNKNOWN
1. ARTIS-TECH (Jeneric)	X			
2. BIOBOND (Dentsply)	X			
3. CERAMCO (Johnson & Johnson)	X			
4. CRYSTAR (Unitek)	X	NO post-soldering, please explain		
5. JELENKO (Jelenko)				X
6. (BIOBOND) SHADEMATE (Dentsply) Low -	X			
Reg -	X			
7. VITA (Vident)	X		0*	
8. WILL-CERAM (Williams)	X			

B. KNOWN OR SUSPECTED PORCELAIN-METAL INCOMPATIBILITIES:

1. Post-soldering with CRYSTAR porcelain.
2. We have observed cracking/crazing of Vita porcelain during the cooling cycle--an indication that the Rexillium III and Vita porcelain may not be as compatible as believed. Rx. Jeneric has an alloy specifically designed for Vita porcelain, Rexillium V.

C. SPECIAL HANDLING INSTRUCTIONS: Restorations fabricated with either Biobond or Crystar porcelain and Rexillium III should be fast cooled.

—SECTION 9: ATTACHMENT 4—

X. PRE-SOLDERING INSTRUCTIONS—REXILLIUM III

A. RECOMMENDED MATERIALS:

1. SOLDER - Non-precious Rx NNP Solder (liquidus 1850-1975 °F/1010-1079 °C);
precious Rx PNP (flows 2075-2130 °F/1135-1166 °C)
2. FLUX - High temperature fluoride flux Rx NNP, or like material
3. INVESTMENT - Hi-Heat Soldering Investment (Whip-Mix), or a NON-CARBON
high-heat casting investment with water (no special liquid).

B. PRE-SOLDERING TECHNIQUE: Use the MAGIC WAND torch (Williams) with its
#248 tip, or the HARRIS 16-S torch with a 2N tip.

1. Grind, with aluminum oxide stones, all surfaces to be soldered. This
process removes oxides or contaminants which would impede pre-soldering.
2. Create a GAP DISTANCE of approximately 0.3 mm.
3. Mix investment so it is thick; turn fixed partial denture upside down;
fill the inside of the castings with the mix; add a little extra on
top; and invert onto a patty of investment. Do not let the casting
settle into the investment.
4. Allow investment to reach final set; place in an oven at a temperature
of 1000 °F (540 °C) for 20 min.
5. The heat source may be OXYGEN (5 psi) and natural GAS (2 psi).
[IDEALLY, manufacturer recommends OXYGEN (5 psi) and PROPANE (2 psi).]
6. Adjust torch to establish LIGHT BLUE inner cone flame(s) (NEUTRAL
FLAME), approximately 1/2 in. long.
7. Drip the Rx NNP high-heat solder rod in the Rx NNP flux, and try to put
as much flux on the rod as it will hold; remove the invested bridge
from the oven; and apply the flux to the joint to be soldered. The
flux should flow through the joint. Pull the solder rod away, and heat
the joint to bring the parent metal to a red hot (ORANGE-WHITE) color.
At this time, put the solder rod TO THE JOINT AREA, and the solder
should flow with the heat of the parent metal.
8. Remove the solder rod; pull back on the torch, but keep the bridge under
the flame for about 5 sec to achieve a chemically bonded solder joint.
9. ALLOW TO BENCH COOL and repolish the metal.
10. Follow the foregoing procedures when using the PRECIOUS SOLDER (Rx PNP,
and the Rx PNP Flux).

--SECTION 9: ATTACHMENT 4--

XI. POST-SOLDERING INSTRUCTIONS--REXILLIUM III

- A. RECOMMENDED MATERIALS: The porcelain units are assumed to have been glazed and polished, and the metal substructures designed appropriately for the post-soldering procedure.
1. SOLDER - Rx Low Fusing Solder (melting range 1155-1225 °F/624-663 °C).
 2. FLUX - Use of Rx Low Fusing Flux is optional.
 3. INVESTMENT - Same as pre-soldering technique.
- B. POST-SOLDERING TECHNIQUE: Use a porcelain furnace for this procedure. It is especially helpful if the oven has a muffle view port (also referred to as a "sight window") to permit observation of the soldering process.
1. Invest in the normal manner for oven soldering. (Protect all glazed porcelain surfaces by covering them with wax.)
 2. Flux the joint generously.
 3. Cut and place small pieces of solder in the joint. (Feed more into it if needed--in molten state, only.)
 4. Dry the investment slowly and thoroughly.
 5. Air-fire the work in a porcelain oven at approximately 1400 °F (760 °C).
 6. The solder should flow readily, and fill the joint space(s).
 7. Cool the work slowly; remove the investment, and polish the joint areas.

SECTION 10:

THE NICKEL-CHROMIUM BERYLLIUM-FREE ALLOYS

10-1. GENERAL DESCRIPTION

The one alloy evaluated from this particular alloy group contained 64% nickel, 22% chromium, and 9% molybdenum, plus an additional 5% of the minor alloying elements iron, columbium (or niobium), and tantalum. The nickel-chromium beryllium-free alloys offer a nickel-base alternative to those who fear that beryllium poses a potentially harmful health risk. At present, the extent of any risk of berylliosis to members of the dental community is not certain.¹ Therefore, the exact nature of this problem remains under study and is not completely clear. However, berylliosis may not be the only potentially harmful side effect of chronic beryllium exposure for technicians, clinicians, and dental patients.

Certainly, the removal of beryllium changed the character of this nickel-base alloy, eliminating the many favorable contributions of beryllium. If the rationale for the development of this alloy group was a concern for the health and safety of the consumer, this logic has failed; for the controversy surrounding the biocompatibility of nickel has not been addressed. Of the two elements, nickel appears to hold more risk potential than beryllium. Nickel will remain in contact with the patient's oral tissues as long as the restoration is in place. On the other hand, simple protective measures (such as the use of a laboratory coat, a surgical mask, and high-speed air evacuation) can apparently control beryllium dust. Additional information has become available on the intraoral behavior of nickel-base beryllium-containing alloys which might alter present thinking in this area.^{2,3}

Beryllium plays an important role in an alloy by lowering the melting range, controlling oxidation, establishing an etchable nickel-beryllium phase, and improving polishability. Remove the beryllium, for whatever reason, and these features are lost. If a laboratory using beryllium-free nickel-chromium alloys were to produce cast-metal resin-bonded retainers (Maryland Bridges), it would have to adopt the Unitek Duralingual technique or (other similar approach) for mechanical retention. Otherwise, the laboratory would need to add an etchable, beryllium-containing, nickel-base alloy to its inventory.

In some castability studies using the polyester sieve cloth as the test pattern,⁴ the beryllium-free nickel-base alloys yielded more incomplete castings than those nickel-base alloys containing beryllium.^{5,6} Without beryllium, more oxides are produced which, in turn, may clog the delicate mesh pattern and prevent complete castings.⁶ Whether the mesh model is a fair evaluator for the castability of nickel-base alloys is, in itself, another issue. Anusavice assessed a castability study by Whitlock et al. and concluded that the beryllium containing nickel-base alloys were not superior to the beryllium-free group.⁷ Large differences between the two groups of alloys, in emissivity values and in the use of induction casting, were considered responsible for the observed castability differences.⁷

—SECTION 10—

Like the nickel-base alloys, in general, the alloys in this group would be expected to produce, on heating, an oxide skim which would prevent molten ingots and/or buttons from pooling together (Fig. 10-1). The nickel-chromium beryllium-free alloys which contain boron (B) will pool during melting, and remain an exception to this generalization.^{8,9} In addition, a substantial dark oxide layer was quite apparent on Forte* castings. This finding raised concerns that these oxides might possibly create not only inclusions in castings, but also incomplete margins, and impede any attempts at pre- or post-soldering. Such questions, however, were beyond the scope of this particular project.



Figure 10-1. This Ni-Cr Be-free alloy (Forte*) produced a substantial amount of dark green oxidation as seen over the entire surface of this casting.

Nonetheless, one of the potential disadvantages of both nickel- and cobalt-base non-precious alloys is their potential for porcelain delamination, due to a separation of a poorly adherent oxide layer from the metal substrate.⁹

10-2. ECONOMIC CONSIDERATIONS

The cost of these alloys is comparable to that of the nickel-chromium-beryllium alloys, since the major constituents are neither noble nor precious. However, the individual ingots were quite heavy, as one ounce of Forte contained only five ingots. Individual ingot weight varied between 4 dwts 1 gr and 4 dwt 3 grs, thus representing the minimum amount of metal which may be cast at any one time. The manufacturer also prefers the use of all new metal, rather than a 50/50 mixture of new and recast alloy. This choice presents the same problem discussed in the Ni-Cr-Be system--that of extensive button accumulation. Small and intermediate sized dental laboratories, with varied work loads, may invest and cast single units rather than multiple units. These laboratories will readily accumulate large buttons of spent metal unless they counter this problem by delaying cases, or by investing and casting only multiple units. High production laboratories, accustomed to multiple-unit castings, could use these large ingots more efficiently.

* Unitek Corporation, Monrovia, CA.

—SECTION 10—

The other variables associated with the beryllium-containing metals also apply to this system. As a result of lapses in technique for spruing, investing, or casting, miscasts appear to be more numerous with these alloys than with the precious alloys. Overheating an alloy is not uncommon for the inexperienced technician, for one needs time to learn the melting behavior of individual alloys. Induction casting reduces such variables and improves castability; but, it also represents a tremendous increase in the start-up cost. Miscasts, the accumulation of large buttons, and increased adjusting and finishing times are economic considerations not frequently included in cost estimates. The assessment of an alloy system on the sole basis of material costs is misleading, and is not indicative of the cumulative expenses which a new system may entail.

10-3. ADVANTAGES:

Forte* is A.D.A. "ACCEPTABLE."
Do not contain beryllium.
Low density produces lightweight castings.
Are low cost.
Are poor thermal conductors.
High modulus of elasticity and yield strength provide rigidity for thin castings.
Thin castings permit maximum porcelain coverage.
Do not have to be secured like precious alloys.
Large buttons minimize the surface area to volume ratio.
Large buttons are beneficial when casting large cases.

10-4. DISADVANTAGES:

Are not A.D.A. CERTIFIED.
Not all are A.D.A. "ACCEPTABLE" or "PROVISIONALLY ACCEPTABLE."
Are much harder than conventional Type III gold alloys.
Nickel is toxic, and may pose a health threat to patients.
Cannot be used for patients with known or suspected nickel sensitivity.
Require a high-heat investment (i.e., phosphate-bonded).
Will oxidize more than nickel-base alloys with beryllium.
Form an oxide skim on heating, and do not "pool" like precious alloys--
 with the exception of those alloys containing boron.
Cannot be electrolytically etched for Maryland Bridge technique.
Require mechanical retention for Maryland Bridge castings (DuraLingual*).
Are difficult to melt and cast with consistent accuracy.
Are more geared to induction casting than to torch casting.
Are more prone to miscasts than are precious alloys.
Propane-oxygen is preferred to natural gas-oxygen.
Need central air evacuation for nickel dust.
Should request periodic environmental monitoring for nickel levels.
Are difficult to solder satisfactorily.

* Unitek Corporation, Monrovia, CA.

—SECTION 10—

10-4. **DISADVANTAGES (Cont'd.):**

Large ingots are a disadvantage when casting small cases.
In smaller laboratories, large ingots tend to produce large buttons.
Have a platinum or white color, rather than traditional yellow hue.
Are not BURNISHABLE.
Are more difficult to adjust.
Are more time consuming to finish and polish.
More difficulty is encountered in sectioning and removing these castings from the mouth.
Have a potential for porcelain delamination from the metal substrate, due to a poorly adherent oxide layer.

10-5. **BIOCOMPATIBILITY**

Despite the absence of beryllium, the unresolved concerns for nickel raise questions for the biocompatibility of all the nickel-base non-precious systems. (The subject of the biocompatibility of dental casting alloys is addressed separately in Section 12.) The reader is also advised to refer to the statements and recommendations on the nickel and beryllium-containing alloys as released by the USAF Special Consultants for Prosthodontics and Laboratory Services.

10-6. **REFERENCES**

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—SECTION 10—

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9. Neidlinger, A: Ceramalloy, An alloy for ceramo-metallic restorations. Quint Dent Tech 9:149, 1985.

EDITOR'S NOTE: The following Attachment provides comprehensive information on an example of the nickel-chromium (beryllium-free) alloy system; specifically, FORTE.

--SECTION 10: ATTACHMENT 1--

FORTE

I. GENERAL INFORMATION

ALLOY TYPE: "NON-PRECIOUS" ALLOY SYSTEM: Nickel-Chromium Beryllium-Free

ALLOY CONTENT: 64% Nickel, 22% Chromium, 9% Molybdenum, 1% Iron, and
4% Columbium (or called Niobium), and Tantalum

MANUFACTURER:

Unitek Corporation
2724 South Peck Road
Monrovia, California 91016

TOLL-FREE PHONE NUMBER:
1-(800) 423-4588

COMMERCIAL PHONE NUMBER:
1-(818) 445-7960

TELEPHONE CONTACTS:

Training Lab Manager
(Call person-to-person: "Collect"
on commercial number)

REGIONAL SALES REPRESENTATIVES:

Yes

ALLOY INTRODUCED IN: 1983

F.D.A. LISTED: 1983

A.D.A. ACCEPTANCE OR PROVISIONAL ACCEPTANCE: "ACCEPTABLE" (1983)

II. PHYSICAL DESCRIPTION

Ingot color - Platinum
Ingot weight - 4 dwt 1 gr to 4 dwt 3 grs
Ingot identification - NONE
(Shape recognition only)

Ingot shape - HEXAGON
Ingots per ounce - 5 per oz
Alloy packaging - 5, 25, 50, 100,
250, 500, and 750 troy oz

III. PHYSICAL AND MECHANICAL PROPERTIES*

Specific gravity (density) - 8.4 g/cc
Brinell hardness number - 190 (converted from Vickers)
Vickers hardness number - 194
Percentage elongation (in 1 in.) - 19%
Ultimate tensile strength - 74,000 psi
Yield strength (0.2% offset) - 49,000 psi
Bond strength - 14,500 psi
Coefficient of thermal expansion - 13.95×10^{-6} in/in/°C (± 0.22)
(from ambient to 600 °C)

* All values for the porcelain fired condition

MELTING RANGE - 2450-2500 °F
(1342-1271 °C)

CASTING TEMPERATURE - 2750-2950 °F
(1510-1621 °C)

—SECTION 10: ATTACHMENT 1—

IV. WAXING AND SPRUING INSTRUCTIONS—FORTE

A. MINIMUM RECOMMENDED WAX THICKNESS:

1. SINGLE UNITS - 0.3 to 0.4 mm
2. THREE-UNITS FIXED PARTIAL DENTURES - 0.3 to 0.4 mm
3. FIXED PARTIAL DENTURES GREATER THAN 3 UNITS - 0.3 to 0.4 mm.

B. RECOMMENDED SPRUING TECHNIQUE:

1. SINGLE UNITS - DIRECT SPRUING: Use FORTE SPRUE PIN (plastic), and maintain a 1/16-in. (1.6-mm) space between reservoir and pattern. Use small amount of sticky wax, and attach the tip of the sprue pin only, thus creating a constriction at the sprue-pattern junction to ensure a spray of metal into the mold. Attach sprue tip to incisal portion of single anterior units, and to any cusp tip of a posterior crown.
2. MULTIPLE SINGLE UNITS - DIRECT SPRUING: Attach FORTE SPRUE PIN (a plastic reservoir sprue) as above, but converge sprues at the center of the sprue former; use full length of sprue, and maintain constriction to ensure sufficient pressure to spray metal into the mold.
3. FIXED PARTIAL DENTURES - INDIRECT METHOD: For a fixed partial denture of three units or more, place one 1/16-in. 12-GAUGE sprue to each pattern (10-GAUGE to a pontic); attach these pattern sprues to an 8-GAUGE connector, or runner bar, which extends beyond the width of the patterns at each end. Use 1 in. long, 6-GAUGE main sprues which are offset to the pattern sprues (Fig. 4-2).

MANUFACTURER ALSO RECOMMENDS THE FOLLOWING FOR FIXED PARTIAL DENTURE:

DIRECT METHOD: Place one FORTE SPRUE PIN directly onto the pontic of a small fixed partial denture. You do NOT have to attach a sprue to the retainers on either side of the pontic (according to the manufacturer).

4. VENTING - Is optional; 18-GAUGE sprue to sprue base, if employed.
5. WAX PATTERN POSITIONING - If the wax pattern is seated too low in the casting ring, build up the sprue former with wax, and raise the pattern to within 1/4 in. of the top of the ring. This technique will facilitate wax elimination and the escape of gases.

—SECTION 10: ATTACHMENT 1—

V. INVESTMENT AND BURNOUT TECHNIQUE—FORTE

A. RECOMMENDED INVESTMENTS:

1. PHOSPHATE-BONDED INVESTMENTS: A NON-CARBON-containing investment is preferred. Increase burnout time, if a CARBON-containing investment is used. Using all undiluted special liquid, as suggested by some manufacturers, may not be necessary (see recommendations below):

<u>NON-CARBON TYPE:</u>	<u>SPECIAL LIQUID</u>	<u>DISTILLED WATER</u>
a. Vestra-fine (Unitek) -	11.0 cc	4.5 cc
b. Hi-Temp (Whip Mix) -	9.5 cc	0 cc

CARBON TYPE: Not tested.

2. GYPSUM-BONDED INVESTMENTS: Not recommended for this alloy.

B. RECOMMENDED METHOD OF INVESTMENT: HIGH-HEAT rather than hygroscopic.

C. MANUFACTURER'S RECOMMENDED ASBESTOS SUBSTITUTE: Ceramic type, DRY.

You may use one WET layer of NON-ASBESTOS ring liner (Whip Mix). Place liner flush with the top of the casting ring, but leave at least a 1/8-in. clearance to lock the investment in the ring when the investment expands (Fig. 4-2). If additional expansion is needed, use two layers of asbestos substitute and more special liquid.

D. BURNOUT TECHNIQUE:

PHOSPHATE-BONDED INVESTMENT: Start with a ROOM TEMPERATURE furnace, with a 30-50 °F rate of rise, and HEAT SOAK, as follows:

1. FOR PLASTIC SPRUES (Use a TWO-STAGE BURNOUT):

- Single unit - 30 min at 572 °F (300 °C); then raise the temperature to 1616 °F (880 °C); HEAT SOAK for 1 hr.
- Three units in a single ring - Same as above.
- Multiple units, 2-3 rings - Add 15 min for each additional ring.

2. FOR WAX SPRUES (Raise to 1616 °F/880 °C) and HEAT SOAK for:

- Single unit - 1 hr
- Three units in a single ring - 1 hr and 10 min
- Multiple units, 2-3 rings, - 1 hr and 15 min.

VI. MELTING AND CASTING INSTRUCTIONS--FORTE

A. CASTING EQUIPMENT:

1. CASTING MACHINE (DO NOT USE THERMATROL 2500 WITH CARBON CRUCIBLE):
 - a. Manufacturer's preferred casting equipment - Unitek's Autocast
 - b. Alternative systems include - Centrifugal, broken-arm casting machine
2. CASTING TORCH - Harris 16-S with #1390 H multi-orifice tip
3. CASTING CRUCIBLE - Quartz or alumina, DO NOT USE CLAY OR CARBON TYPE.

B. QUANTITY OF ALLOY NEEDED:

1. VOLUME OF METAL NEEDED - Refer to conversion chart (Table 1).*
2. PREFERRED RATIO OF NEW METAL TO RECAST METAL - 50/50% by weight
(Manufacturer prefers all virgin metal for each cast)
3. MINIMUM RATIO OF NEW METAL TO RECAST METAL - 50/50% by weight.

C. MELTING AND CASTING TECHNIQUE (PROPANE preferred; NATURAL GAS satisfactory):

1. OXYGEN-GAS RATIO - 25 psi (OXYGEN) and 15 psi (PROPANE).
2. SETTING CASTING MACHINE - Add one turn to casting machine to compensate for the alloy's lower density.
3. FLAME ADJUSTMENT - MULTI-ORIFICE TIP, use 1/4-in. inner blue cones; SINGLE ORIFICE TIP, set flame length 3/4 to 1 in.
4. APPEARANCE OF THE MELT - Place the alloy in a preheated crucible; hold the torch approximately 3 in. away from the ingots; and keep the torch moving in a rotating motion to distribute heat evenly, so they appear to be the same color. When small "dots" or "stars" appear, concentrate the heat on ingot corners.
5. CASTING FLUX - Not recommended. Do NOT disturb the oxide layer.
6. WHEN TO CAST - Ingot will SLUMP and start to lose its shape; small ripples will appear on the surface; CONTINUE slow, even heating until the metal can be PUSHED easily with the force of the flame. (DO NOT BREAK THE OXIDE.) THE METAL IS READY TO CAST.
7. RECOVERY OF CASTING - ALLOW TO BENCH COOL. DO NOT QUENCH. DO NOT PICKLE.

D. INDUCTION CASTING (Start with a preheated quartz crucible):

1. Set ACCELERATION at 6.
2. Set CASTING TEMPERATURE to 2750-2950 °F (1510-1621 °C).
3. Check ingots VISUALLY for shadow of unmelted alloy to disappear.
4. Place ring in machine and CAST.

* At close of text.

--SECTION 10: ATTACHMENT 1--

VII. ADJUSTING AND FINISHING--FORTE

A. REMOVING THE SPRUE:

1. SEPARATING DISC - Use any thin separating disc of your choice.
2. GRINDINGS - Use suction to remove grindings, and try to avoid mixing non-precious with precious grindings.

B. FITTING THE CASTING:

1. REMOVE INTERNAL NODULES - Carefully inspect the inside of each casting under magnification, and remove any irregularities.
2. EVALUATE THE FIT - Verify an acceptable level of occlusal/incisal seat and marginal seal, before proceeding to any additional finishing steps.
3. QUALITY CONTROL CHECK - Unsatisfactory castings (poor fit, overheated alloy, extensive porosity) should be remade.
4. INITIAL OCCLUSAL ADJUSTMENT - Articulate the casting and refine the occlusion, as necessary.

C. FINISHING THE CASTING:

1. STONES AND WHEELS - Use UTK Brown stones (Unitek) or comparable stones, carbide burs, and burlew wheels.
2. POLISHING - Use the UTK Alloy finishing kit (732-103) or similar materials. [We recommend the use of removable partial denture polishing compounds, such as Ti-Cor and Ti-Hi (Ticonium), rather than Buffing Bar Compound (BBC).]

NOTE: Non-precious alloys are more difficult to adjust, polish, and finish than their precious alloy counterparts. Therefore, be sure to allow additional time for these steps. Since this alloy contains nickel, use central evacuation and physical protection for maximum protection.

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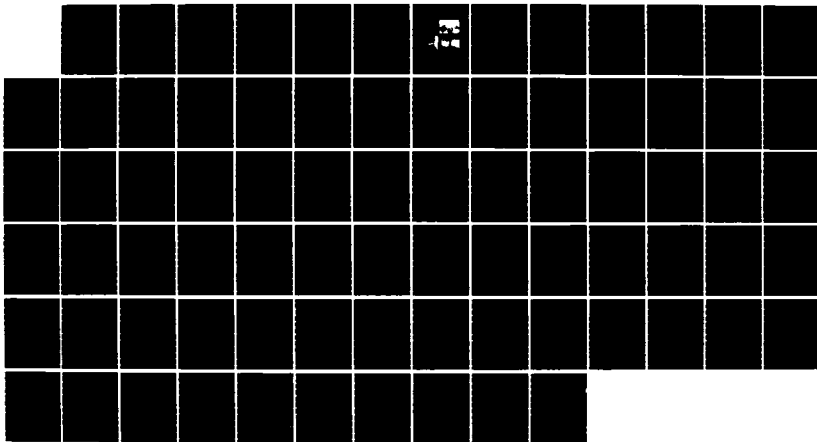
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USAFSAM-TR-86-5

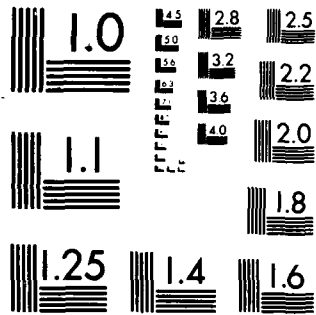
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—SECTION 10: ATTACHMENT 1—

VIII. PREPARATION OF THE METAL FOR PORCELAIN—FORTE

A. PREPARATION OF THE METAL SUBSTRATE:

1. NON-PORCELAIN BEARING SURFACES - Rubber wheel all non-porcelain bearing areas (lingual/occlusal surfaces, interproximal struts and metal collars) to remove all scratches prior to the application of porcelain.
2. PORCELAIN BEARING SURFACES - Air-abrade the finished metal surfaces with 50- μ m non-recycled, uncontaminated aluminum oxide (white) abrasive under 90-100 psi.
3. CLEANING - Steam clean the metal substrate, or place in distilled water in an ultrasonic unit for 10 min.

B. OXIDATION (DEGASSING) OF THE METAL SUBSTRATE:

AS OF THIS TIME, THE MANUFACTURER RECOMMENDS THAT THIS ALLOY NOT UNDERGO THE CUSTOMARY OXIDATION PROCEDURE.

1. LOW temperature setting - N/A
2. HIGH temperature setting - N/A
3. Rate of rise - N/A
4. Atmosphere - N/A
5. HOLD time at HIGH temperature - N/A
6. Appearance of the oxide layer:
 - a. A PROPERLY oxidized layer - N/A
 - b. An OVERoxidized layer - N/A
 - c. An UNDERoxidized layer - N/A.

--SECTION 10: ATTACHMENT 1--

IX. PORCELAIN COMPATIBILITY--FORTE

A. PORCELAIN SYSTEM COMPATIBILITY CHART: The following information has been provided by the alloy manufacturer (X):

<u>DENTAL PORCELAIN</u>	<u>PORCELAIN COMPATIBILITY</u>			
	<u>YES</u>	<u>NO</u>	<u>MARGINAL</u>	<u>UNKNOWN</u>
1. ARTIS-TECH (Jeneric) -				X
2. BIOBOND (Dentsply) -				X
3. CERAMCO (Johnson & Johnson) -				X
4. CRYSTAR (Unitek) -			X	
5. JELETKO (Jelenko) -				X
6. (BIOBOND) SHADEMATE (Dentsply) Reg- Low-				X
7. VITA (Vident) -	X			
8. WILL-CERAM (Williams) -				X

B. KNOWN OR SUSPECTED PORCELAIN-METAL INCOMPATIBILITIES: None

C. SPECIAL HANDLING INSTRUCTIONS: None

—SECTION 10: ATTACHMENT 1—

X. PRE-SOLDERING INSTRUCTIONS—FORTE

A. RECOMMENDED MATERIALS:

1. SOLDER - Use Unitek High-Fusing Solder (flows at 2100 °F/1150 °C).
2. FLUX - Use Unitek High-Fusing Solder Flux Paste.
3. INVESTMENT - Use a high-heat solder investment or a NON-CARBON casting investment with all distilled water and no special liquid.

B. SOLDERING TECHNIQUE: For precise heating, use the MAGIC WAND Torch (Williams) with its #248 tip, or the HARRIS 16-S torch with a 2N tip.

1. Prepare a GAP DISTANCE of 0.3-mm for each solder joint.
2. Lute units together with acrylic resin or sticky wax.
3. Invest in a high-heat solder investment with a 3/8-in. (9-mm) base.
4. Boil off sticky wax, or heat to 1000 °F (538 °C), to remove any acrylic resin. Allow to cool to room temperature before continuing.
5. AIR-ABRADE with 50- μ m aluminum oxide; set at 80-100 psi.
6. Cover joints with solder flux paste, and be sure to get the paste between each abutment. Use an instrument, if necessary.
7. Use 20 psi OXYGEN with NATURAL GAS or 15 psi PROPANE.
8. Glaze the High-Fusing Solder rod by first dipping it in the flux paste, and then heating until the flux melts on the rod.
9. Move torch in circular motion until investment looks dry and chalky; then move torch in and concentrate on the joint. Apply solder and touch "cherry-red" joint area.
10. When the flux comes to the surface, remove the flame.
11. BENCH COOL. Clean with 50- μ m aluminum oxide; adjust; and finish.

—SECTION 10: ATTACHMENT 1—

XI. POST-SOLDERING INSTRUCTIONS—FORTE

A. RECOMMENDED MATERIALS:

1. SOLDER - Use non-precious Low Fusing Solder
(flows between 1112 and 1382 °F/600 and 750 °C)
2. FLUX - Use Unitek Low Fusing Solder flux.
3. INVESTMENT - No preference. Use either a soldering investment or a high-heat casting investment with distilled water.

B. SOLDERING TECHNIQUE: Use a porcelain furnace with a view port to monitor the soldering process.

1. Prepare a uniform GAP DISTANCE of no more than 0.1-0.2 mm.
2. Join the units to be soldered with sticky wax or acrylic resin; then reinforce with heavy gauge wire.
3. Cover all the porcelain surfaces with white or ivory wax to prevent contact with the soldering investment and porcelain discoloration.
4. Invest and trim the investment block to a thickness of 3/8 in.
5. Boil out the sticky wax and clear waxes.
6. Air-abrade the solder area(s) with 50- μ m aluminum oxide under 20 psi.
7. Apply a thin layer of low fusing flux to the solder; and place it in each joint. Remove any excess to prevent porcelain discoloration.
8. Preheat the assembly in front of the furnace muffle for 15 min.
9. Gradually introduce the work into the furnace, preheated to 1200 °F (649 °C).
10. Raise vacuum to 700 mm Hg.
11. Set the furnace maximum temperature to the solder working temperature (1112-1382 °F/600-750 °C).
12. Observe when solder has flowed completely.
13. If necessary, the temperature may be increased in 10 °F increments until the solder flows.
14. Carefully remove the work and inspect the solder joints. Allow the metal to cool uniformly, before divesting and repolishing.

SECTION 11:

THE COBALT-CHROMIUM ALLOYS

11-1. GENERAL DESCRIPTION

Traditionally, cobalt-chromium alloys have been used to cast removable partial denture frameworks, and rarely have been involved in the production of a PFM restoration.¹ As concerns for the biocompatibility of nickel and beryllium continue, interest in alternative non-precious alloy systems has increased. The cobalt-chromium alloys evaluated in this study contained 55-68% cobalt and 25-27% chromium, in addition to wolfram, ruthenium, aluminum, yttrium, zirconium, niobium, and various unspecified trace elements. The processing of these alloys is definitely different from that of either the Ni-Cr-Be or the Ni-Cr systems. The cobalt chromium alloys are slightly more dense than the nickel-base metals, and tend to be a little more difficult to melt. Like the nickel-base system, the cobalt-chromium alloys form an oxide skim over the molten metal. In the majority of cobalt-chromium alloys, this oxide layer prevents the ingots and buttons from pooling together, as is customary with precious metals. Two notable exceptions are Biocast* and Excel,** since these particular alloys will pool.²

Nonetheless, some manufacturers are promoting the cobalt-chromium alloys as "nickel-free, beryllium-free", "non-precious" alternatives for the PFM restoration. The castings are lightweight, strong, and reportedly suitable for multiple-unit restorations. The same equipment used to cast nickel-base alloys can be employed for the cobalt-chromium metals. Despite this advertising information, less research is available on the handling characteristics and performance of this particular system as a substrate for dental porcelain. Despite concerns for the biocompatibility of nickel and beryllium, acceptance by the dental profession appears to be slow at this time. The palladium-base systems are competitively priced, and have attracted many former consumers of non-precious, nickel-chromium alloys.

One characteristic feature of the cobalt-chromium castings is the presence of a rather distinctive greenish-black external oxide film. Extensive oxidation of this nature might predispose these alloys to a greater tendency toward oxide inclusions and/or incomplete castings, and might make pre-soldering quite difficult. Individuals unaccustomed to melting these alloys might inadvertently prolong the heating, or inadvertently overheat the metal. These alloys require a learned skill for proper casting.

Even with an acceptable casting, the major weakness in this system is its tendency to produce a thick, dark oxide. A greater number of porcelain bond failures might occur with these alloys, as compared with the nickel-chromium-beryllium alloys (Fig. 11-1). Such bond failures may appear as porcelain delaminations due to separation of a poorly adherent oxide layer from the metal substructure (Figs. 11-2 and 11-3).³

* Rx Jeneric Gold Co., Wallingford, CT.
** Pentron Corp., Wallingford, CT.

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This is not a precious system, so one can expect to have the same general processing challenges as those encountered with non-precious alloys as a whole: castability problems, increased hardness, lack of burnishability, heavy oxide formation, bond failures, difficulty adjusting and finishing, etc.

Figure 11-1. The oxides produced by this cobalt-chromium alloy (Cobond*) are a greenish-black color and can be seen on the casting itself as well as on the casting investment.

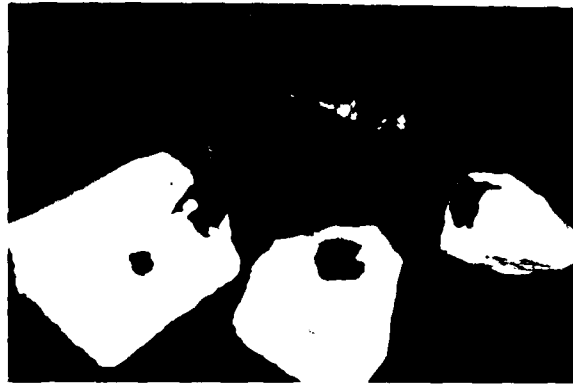


Figure 11-2. The porcelain-metal bond failed in the cobalt-chromium* unit after the crown had been cemented. This type of bond failure through the oxide layer is often referred to as a "delamination" of the porcelain.



Figure 11-3. The oxidation produced by the metal evidently was substantial. Note the presence of a thick, dark oxide film adhering to the porcelain (left), with an apparent oxide layer also remaining on the surface of the metal (right).

* The alloy used to make this particular casting was neither Cobond nor Novarex, but a cobalt-chromium product previously tested by the author. This case has been included because it depicts a classic example of the problems of excessive oxide production and porcelain delamination with a non-nickel base, non-precious alloy.

--SECTION 11--

11-2. ECONOMIC CONSIDERATIONS:

Since none of the major constituents are noble or precious, these alloys are inexpensive, and are priced like their Ni-Cr-Be counterparts by manufacturers of both systems. However, individual buttons vary in weight from 2 dwts 3 gr to 2 dwts 20 gr (Novarex) to approximately 3 dwts (Jobond), and represent the minimum quantity of metal which may be cast at any one time. For small castings, more metal may be expended than is necessary, and large buttons will accumulate. To maintain the recommended 90:10% ratio of new metal to recast metal, single unit castings become less economical. If recast metal is not enriched with new alloy, an elevation in the casting temperature and hardness in the metal may occur, since minor alloying elements are not replenished.

Overheating a non-precious alloy is not uncommon to the uninitiated, since learning to appreciate the particular melting behavior of each individual alloy takes time. Induction casting reduces such variables and improves castability, but also increases the initial expense for this system. Miscasts, the regular accumulation of large buttons, and increased adjusting and finishing times are economic considerations which should be included in cost estimates.

As stated for the Ni-Cr-Be and Ni-Cr-Be-free systems, the purchase price of the alloy is but one factor to be considered in assessing the total expense of this or of any other non-precious system.

NOTE: Because Novarex contains 5% of the noble metal, ruthenium, it has scrap value.

11-3. ADVANTAGES:

- Do not contain **NICKEL**.
- Do not contain **BERYLLIUM**.
- Low density yields lightweight castings.
- Are low cost.
- Are poor thermal conductors.
- High modulus of elasticity and yield strength provide rigidity for thin castings.
- Do not have to be secured, like precious alloys.

11-4. DISADVANTAGES:

- Are not A.D.A. CERTIFIED.
- Not all are A.D.A. "ACCEPTABLE" or "PROVISIONALLY ACCEPTABLE."
- Are much harder than gold- and palladium-base porcelain alloys.
- Are more difficult to process than the nickel-base alloys.
- Are more suitable for induction casting than torch casting.
- Are not BURNISHABLE.
- Are more prone to miscasts than are precious alloys.

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Propane-oxygen is preferred to natural gas-oxygen.
Are more prone to porcelain-metal bond failure than precious alloys.
Are difficult to solder satisfactorily.
Require a high-heat investment (i.e., phosphate-bonded).
Are more difficult to adjust.
Some alloys do not have any identification on their ingots.
More difficulty arises in sectioning and removing these castings
from the mouth.

11-5. BIOCOMPATIBILITY

The subject of "The Biocompatibility of Dental Casting Alloys" is addressed separately in Section 12. Since the cobalt-chromium system is both nickel- and beryllium-free, few questions have been raised concerning the biocompatibility of the alloys.

11-6. REFERENCES

1. McLean, J. W.: The Science and Art of Dental Ceramics. Vol II: Bridge Design and Laboratory Procedures in Dental Ceramics. Chicago, Ill., 1980, Quintessence Publishing Co.
2. Baran, G. R.: Selection criteria for base metal alloys for use with porcelains. Dent Clin North Am 29:779, 1985.
3. Association Report: Report on base metal alloys for crown and bridge applications: benefits and risks. J Am Dent Assoc 111:479, 1985.

EDITOR'S NOTE: The following Attachments provide comprehensive information on two examples of the cobalt-chromium alloy system; specifically, COBOND, and NOVAREX.

--SECTION 11: ATTACHMENT 1--

COBOND

I. GENERAL INFORMATION

ALLOY TYPE: "NON-PRECIOUS" ALLOY SYSTEM: Cobalt-Chromium

ALLOY CONTENT: 65-68% Cobalt, 25-27% Chromium, 4-6% Molybdenum, and unspecified trace elements

MANUFACTURER:

Dentsply International, Inc.
570 West College Avenue
P.O. Box 872
York, Pennsylvania 17405

TOLL-FREE PHONE NUMBER:
1-(800) 233-9454, ext.511

COMMERCIAL PHONE NUMBER:
1-(717) 845-7511, ext. 511

TELEPHONE CONTACTS:

Mr. John Appelbaum

REGIONAL SALES REPRESENTATIVES:

Yes

ALLOY INTRODUCED IN: September 1982

F.D.A. LISTED: Yes, 1981

A.D.A. ACCEPTANCE OR PROVISIONAL ACCEPTANCE: "ACCEPTABLE" (1985)

II. PHYSICAL DESCRIPTION

Ingot color - Platinum
Ingot weight - Approximately 3 dwts each
Ingot identification - Raised rectangle
with letter "D" on second tier

Ingot shape - Raised rectangle
Ingots per ounce - 7 per oz
Alloy packaging - 2-oz packages

III. PHYSICAL AND MECHANICAL PROPERTIES

Specific gravity (density) - 8.2 g/cc
Brinell hardness number - 303
Vickers hardness number - 320
Percentage elongation (in 1 in.) - 3% minimum
Ultimate tensile strength - 80,000 psi
Yield strength (0.2% offset) - 60,000 psi
Bond strength - No value available
Coefficient of thermal expansion - Proprietary information

MELTING RANGE - 2250-2400 °F
(1290-1320 °C)

CASTING TEMPERATURE - 2750 °F
(1510 °C)

--SECTION 11: ATTACHMENT 1--

IV. WAXING AND SPRUING INSTRUCTIONS--COBOND

A. MINIMUM RECOMMENDED WAX THICKNESS:

1. SINGLE UNITS - 0.3 mm
2. THREE-UNITS FIXED PARTIAL DENTURES - 0.3 mm to 0.5 mm
3. FIXED PARTIAL DENTURES GREATER THAN 3 UNITS - 0.3 mm to 0.5 mm.

B. RECOMMENDED SPRUING TECHNIQUE:

1. SINGLE UNITS - Use DIRECT SPRUING, with 8- or 10-GAUGE reservoir sprues attached to the thickest part of the wax pattern. If you elect to fashion your own reservoir, make sure it is equal in diameter to the thickest part of the wax pattern, and is positioned about 1 mm from the wax pattern (Fig. 4-1).
2. MULTIPLE SINGLE UNITS - INDIRECT SPRUING is recommended, with 10-GAUGE, 1/4-in. length sprues to each unit connected to an 8-GAUGE runner bar, which is joined to the sprue former by offset 8-GAUGE sprue leads. Extend the length of the runner bar slightly beyond the width of the units at each end. Allow 1/4-in. space between the wax pattern and the top of the casting ring (Fig. 4-2).
3. FIXED PARTIAL DENTURES - INDIRECT SPRUING is recommended, with 10-GAUGE, 1/4-in. length sprues to each unit connected to an 8-GAUGE runner bar, which is joined to the sprue former by offset 8-GAUGE sprue leads. Extend the length of the runner bar slightly beyond the width of the units at each end. Allow 1/4-in. space between the wax pattern and the top of the casting ring (Fig. 4-2).

NOTE: The runner bar should be shaped to conform to the contour of the fixed partial denture. If the bar must be bent, then cut, and re wax it at each cut in order to destroy any memory in the wax.

4. VENTING - Not required.
5. WAX PATTERN POSITIONING - If the wax pattern is seated too low in the casting ring, build up the sprue former with wax. This technique will facilitate wax elimination and the escape of gases. Design the spruing system so that any reservoir is in the HEAT CENTER of the casting ring, with the wax patterns in a "COLD ZONE" (Fig. 4-2).

—SECTION 11: ATTACHMENT 1—

V. INVESTMENT AND BURNOUT TECHNIQUE—COBOND

A. RECOMMENDED INVESTMENTS:

1. PHOSPHATE-BONDED INVESTMENTS: The manufacturer does not market a NON-CARBON containing casting investment, and does NOT require the use of such investments with this cobalt-base alloy.

<u>NON-CARBON TYPE:</u>	<u>SPECIAL LIQUID</u>	<u>DISTILLED WATER</u>
Hi-Temp (Whip-Mix)	9.5 cc	0

NOTE: Vestra-fine (Unitek) was not tested with this alloy.

CARBON TYPE:

a. Biovest (Dentsply) -	11.0 cc	0
b. Deguvest HFG (Degussa) -	9.0 cc	0

2. GYPSUM-BONDED INVESTMENTS: Not recommended for this alloy.

B. RECOMMENDED METHOD OF INVESTMENT: HIGH-HEAT rather than hygroscopic.

C. MANUFACTURER'S RECOMMENDED ASBESTOS SUBSTITUTE: KAOLINER(Dentsply), DRY.

You may use one WET layer of NON-ASBESTOS ring liner (Whip-Mix) or other asbestos substitute. Place liner flush with the top of the casting ring, but leave at least a 1/8-in. clearance at the bottom of the ring. The 1/8-in. clearance will help lock the investment in the ring when the investment expands (Fig. 4-2). If additional expansion is needed, use two layers of asbestos substitute, more special liquid, and less distilled water.

D. BURNOUT TECHNIQUE:

1. PHOSPHATE-BONDED INVESTMENT: Start with a ROOM TEMPERATURE oven, raise temperature to 1550 °F (843 °C) at a rate of 25 °F/min, and HEAT SOAK as follows:

HEAT SOAK

- Single ring - 1 hr
- Three units in a single ring - 1 hr
- Multiple units, 2-3 rings - 1 hr plus 10 min for each additional ring.

2. GYPSUM-BONDED INVESTMENT: Not recommended for this alloy.

--SECTION 11: ATTACHMENT 1--

VI. MELTING AND CASTING INSTRUCTIONS--COBOND

A. CASTING EQUIPMENT:

1. CASTING MACHINE (DO NOT USE A THERMATROL 2500 WITH CARBON CRUCIBLE):
Manufacturer's preferred casting equipment - Broken-arm casting machine
2. CASTING TORCH - Harris 16-S torch, with a #1390 H multi-orifice tip.
3. CASTING CRUCIBLES - Quartz, alumina, or clay; a graphite crucible is NOT recommended.

B. QUANTITY OF ALLOY NEEDED:

1. VOLUME OF METAL NEEDED - Refer to conversion chart (Table 1). *
2. PREFERRED RATIO OF NEW METAL TO RECAST METAL - 50/50% by weight
3. MINIMUM RATIO OF NEW METAL TO RECAST METAL - 50/50% by weight.

C. MELTING AND CASTING TECHNIQUE (PROPANE, preferred, NATURAL GAS, adequate):

1. OXYGEN-GAS RATIO - 20 psi OXYGEN, 5 psi PROPANE
2. SETTING CASTING MACHINE - Add one turn to casting machine to compensate for the alloy's lower density.
3. FLAME ADJUSTMENT - The multiple light blue inner cones should be set to a 1/4-in. length by adjusting the gas valve. Oxygen should be kept at 20-psi flow. The REDUCING ZONE will be an additional 2-1/2 in. long, with the balance of the flame being the oxidizing zone. Maximum flame length is approximately 8 in., and a distinct hissing sound should be audible if the flame has been adjusted correctly (Fig. 4-12).
4. APPEARANCE OF THE MELT - Place the alloy in a preheated quartz or other non-carbon crucible. Do NOT use a casting ring LINER or FLUX. Rotate the torch in a circular motion to distribute the heat evenly over the ingots.
5. WHEN TO CAST - The alloy will begin to SLUMP, and an oxide film will form over each ingot. When the molten alloy under the oxide surface moves with the motion of the torch, THE ALLOY IS READY TO CAST.
6. RECOVERY OF CASTING - ALLOW TO BENCH COOL; DO NOT QUENCH; DO NOT PICKLE.

D. INDUCTION CASTING (Start with a preheated crucible):

1. Set ARM SPEED between 425 and 450 RPM.
2. Set POWER (amperage) to HIGH.
3. Set TEMPERATURE to 2750 °F (1510 °C) with a maximum of 5-sec HEAT SOAK.
4. When the alloy is PULSATING, you may CAST.

* At close of text.

--SECTION 11: ATTACHMENT 1--

VII. ADJUSTING AND FINISHING--COBOND

A. REMOVING THE SPRUE:

1. SEPARATING DISC - Use a Faskut #8 metal cut-off disc (Dentsply), or other similar separating disc to cut off the sprue.
2. GRINDINGS - Use suction to remove grindings, and try to avoid mixing non-precious with precious grindings.

B. FITTING THE CASTING:

1. REMOVE INTERNAL NODULES - Carefully inspect the inside of each casting under magnification, and remove any irregularities.
2. EVALUATE THE FIT - Verify an acceptable level of occlusal/incisal seat and marginal seal, before proceeding with additional finishing steps.
3. QUALITY CONTROL CHECK - Unsatisfactory castings (poor fit, overheated alloy, porosity) should be remade.
4. INITIAL OCCLUSAL ADJUSTMENT - Articulate the casting and refine the occlusion, as necessary.

C. FINISHING THE CASTING:

1. STONES AND WHEELS - For bulk metal removal, use Faskut #10 wheel (Dentsply), Faskut Bornide Mounted Points, or other similar materials.
2. POLISHING - Use removable partial denture polishing compounds, such as Ti-Cor and Ti-Hi (Ticonium).

NOTE: Non-precious alloys are more difficult to adjust, polish, and finish than their precious alloy counterparts. Therefore, allow more time for these steps. Use central evacuation (suction); limit grinding to as few areas as possible; and wear protective eyewear and mask, as well as a laboratory coat.

3. AVOID METAL CONTAMINATION - Set aside a set of finishing stones for this particular alloy, to prevent contamination of the metal.
4. ADJUSTMENT TECHNIQUE - Use the uncontaminated aluminum oxide abrasives to produce a smooth, even textured surface for all porcelain-bearing areas. Finish the metal surface in one direction, using light pressure.

—SECTION 11: ATTACHMENT 1—

VIII. PREPARATION OF THE METAL FOR PORCELAIN—COBOND

A. PREPARATION OF THE METAL SUBSTRATE:

1. NON-PORCELAIN BEARING SURFACES - Rubber wheel all non-porcelain bearing areas (lingual/occlusal surfaces, interproximal struts, and metal collars) to remove all scratches prior to the application of porcelain.
2. PORCELAIN-BEARING SURFACES - Air-abrade the finished metal surfaces with a 50- μ m non-recycled, uncontaminated aluminum oxide (white) abrasive under a minimum of 75 psi.
3. CLEANING - After cutting and grinding, flush and brush the casting in running tap water, or steam clean the metal substrate. Then place in distilled water in an ultrasonic unit for 10 min, after rubber-wheeling and air-abrading.

B. OXIDATION (DEGASSING) OF THE METAL SUBSTRATE:

1. LOW temperature setting - Preheat oven to 1740 °F (950 °C).
 2. HIGH temperature setting - 1740 °F (950 °C)
 3. Rate of rise - 0
 4. Atmosphere - FULL VACUUM (26-28 in. of Hg)
 5. HOLD time at HIGH temperature - 10 min (release vacuum slowly and remove casting).
 6. Appearance of the oxide layer:
 - a. A PROPERLY oxidized layer
 - b. An OVERoxidized layer
 - c. An UNDERoxidized layer
- } As long as the casting was properly oxidized, any oxide surface would be satisfactory as long as it is not BLACK in color.

C. POST-OXIDATION TREATMENT:

1. REMOVE THE OXIDE LAYER - Air-abrade all surfaces which are to receive porcelain with non-recycled, 50- μ m aluminum oxide or quartz, under 75 psi (minimum) air pressure.
2. CLEANING - Flush and brush the casting thoroughly in tap water, then rinse in 99% isopropyl alcohol for 15 sec. Pat dry with tissue and apply opaque porcelain.

--SECTION 11: ATTACHMENT 1--

IX. PORCELAIN COMPATIBILITY PROFILE--COBOND

A. PORCELAIN SYSTEM COMPATIBILITY CHART: The following information has been provided by the alloy manufacturer (X):

<u>DENTAL PORCELAIN</u>	<u>PORCELAIN COMPATIBILITY</u>			
	YES	NO	MARGINAL	UNKNOWN
1. ARTIS-TECH (Jeneric)				X
2. BIOBOND (Dentsply)	X			
3. CERAMCO (Johnson & Johnson)	X			
4. CRYSTAR (Unitek)				X
5. JELENKO (Jelenko)				X
6. (BIOBOND) SHADEMATE (Dentsply)Low - Reg -		X		
7. VITA (Vident)				X
8. WILL-CERAM (Williams)				X

B. KNOWN OR SUSPECTED PORCELAIN-METAL INCOMPATIBILITIES: Unknown

C. SPECIAL HANDLING INSTRUCTIONS: None.

Follow the dental porcelain manufacturer's instructions.

—SECTION 11: ATTACHMENT 1—

X. PRE-SOLDERING INSTRUCTIONS--COBOND

A. RECOMMENDED MATERIALS:

1. SOLDER - COBOND Non-Precious Presolder [flows at 2100 °F (1150 °C)].
2. FLUX - BIOBOND C&B Fluoride Flux
3. INVESTMENT - Biovest Soldering Investment (12 cc water:100 g powder)

B. SOLDERING TECHNIQUE: For precise heating, use the MAGIC WAND Torch (Williams) with its #248 tip, or the HARRIS 16-S torch with a 2N tip.

1. Grind, with fine aluminum oxide stones, all surfaces to be soldered. This process will remove debris and oxide contamination.
2. Create a GAP DISTANCE of approximately 0.25 mm.
3. Invest in BIOVEST Soldering Investment. Fashion openings and access to the solder joint before the investment has hardened. Allow investment to set for 30 min.
4. Boil out any wax, and clean the joint area thoroughly. (If Duralay or other acrylic resin is used to lute the joint, heat the investment to approximately 900 °F (842 °C), remove any remaining resin, and apply flux.)
5. Apply BIOBOND C&B fluoride soldering flux to the solder area.
6. Dry investment for 15 min; place in a burn-out oven at room temperature; and increase temperature to 1050 °F (566 °C).
7. The heat source may be OXYGEN (5 psi) and NATURAL GAS, or PROPANE.
8. Establish a fine blue inner cone flame, extending approximately 3/4 in.
9. Apply even heat to joint area until alloy becomes a DULL RED COLOR. Keep torch on the joint to be soldered, and position a fluxed solder rod on the joint.
10. Apply the inner blue tip (hottest part) of the flame to the joint and solder rod. Be prepared to PUSH the ball of molten solder directly into the cavity of the joint.
11. Continue to apply heat, but move the inner blue tip back to a distance of 1 in. to 1-1/2 in. Keep heat on the joint until sufficient solder has filled the cavity. Only use the REDUCING ZONE of the flame.
12. Remove the torch, and permit the unit to bench cool.
13. Total elapsed time for soldering should be approximately 30 sec.

--SECTION 11: ATTACHMENT 1--

XI. POST-SOLDERING INSTRUCTIONS--COBOND

A. RECOMMENDED MATERIALS:

1. SOLDER - Use 615 solder (flows at 1350 °F/732 °C)
2. FLUX - Dentsply C&B Fluoride Flux
3. INVESTMENT - Use BIOVEST Soldering Investment rather than a high-heat phosphate-bonded casting investment.

B. SOLDERING TECHNIQUE: We recommend a porcelain furnace with a view port to monitor the soldering process. The manufacturer considers the use of a view port as being optional.

1. Remove any edges, debris, or porcelain covering the metal surfaces to be soldered.
2. Create a GAP DISTANCE of 0.25 mm.
3. Cover all porcelain with sticky wax to prevent possible investment contamination or discoloration of the glazed porcelain.
4. Invest the units in BIOVEST Soldering Investment.
5. Boil out wax and pieces of investment to clean the joint area. (If Duralay is used to join the units, heat to 900 °F/482 °C and clean.)
6. Flux the areas to be soldered.
7. Cut several 1/8 in. to 1/4 in. pieces of 615 Solder, and place them in the joints to be soldered.
8. Place the invested units in the front of an opened porcelain furnace muffle, preset to a temperature of 600 °F/316 °C (manual oven with horizontal muffle). The preset temperature may be as high as 900 °F/482 °C for automatic ovens, or variations in the horizontal muffle.
9. Hold at the muffle entrance for 15 min. HEAT THE WORK SLOWLY AND CAREFULLY TO PREVENT PORCELAIN CHECKING AND CRACKING.
10. Gradually introduce the investment block into the muffle, and increase the temperature to 1550 °F (843 °C).
11. You may post-solder with or without vacuum.
12. Once 1550 °F (843 °C) has been reached, HOLD for 1 min.
13. Inspect the soldered units, and BENCH COOL before deinvesting.
14. Finish the soldered joints with stones and rubber wheels, and polish to a high shine.

—SECTION 11: ATTACHMENT 2—

NOVAREX

I. GENERAL INFORMATION

ALLOY TYPE: "NON-PRECIOUS"

ALLOY SYSTEM: Cobalt-Chromium

ALLOY CONTENT: 55% Cobalt, 25% Chromium, 11% Wolfram, 5% Ruthenium, and
9% Aluminum, Yttrium, Zirconium, and Niobium.

MANUFACTURER:

Rx. Jeneric Gold Company
Jeneric Industries, Inc.
P.O. Box 724
Wallingford, Connecticut 06492

TOLL-FREE PHONE NUMBER:
1-(800) 243-3969, Ext.212 or 310

COMMERCIAL PHONE NUMBER:
1-(203) 265-7397 (in Connecticut
and outside U.S., call "Collect ")

TELEPHONE CONTACTS:

Laboratory: Mr. Grant Day
Mr. Rick Tobey
Research: Dr. Arun Prasad

REGIONAL SALES REPRESENTATIVES:

None

ALLOY INTRODUCED IN: 1982

F.D.A. LISTED: Yes

A.D.A. ACCEPTANCE OR PROVISIONAL ACCEPTANCE: NO

II. PHYSICAL DESCRIPTION

Ingot color - Platinum
Ingot weight - 2 dwt 3 grs to 2 dwt 20 grs
Ingot identification - NONE

Ingot shape - Cylinder
Ingots per ounce - 7 per oz
Alloy packaging - 1 or 5 oz

III. PHYSICAL AND MECHANICAL PROPERTIES

Specific gravity (density) - 8.75 g/cc
Brinell hardness number - 260
Vickers hardness number - 275
Percentage elongation (in 1 in.) - 7%
Ultimate tensile strength - 110,000 psi (774 kg/mm²)
Yield strength (0.2% offset) - 90,000 psi (634 kg/mm²)
Bond strength - 13,000 psi
Coefficient of thermal expansion - .590% @ 450 °C

MELTING RANGE - 2425-2475 °F
(1329-1357 °C)

CASTING TEMPERATURE - 2675 °F
(1468 °C)

--SECTION 11: ATTACHMENT 2--

IV. WAXING AND SPRUING INSTRUCTIONS--NOVAREX

A. MINIMUM RECOMMENDED WAX THICKNESS:

1. SINGLE UNITS - 0.4 mm
2. THREE-UNITS FIXED PARTIAL DENTURES - 0.4 mm
3. FIXED PARTIAL DENTURES GREATER THAN 3 UNITS - 0.4 mm.

B. RECOMMENDED SPRUING TECHNIQUE:

1. SINGLE UNITS - Use the DIRECT METHOD, with 1/4 in. long, straight 10- or 8-GAUGE sprues for small units, and 6- or 8-GAUGE 1/4 in. long, straight sprues for larger ones (Fig. 4-1).
2. MULTIPLE SINGLE UNITS - INDIRECT SPRUING is recommended for multiple units with 1/4 in. long, 10- or 8-GAUGE sprues (depending on the size of the crown, pontic, or coping) connected to a 6- or 8-GAUGE runner bar. Extend the length of the runner bar slightly beyond the width of the units at each end. Use 6- or 8-GAUGE offset sprue leads to join the runner bar to the sprue former (Fig. 4-2).
3. FIXED PARTIAL DENTURES - INDIRECT SPRUING is recommended for multiple units with 1/4 in. long 8- or 10-GAUGE sprues (depending on the size of the crown, pontic, or coping) connected to a 6- or 8-GAUGE runner bar. Extend the length of the runner bar slightly beyond the width of the units at each end. Use 6- or 8-GAUGE offset sprue leads to join the runner bar to the sprue former.

NOTE: The runner bar should be shaped to conform to the contour of the fixed partial denture. If the bar must be bent, then cut and re wax it at each end in order to destroy any memory in the wax (Fig. 4-2).

4. VENTING - Use 18-GAUGE wire wax, approximately 1.0 mm from the gingival or marginal edge of the facial margin. Extend the vent down to the outer edge of the sprue former base. DO NOT CONNECT THE VENT TO THE SPRUE FORMER BASE.
5. WAX PATTERN POSITIONING - If the wax pattern is seated too low in the casting ring, build up the sprue former with wax and raise the pattern. This technique will facilitate wax elimination and the escape of gases. Arrange the spruing system so that the reservoir portion is in the HEAT CENTER of the casting ring, with the wax patterns in a COLD ZONE (Fig. 4-2).

--SECTION 11: ATTACHMENT 2--

V. INVESTMENT AND BURNOUT TECHNIQUE--NOVAREX

A. RECOMMENDED INVESTMENTS:

1. PHOSPHATE-BONDED INVESTMENTS: A NON-CARBON-containing investment (white color) is preferred. Increase burnout time if a CARBON-containing investment (black color) is used. The manufacturer suggests you use undiluted special liquid, but we frequently noted overexpansion. Thus, we often use 50% undiluted special liquid and 50% distilled water to reduce expansion. Although no nickel is in this alloy, the manufacturer warns that carbon-containing investments may react with elements such as chromium, wolfram, and niobium and form carbides. If these carbides are allowed to form, the hardness of the alloy increases.

<u>NON-CARBON TYPE:</u>	<u>SPECIAL LIQUID</u>	<u>DISTILLED WATER</u>
a. Vestra-fine (Unitek) -	15.5 cc	0
b. Hi-Temp (Whip-Mix) -	9.5 cc	0
<u>CARBON-TYPE:</u>		
a. Biovest (Dentsply) -	11.0 cc	0
b. Deguvest HFG (Degussa) -	9.0 cc	0

2. GYPSUM-BONDED INVESTMENTS: Not recommended for this alloy.

B. RECOMMENDED METHOD OF INVESTMENT: HIGH-HEAT rather than hygroscopic.

C. MANUFACTURER'S RECOMMENDED ASBESTOS SUBSTITUTE: KAOLINER (Dentsply), DRY.

We prefer to use one WET layer of the NON-ASBESTOS ring liner (Whip-Mix). Place the liner flush with the top of the casting ring, but leave at least a 1/8-in. clearance at the bottom of the ring. The 1/8-in. clearance will help lock the investment in the ring when the investment expands (Fig. 4-2). If additional expansion is needed, use two layers of asbestos substitute, or more of the special liquid with less distilled water.

D. BURNOUT TECHNIQUE:

PHOSPHATE-BONDED INVESTMENT: Start with a COLD oven, and raise the temperature to 1600 °F (871 °C) and HEAT SOAK as follows:

- a. Single ring - 1 hr
- b. Three units in a single ring - 1 hr and 15 min
- c. Multiple units, 2-3 rings - 2 hr.

VI. MELTING AND CASTING INSTRUCTIONS--NOVAREX

A. CASTING EQUIPMENT:

1. CASTING MACHINE (DO NOT USE THERMATROL 2500 WITH CARBON CRUCIBLE):
 - a. Manufacturer's preferred casting equipment - Induction system
 - b. Alternative systems include - Centrifuge
2. CASTING TORCH - Harris 16-S with #1390 H multi-orifice tip
3. CASTING CRUCIBLES - Quartz or alumina; DO NOT USE CLAY OR CARBON TYPE.

B. QUANTITY OF ALLOY NEEDED:

1. VOLUME OF METAL NEEDED - Refer to conversion chart (Table 1).*
2. PREFERRED RATIO OF NEW METAL TO RECAST METAL - 50/50% by weight
3. MINIMUM RATIO OF NEW METAL TO RECAST METAL - 30/70% by weight.

C. MELTING AND CASTING TECHNIQUE (PROPANE, preferred, NATURAL GAS, adequate):

1. OXYGEN-GAS RATIO - 35 psi (OXYGEN) or 5 psi (PROPANE).
2. SETTING CASTING MACHINE - Add one turn to casting machine to compensate for the alloy's lower density.
3. FLAME ADJUSTMENT - Adjust the torch to produce inner blue cones 1/4 in. in length, and to create a distinct hissing sound (Fig. 4-12). (The length of the inner blue cones in the neutral condition depends on the flow and the regulated pressure of both the oxygen and the gas.)
4. APPEARANCE OF THE MELT (Same as Rexillium III) - Place the alloy in a preheated crucible, and keep the torch moving in a rotating motion to heat all of the metal evenly. Oxides will form around each ingot or button and prevent coalescence or pooling.
5. CASTING FLUX - Not recommended; do not disturb the oxide layer.
6. WHEN TO CAST - When the alloy starts to SLUMP or SAG, place the casting ring in position. CAST the metal after the dark shadow disappears, and the pressure of the flame causes molten alloy inside the oxide skin to move.
7. RECOVERY OF CASTING - FENCH COOL; DO NOT QUENCH; DO NOT PICKLE.

D. INDUCTION CASTING (Start with a preheated crucible):

1. Set ARM SPEED between 400 and 450 RPM.
2. Set POWER to HIGH.
3. Make sure alloy is PULVATING and CLUMPING.
4. Automatic casting equipment - 2700 °F (1482 °C).

* At close of text.

—SECTION 11: ATTACHMENT 2—

VII. ADJUSTING AND FINISHING—NOVAREX

A. REMOVING THE SPRUE:

1. SEPARATING DISC - Use any thin separating disc of your choice.
2. GRINDINGS - Use suction to remove grindings, and try to avoid mixing non-precious with precious grindings.

B. FITTING THE CASTING:

1. REMOVE INTERNAL NODULES - Carefully inspect the inside of each casting under magnification, and remove any irregularities.
2. EVALUATE THE FIT - Verify an acceptable level of occlusal/incisal seat and marginal seal, before proceeding to any additional finishing steps.
3. QUALITY CONTROL CHECK - Unsatisfactory castings (poor fit, overheated alloy, extensive porosity) should be remade.
4. INITIAL OCCLUSAL ADJUSTMENT - Articulate the casting and refine the occlusion, as necessary.

C. FINISHING THE CASTING:

1. STONES AND WHEELS - Use stones, carbide burs, and burlew wheels.
2. POLISHING -
 - a. Use Rx NP Polishing Compounds #1 and #2, or similar materials;
 - b. or use removable partial denture polishing compounds, such as Ti-Cor and Ti-H1 (Ticonium), rather than BBC (Jelenko).

NOTE: Non-precious alloys are more difficult to adjust, polish, and finish than their precious alloy counterparts. Therefore, allow additional time for these steps.

3. AVOID METAL CONTAMINATION - Put aside a set of finishing stones for this particular alloy, to prevent contamination of the metal.
4. ADJUSTMENT TECHNIQUE - Use the uncontaminated aluminum oxide abrasives to produce a smooth, even textured surface for all porcelain-bearing areas. Finish the metal surface in one direction, using light pressure.

—SECTION 11: ATTACHMENT 2—

VIII. PREPARATION OF THE METAL FOR PORCELAIN--NOVAREX

A. PREPARATION OF THE METAL SUBSTRATE:

1. NON-PORCELAIN BEARING SURFACES - Rubber-wheel all non-porcelain bearing areas (lingual/occlusal surfaces, interproximal struts, and metal collars) to remove all scratches prior to the application of porcelain.
2. PORCELAIN-BEARING SURFACES - Air-abrade the finished metal surfaces with a 50- μ m non-recycled, uncontaminated aluminum oxide (white) abrasive under 90-100 psi.
3. CLEANING - Steam clean the metal substrate, or place in distilled water in an ultrasonic unit for 10 min, after rubber-wheeling and air-abrading.

B. OXIDATION (DEGASSING) OF THE METAL SUBSTRATE:

1. LOW temperature setting - 1200 °F (649 °C)
2. HIGH temperature setting - 1900 °F (1040 °C)
3. Rate of rise - 90-100 °F (50-55 °C)
4. Atmosphere - FULL VACUUM (26-28 in. of Hg)
5. HOLD time at HIGH temperature - None
6. Appearance of the oxide layer:
 - a. A PROPERLY oxidized layer - YELLOWISH-BROWN color
 - b. An OVERoxidized layer - GREENISH color
 - c. An UNDERoxidized layer - BLUE-GRAY color

C. POST-OXIDATION TREATMENT: The manufacturer has indicated that two options are available in the management of the oxidized casting.

1. REMOVE THE OXIDE LAYER - Air-abrade all porcelain-bearing areas with non-recycled, 50- μ m aluminum oxide (white in color).
2. CLEANING - Steam clean or place in distilled water in an ultrasonic unit for 10 min, if you air-abraded the oxide layer. Proceed with the application of opaque porcelain after this cleaning step.
3. **RETAIN THE OXIDE LAYER** - You may apply opaque porcelain directly over the oxide layer (manufacturer's preference).

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IX. PORCELAIN COMPATIBILITY—NOVAREX

A. PORCELAIN SYSTEM COMPATIBILITY CHART: The following information has been provided by the alloy manufacturer (X):

<u>DENTAL PORCELAIN</u>	<u>PORCELAIN COMPATIBILITY</u>			
	<u>YES</u>	<u>NO</u>	<u>MARGINAL</u>	<u>UNKNOWN</u>
1. ARTIS-TECH (Jeneric) -	X			
2. BIOBOND (Dentsply) -			X	
3. CERAMCO (Johnson & Johnson) -	X			
4. CRYSTAR (Unitek) -			X	
5. JELENKO (Jelenko) -	X			
6. (BIOBOND) SHADEMATE (Dentsply) Reg-	Low- X		X	
7. VITA (Vident) -	X			
8. WILL-CERAM (Williams) -			X	

B. KNOWN OR SUSPECTED PORCELAIN-METAL INCOMPATIBILITIES: None

C. SPECIAL HANDLING INSTRUCTIONS: None

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X. PRE-SOLDERING INSTRUCTIONS—NOVAREX

A. RECOMMENDED MATERIALS:

1. SOLDER - Non-precious (Rx HF Solder - flows at 2200 °F/1204 °C);
precious (Rx PNP - flows 2075-2130 °F/1135-1166 °C)
2. FLUX - HF Flux
3. INVESTMENT - Hi-Heat Soldering Investment (Whip-Mix), or a NON-CARBON high-heat casting investment with distilled water (no special liquid).

B. PRE-SOLDERING TECHNIQUE: Use the MAGIC WAND torch (Williams) with its #248 tip, or the HARRIS 16-S torch with a 2N tip.

1. Grind, with aluminum oxide stones, all surfaces to be soldered. This process will remove any oxides or contaminants which would impede pre-soldering.
2. Create a GAP DISTANCE between 0.4 and 0.5 mm.
3. Mix investment so it is thick; turn fixed partial denture upside down; fill the inside of the castings with the mix; add a little extra on top; and invert onto a patty of investment. Do not let the casting settle into the investment.
4. Allow investment to reach final set; place in an oven at a temperature of 1000 °F (540 °C) for 20 min.
5. The heat source may be OXYGEN (5 psi) and natural GAS (2 psi).
[IDEALLY, manufacturer recommends OXYGEN (5 psi) and PROPANE (2 psi).]
6. Adjust torch to establish LIGHT BLUE inner cone flame(s) (NEUTRAL FLAME) approximately 1/2 in. long.
7. Drip the Rx HF solder rod in the LF flux, and try to put as much flux on the rod as it will hold; remove the invested bridge from the oven; and apply the flux to the joint to be soldered. The flux should flow through the joint. Pull the solder rod away, and heat the joint to bring the parent metal to a red hot (ORANGE-WHITE) color. At this time, put the solder rod TO THE JOINT AREA, and the solder should flow with the heat of the parent metal.
8. Remove the solder rod; pull back on the torch, but keep the bridge under the flame for about 5 sec to achieve a chemically bonded solder joint.
9. ALLOW TO BENCH COOL, and repolish the metal.
10. Follow the foregoing procedures when using the PRECIOUS SOLDER, Rx PNP, and the Rx PNP Flux.

XI. POST-SOLDERING INSTRUCTIONS—NOVAREX

A. RECOMMENDED MATERIALS: The porcelain units are assumed to have been glazed and polished, and the metal substructures designed appropriately for the post-soldering procedure.

1. SOLDER - WLF Solder (melting range 1310-1370 °F/710-743 °C)
2. FLUX - LF Flux is optional
3. INVESTMENT - Same as pre-soldering technique.

B. POST-SOLDERING TECHNIQUE: Use a porcelain furnace for this procedure. It is especially helpful if the oven has a muffle view port (also referred to as a "sight window") to permit observation of the soldering process.

1. Invest in the normal manner for oven soldering (protect all glazed porcelain surfaces by covering them with wax.)
2. Flux the joint generously.
3. Cut and place small pieces of solder in the joint. (Feed more into the joints as needed.)
4. Dry the investment slowly and thoroughly.
5. Vacuum-fire the work in a porcelain oven at approximately 1574 °F(857 °C).
6. The solder should flow readily and fill the joint space(s).
7. Cool the work slowly; remove the investment; and polish the joint areas.

SECTION 12:

THE BIOCOMPATIBILITY OF DENTAL CASTING ALLOYS

12-1. INTRODUCTION

One of the major advantages of the use of substantial quantities of gold in dental casting alloys has been the high degree of confidence in the biocompatibility of restorations made with such material. During the last decade, there was an unprecedented increase in the number of dental casting alloy formulations, many of which did not contain gold or some other noble or precious metal.¹ Low cost, non-precious nickel-chromium alloys appear to have been particularly popular,² especially those which contained beryllium. However, the absence of substantiated safety, efficacy, and studies of their long-term clinical reliability has raised concerns for the biocompatibility of the nickel- and the beryllium-containing alloys.¹

The situation is further compounded if clinicians and dental technicians do not know the composition of the alloys they use routinely. Dental casting alloys are an integral part of the practice of dentistry, so an appreciation of their biocompatibility and safety should be of interest to dental laboratory technicians, clinicians, and patients alike.

Unfortunately, it is not always easy to study these issues and draw clear-cut conclusions or correlations. Moreover, published reports appear in various publications (medical/dental journals, textbooks, etc.), and the information may not be widely read. Therefore, this Section incorporates pertinent findings, conclusions, and recommendations from several published reports which should be accessible to dental personnel. The literature is too extensive on this particular subject to permit other than an overview of important facts.

12-2. ESTIMATES OF THE COMMERCIAL USE OF NON-PRECIOUS ALLOYS

One survey of 1,000 commercial dental laboratories in 1978 reported that only 29% of the laboratories were using either nickel-chromium or cobalt-chromium alloys.³ In the ensuing years, the percentages of base metal alloy use increased to 66% in 1980, and then to 70% in 1981.³ Of all the non-precious systems used for PFM restorations, the majority were nickel-chromium as opposed to cobalt-chromium alloys.

12-3. THE BIOCOMPATIBILITY OF NICKEL

Nickel is the primary constituent in the nickel-chromium-beryllium and the nickel-chromium beryllium-free alloys used for the PFM restoration. Since these alloys are so inexpensive, they are also employed to fabricate full and partial metal crowns, as well as to cast posts and cores.

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Even alloys used for removable partial denture frameworks, such as Ticonium,* are nickel-chromium-beryllium formulations. So nickel, chromium, and beryllium are components of a wide array of materials that are routinely used in both civilian and military laboratories.

Exposure to nickel is not limited to dental alloys. In fact, nickel is part of everyday living due to its presence in air, food and cooking utensils, as well as the silver coins we carry.⁴

a. Nickel Sensitivity

Studies have shown that approximately 10% of the female population and less than 1% of the male population are nickel sensitive.⁵ A rate of 10% is considered high,⁴ yet among female dermatological patients, 10-30% of this patient population will have a positive patch test to nickel.⁶

Moffa and others reported that 80% of the confirmed nickel-sensitive patients they examined also had a positive response to nickel-chromium dental casting alloys.⁷ Therefore, the nickel in non-precious casting alloys is available as an allergen, and could be considered as a potential sensitizer.⁴

b. The 1974 Report of the Council on Dental Materials and Devices⁸

This 1974 Report to the American Dental Association presented an overview of the physical and mechanical properties, as well as the handling characteristics, of non-precious alloys intended for use in the fabrication of the PFM restoration.⁸ The subject of biocompatibility was addressed briefly, with conflicting reports of tissue acceptance. One conclusion was that the "clinical implications of the soft tissue implantation are not clear."⁸

The handling recommendations for nickel-containing alloys included in the 1974 Report centered on controlling the beryllium component of the alloys. At that particular time, no mention was made of any restrictions in the use of nickel-containing alloys.

c. The 1982 Report of the Council on Dental Materials, Instruments, and Equipment⁴

In the eight years following the 1974 Report, nickel-chromium alloys took over 70% of the market by some estimates.² Consequently, the 1982 Report focused on the carcinogenic risk, sensitivity risk, and nickel exposure standard for nickel-containing alloys.

The 1982 Report stated that no A.D.A. specifications existed for certification of non-precious (base) metals for fixed prosthodontics. However, these alloys are eligible for classification under the A.D.A. Acceptance Program--

* Ticonium Company, Albany, NY 12201.

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for metals used for Cast Dental Restorative and Prosthetic Devices--on the basis of submission of biological, laboratory, and clinical evidence of safety and efficacy. One precondition to the award of A.D.A. Acceptance or Provisional Acceptance is that the alloy package must bear the following warning label: **"CAUTION: THIS ALLOY CONTAINS NICKEL AND SHOULD NOT BE USED FOR INDIVIDUALS WITH A KNOWN NICKEL SENSITIVITY."**

It was also pointed out that the data implicating nickel and nickel compounds were derived from epidemiologic studies of workers associated with nickel industries. No direct evidence existed which implicated the use of nickel-containing dental alloys with induced nickel sensitivity.

Since a significant portion of the population may be allergic to nickel, it was emphasized that particular attention should be focused on identifying the nickel-sensitive patient. An accurate and complete health history was recommended, since nickel-containing alloys were contraindicated in patients with a known or suspected nickel sensitivity.

Also, "there was no experimental evidence that nickel compounds are carcinogenic when administered by oral or cutaneous routes."⁴ High incidence of cancer of the respiratory organs has been noted, however, in workers associated with nickel refining, smelting, and electroplating. Exposure to airborne nickel or its compounds was considered a major contributing factor in a large portion of the deaths from lung and nasal cancer in nickel refinery workers. Based on this information, the 1982 Report recommended that "precautions be taken to prevent the aspiration of nickel-containing dust produced during grinding operations."

Emphasis was also placed on the responsibility of dentists to know the composition of the alloys they use and whether or not these alloys contain nickel. Dentists should inform their patients of the make-up of the alloys used, and document that information in each patient's chart.

The report summary pointed out that no direct evidence was available to indicate that nickel sensitivity could be caused by the use of nickel-containing alloys. Moreover, "the question remains unanswered as to whether there is a danger that long-term intraoral exposure to a nickel-containing dental alloy can result in an induced nickel sensitivity."⁴

The 1982 Report concluded: "Therefore, based on extant information, the use of nickel-containing dental alloys should be done in a knowledgeable manner."⁴

d. The 1985 Report of the Council on Dental Materials, Instruments, and Equipment²

The 1985 Report for the Council was not prepared by the same individual who wrote the 1974 and 1982 articles on nickel- and beryllium-containing alloys. By comparison, the 1985 Report provided additional data from studies dealing with nickel sensitivity and nickel allergy, and expressed more serious concerns for the biocompatibility of nickel-base alloys.

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An example was from a study reported by Moffa et al.,⁷ in which one of the sensitized patients reported a burning and itching sensation during the first 24 hr. That same patient had a slight erythematous reaction on the palatal mucosa. In addition, three patients reported itching at the site of the nickel patch test, while the intraoral appliance containing nickel was in use. The 1985 Association Report assessed this information in the following manner:

"Such reactions at remote sites may result in underestimations of the incidence of allergic response triggered by intraoral appliances."² In other words, the mere absence of intraoral changes may not indicate that adverse reactions have not occurred. The implication is that changes may occur from the placement of nickel-base alloys, but since they are remote from the oral cavity, no direct connections have been made between the two events to date. The report recommended that "as a conservative approach, the dentist should adopt the policy that evidence of a previous allergic response to any alloy is sufficient to contraindicate the use of nickel-based alloys."²

Despite the reported correlation between nickel and cancer among workers in the nickel industry, emphasis was placed on the statement that "it appears that the potential carcinogenic risks of nickel are less likely to affect dental patients." Dental technicians, on the other hand, "should be provided with adequate protective facilities so that such risks are minimized" due to "their far greater time-weighted exposure to nickel and beryllium."²

The summary of the 1985 Report contained several highly significant statements regarding the nickel-chromium alloys. First, it was pointed out that "despite the widespread use of nickel-based alloys, claims for the safety of these alloys have not yet been accepted universally." More importantly, "the dental profession may be overgeneralizing the relative safety of nickel alloys because of the lack of allergy-induced intraoral lesions observed in private practices."

e. Other Pertinent Reports on Nickel Biocompatibility

Piliero et al. studied the biocompatibility of various of dental casting alloys, including one that contained nickel, chromium, and beryllium, in hamsters.⁹ They were unable to detect any adverse weight changes or abnormal behavioral patterns during the 14-day study. Gross examination of the cheek pouches, where the alloy specimens were placed, did not differ from the control animals. It is difficult to assess the impact of a report such as this because the study was only two weeks in length. It remains to be seen what the findings might be at 6 months, 2 years, 5 years, etc. Restorations are placed with the expectation that they will last for years rather than two weeks.

In contrast, one of the more controversial articles to appear in the dental literature was a preliminary report, on the effects of nickel and dental amalgam on T-lymphocytes, published in 1984.¹⁰ The restorations of three patients were removed. The type of restorative material used was switched each time while the T-lymphocyte level was measured with every change. The

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T-lymphocyte levels decreased more than normal when dental amalgam restorations and a nickel-chromium beryllium-free PFM crown were inserted. Replacing the amalgams and nickel-based crown with acrylic resin provisional restorations, cast gold restorations, or an all-ceramic crown resulted in a corresponding increase in the total number of T-lymphocytes.

The implication was made that dental amalgam and nickel-based casting alloys were responsible for the reduction in T-lymphocyte levels. Since the human T-lymphocytes regulate the immune response system, it was concluded that normal immune function might be impaired due to the reduction in the quantity, quality, and ratio of the helper and suppressor T-lymphocytes. The conclusions of such a preliminary report merit our attention. However, more research is needed in order to determine the ramifications of such a study.

Strauss and Eggleston recently published a case report in which they suggested that a female patient may have developed IgA nephropathy as the result of placement of PFM crowns constructed from a nickel-base alloy.¹¹ They contended that the kidney disorder "occurred following placement of nickel alloy base dental crowns and showed evidence of resolution following their removal years later." In this report, Strauss and Eggleston stated that they "suggest the possibility that intraoral nickel placement may have induced immune-mediated events resulting in this form of immune complex glomerulonephritis." Moreover, they concluded that their "patient may represent an example of nickel-induced sensitization..." Should this conclusion prove to be true, it would represent the most serious challenge to the long held belief that "currently, there is no direct evidence to indicate that the intraoral use of nickel-containing alloys will result in an induced nickel-sensitivity."⁴

Covington et al. used 30 casting alloys, 14 of which contained nickel or nickel and beryllium, to study nickel and beryllium release from the alloy surface.¹² After preliminary work to determine the nature of nickel release in human saliva at pH levels of 2 through 6 for 5, 10, 20, and 30 days, the specimens were immersed for 120 days. The results of the 120-day analysis for nickel and beryllium were compared with those of the 5-, 10-, 20-, and 30-day incubation levels.

These results indicated that allergic responses to nickel-containing cast crowns may occur through two possible mechanisms¹²: First, a patient who already is sensitized to nickel, whether previously diagnosed or not, may develop a reaction from the dissolution of nickel by the saliva and from the subsequent ingestion of the metal.¹² Second, the nonsensitized patient may become sensitized by the dissolved and ingested nickel or by local irritation from gingival fluid exchange.¹² In addition, the presence of beryllium in the alloy appeared to increase the amount of nickel dissolution.¹² In fact, "the combination of nickel and beryllium in an alloy potentiates the dissolution of the other in acidic media".¹²

On the basis on their study, Covington et al. concluded that "nickel-beryllium dental casting alloys possess the potential to be a significant hazard to the laboratory technician, dentist, and patient."¹²

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f. A Summary of Important Information on Nickel

From the reports cited in the discussion of nickel sensitivity and allergy, the following information about nickel should be considered:

1. Nickel is one of the most common allergens and the most potent sensitizer of all metals.¹²
2. Approximately 10% of all women and less than 1% of all men are nickel sensitive.⁵
3. Chronic exposure to nickel-containing jewelry and stainless steel utensils is believed to be linked to nickel sensitivity and/or nickel allergy.¹²
4. "Dermatologists currently believe that ingestion of small quantities of nickel may be a more important factor in allergic response to nickel than external contacts with the metal."¹²
5. Beryllium apparently enhances the release of nickel.¹²
6. Nickel-containing casting alloys may adversely affect the quantity of T-lymphocytes in humans.¹⁰
7. A case of suspected nickel-induced sensitivity brought about from the use of a nickel-containing PFM alloys has been reported.¹¹
8. "Despite the widespread use of nickel-based alloys, claims for the safety of these alloys have not yet been accepted universally."²
9. "The dental profession may be overgeneralizing the relative safety of nickel alloys because of the lack of allergy-induced intraoral lesions observed in private practices."²

12-4. THE BIOCOMPATIBILITY OF BERYLLIUM

Beryllium is a popular component of the nickel-chromium alloy system because it lowers the melting range of the alloy, improves castability, acts as a hardener, and helps control oxide formation for the porcelain-to-metal bond. Of the nickel-base alloys for the PFM restoration, the nickel-chromium-beryllium group seems to be the more popular of the two.

The weight percentage of beryllium in PFM alloys generally ranges between 1.7 and 1.8%, and rarely exceeds 2%.² The Ni-Cr-Be alloy formulations for removable partial dentures may contain less than 1% beryllium, by weight.

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a. The 1974 Report of the Council on Dental Materials and Devices⁸

Beryllium was clearly presented in this Report as a "potentially toxic" material "under uncontrolled conditions."⁸ It was emphasized that the main hazards associated with exposure to beryllium and beryllium compounds came from the melting, grinding, and milling of metals containing these substances. It was further pointed out that the primary route of exposure has inhalation of beryllium fumes and dust produced from the melting and grinding of beryllium-containing alloys. Therefore, adequate local exhaust ventilation should be provided when such operations are performed.

According to the Report, no instances of beryllium toxicity had been reported, and no evidence existed that small amounts of grinding and polishing of restorations in the mouth would generate toxic levels of beryllium dust.

Despite these assurances, the Report emphasized the need to comply with the Occupational Safety and Health Administration (OSHA) guidelines for handling beryllium-containing alloys. The handling recommendations for dental laboratories included: use adequate local exhaust ventilation; wear approved respirators when local exhaust ventilation is not operating or until it is installed; ensure adequate general ventilation in the laboratory; place warning signs in areas where dust is produced from the grinding of beryllium-containing alloys; exchange laboratory coats for clean ones on a weekly basis; remove dust from clothing and work areas with power suction rather than air hoses; inform every employee of the hazards, and advise them of the proper handling of beryllium-containing alloys.

In addition, manufacturers should inform laboratory purchasers of the beryllium content and the need for handling safeguards. Moreover, the laboratories should advise the dentist of the presence of beryllium in fixed or removable partial denture prostheses, so that the dentist can take appropriate steps when making adjustments.

b. The 1982 Report of the Council on Dental Materials, Instruments, and Equipment⁴

The 1982 Report dealt exclusively with the issues surrounding the biocompatibility of nickel, and did not include any additional information on beryllium or beryllium compounds.

c. The 1985 Report of the Council on Dental Materials, Instruments, and Equipment²

In a discussion of the hazards of and precautions in handling beryllium-containing alloys, it was noted that despite the small weight percentage of beryllium (less than 2%), "the amount of beryllium vapor released into the breathing space during the melting of nickel-chromium-beryllium alloys may

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be significant over an extended period."² A nickel-chromium alloy which contains 1.8% beryllium on a weight basis will contain 10.7% beryllium on an atomic basis, due to the fact that beryllium has an atomic weight of 9 and a density of 1.85.¹² Therefore, to make up 1.8% of the weight of an alloy, approximately 10.7% of the total volume of the metal is beryllium.²

The 1985 Report mentioned that "exposure to beryllium may result in acute and chronic forms of beryllium disease." Equally important was the statement that "workers exposed to moderately high concentrations of Be dust for a short time or exposed to low concentrations of beryllium for a long time, may experience symptoms of acute diseases."¹² The types of physiological responses which one may experience "vary from contact dermatitis to severe chemical pneumonitis, which can be fatal."¹² Also, the symptoms of chronic disease may not appear for years following the time of exposure. This point was emphasized when the two-week study by Piliero et al. was discussed.⁹ Some of the symptoms of beryllium disease included coughing, chest pains, and general weakness due to pulmonary dysfunction.

According to a 1976 Report, the incidence of lung cancer among dental laboratory technicians was then 4.05 time higher than that of all the other occupations identified.¹³ No direct link was intended to be made with Be; for dental technicians have a higher incidence of cigarette smoking and also handle other potentially harmful materials, such as investment powder, gypsum products, dental porcelain, nickel and chromium alloy grindings, and some may still be using asbestos.²

As mentioned in the discussion on nickel, the Report emphasized that the "safety of these alloys has not yet been accepted universally."² At the same time "the dental profession may be overgeneralizing the relative safety of nickel alloys because of the lack of allergy-induced intraoral lesions observed in private practices."²

d. Other Pertinent Reports on Beryllium Biocompatibility

In 1984, Covington et al. reported a brief summary of the results from a study of nickel-chromium-beryllium alloys in which they noted that beryllium has a tendency to migrate and localize on the alloy surface.¹⁴ The alloy surface concentrations of Be ranged from 14 atom% for an ingot to 39 atom% for an incubated sample.¹⁴

In a comprehensive report of the Covington study, published in 1985,¹² the study findings were presented in greater detail. In the discussion of beryllium, it was reported that "every beryllium compound cited in the literature seems to have some hazard associated with it."¹² More importantly, it was pointed out that, after moving to the alloy's surface, beryllium may then go into solution (leave the alloy surface), and therefore may be ingested and subject to attempts by the body to remove it. The presence of beryllium in an alloy also apparently increases nickel dissolution.

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The exact mechanism for the handling of beryllium by the human body is not known and is subject to speculation. Covington et al. feel the end product of beryllium ingestion may be "beryllium hydroxide, which is insoluble and unlikely to be cleared by the body; much the same as mercury."¹³ However, they pointed out that "to what extent the ingested beryllium is transported into the body is not known."¹² Yet, if their theory on the behavior of beryllium is correct, then "even the lowest levels would be expected to have a cumulative effect (also similar to mercury) in terms of chronic exposure."¹²

The Covington article concluded with the statement: "it is our opinion that nickel-beryllium dental casting alloys possess the potential to be a significant hazard to the laboratory technician, dentist, and patient."¹²

In 1982, a dental laboratory technician wrote a letter to the editor of Dental Laboratory Review in which he described how his health deteriorated over a three-week period.¹⁵ During this time, he used 15 oz of a nickel- and beryllium-containing non-precious alloy, but followed the recommended handling instructions (mask, suction, well ventilated work area). What started as an unproductive cough progressed to violent coughing spells and to loss of breath, was accompanied by weight loss. The technician reported that he was examined by a physician and told that he had acute beryllium poisoning. In a subsequent issue of Dental Laboratory Review the editor mentioned that the Rocky Mountain Center for Occupational & Environmental Health in Salt Lake City, Utah, was undertaking a study of 100 technicians in the area.¹⁶ Unfortunately, there was no independent substantiation of this claim.

The feature article of the January 1985 issue of the Journal of the American Dental Association included beryllium as one of the environmental hazards of concern to dentists.¹⁷ According to the article, "direct skin contact with beryllium particles or beryllium fumes also poses a health threat to dental personnel".¹⁷ The article did not mention whether continued handling of beryllium-containing alloys represented direct skin contact with beryllium particles or not. However, it was reemphasized that beryllium disease may not cause symptoms for several years after exposure.¹⁷ The first signs of beryllium toxicity include weight loss, fatigue, and general malaise so common with many other illnesses that beryllium poisoning may not be suspected immediately as a possible cause.¹⁷

For physical protection, it was recommended that clinicians grinding beryllium-containing alloys wear face masks and gloves, and use the washed field technique, along with high velocity suction. Intraoral grinding and polishing of nickel-chromium-beryllium alloys was discouraged. Furthermore, it was stressed that dentists should be aware of the contents of the casting alloys they used for the obvious protection of the patient and the clinician.

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e. A Summary of Important Information on Beryllium

Based on the references just cited, the following information about beryllium should be understood:

1. Although Be may compose only approximately 1.8% of the weight of a PFM alloy, beryllium accounts for approximately 10.7% of the alloy's atomic volume.²
2. Beryllium reportedly migrates to the alloy surface.^{12,14}
3. The surface concentration of beryllium in a Ni-Cr-Be alloy may be as much as 35%.¹²
4. "Direct skin contact with beryllium particles and beryllium fumes poses a health threat to dental personnel."¹⁷
5. Beryllium may leave the surface of a Ni-Cr-Be alloy and go into solution.¹²
6. Nickel dissolution seems to be increased by the presence of beryllium.¹²
7. Beryllium migration to the alloy's surface may continue should a vacancy occur in the oxide layer through dissolution.¹²
8. Every beryllium compound cited in the literature seems to have some hazard associated with it.¹²
9. The beryllium compound, beryllium hydroxide, is insoluble and unlikely to be cleared by the body.¹
10. The extent to which beryllium is transported in the human body is unknown.¹²
11. The symptoms of beryllium disease may not appear for years after the actual exposure.¹⁷
12. There has been at least one reported claim of beryllium poisoning of a dental technician who used a Ni-Cr-Be alloy.¹⁵

12-5. THE BIOCOMPATIBILITY OF COBALT

Cobalt is the major constituent of the cobalt-chromium non-precious PFM alloy system, and may account for 53-68% of a Co-Cr alloy's composition (refer to Section 11).² Of the high palladium precious alloys, the high palladium-cobalt group in this study contained up to 8% cobalt (refer to Section 7).

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In terms of biocompatibility, less than 1% of the population is estimated to be allergic to cobalt, and the allergy is found mainly among women.⁵ Patch testing has been used to diagnose contact sensitivity. However, additional testing is recommended for patients with a history or clinical symptoms suggesting a possible allergy to a cobalt-containing alloy.⁵

Cobalt-containing alloys have also been used to fabricate human prosthetic devices, and there have been no indications at this time that these alloys may be carcinogenic.¹⁸

12-6. THE BIOCOMPATIBILITY OF CHROMIUM

Chromium is the second major element of the three major non-precious alloys systems: nickel-chromium-beryllium, nickel-chromium beryllium-free, and cobalt-chromium. The percentage of chromium in these alloys may range from 13-31% by weight, with the highest percentages in the cobalt-chromium system.

Since the Co-Cr alloys are being offered as non-nickel, non-beryllium, non-precious alloys, it is important to consider the biocompatibility of both major constituents. Some association has been reported between certain forms of chromium and lung cancer in industrial exposures.⁵ However, no association has been reported between chromium and cancer from the dental and medical applications of chromium-containing alloys.⁵

Chromium has been known to sensitize individuals, and to result in the development of a chronic dermatitis from the chromate salts produced by the corrosion of the alloys.⁵ The dermatitis may linger for years, and reportedly may produce serious cosmetic problems.⁵ However, allergy to chromium is believed to be rare.⁵ Patch testing for chromium sensitivity has the potential to sensitize the individual from the test itself.⁵

12-7. THE 1984 WORKSHOP: THE BIOCOMPATIBILITY OF METALS IN DENTISTRY

In the summer of 1984, the American Dental Association hosted the Workshop of the Biocompatibility of Metals in Dentistry, sponsored by the National Institute of Dental Research, National Institutes of Health.⁵ The purpose of the Workshop was to review existing scientific evidence and the literature, as related to the metals currently used in dentistry.

Some of the information presented in the preceding portions of this Section has been drawn from the Workshop proceedings, as well as the published final report.⁵

As mentioned in Section 12 of Volume I,¹⁹ the report could not include all the comments made during the Workshop. One informal recommendation made to the conference at large was a call for a moratorium on the continued use of nickel- and beryllium-containing alloys. The point was made that several precious metal alternative alloy systems are currently available which do not involve issues of biocompatibility or sensitivity.

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12-8. ENVIRONMENTAL SURVEY OF THE DENTAL LABORATORY

If nickel- and beryllium-containing non-precious alloys are used on a regular basis in a dental laboratory, then an annual survey for nickel and beryllium levels is recommended.

For technicians who use these alloys routinely, an 8-hr air sampling should be accomplished, along with the collection of dust from common work areas throughout the facility. Casting areas and suction equipment should also be evaluated.

A specific survey plan can be arranged by your base bioenvironmental engineering department, and scheduled to collect data on a representative work day. Test results will be provided in writing for comparison with the Occupational Safety and Health Administration (OSHA) standards. An acceptable maximum concentration of airborne beryllium is $2 \mu\text{g Be/m}^3$ time-weighted average for an 8-hr day, and a peak concentration of $25 \mu\text{g Be/m}^3$ for a 30-min sample.¹⁷

12-9. NICKEL AND BERYLLIUM BIOCOMPATIBILITY AND THE A.D.A. ACCEPTANCE PROGRAM

Several of the non-precious alloys in this study have been awarded acceptance or provisional acceptance under the Acceptance Program of the American Dental Association. However, consumers should bear in mind that those designations were bestowed on the alloys in question prior to the majority of published reports cited in this Section.

In other words, the American Dental Association, like the dental profession in general, was unaware of the proposed theories on nickel and beryllium migration and of nickel and beryllium dissolution. At the time these alloys were granted their acceptance, the Council on Dental Materials, Instruments, and Equipment also did not know of the reports suggesting a link between nickel-base alloys and nickel-induced sensitivity.

Therefore, it may be unwise to assume that the award of A.D.A. acceptance or provisional acceptance assures human biocompatibility.

12-10. RECOMMENDATIONS

In the interval following the publication of Volume I,¹⁹ no reports have undermined the recommendation that precious metal systems should be considered the alloys of choice. In fact, new reports have been published^{2,11,12} which indicate that the biological effects of both nickel and beryllium may not have been fully understood and, perhaps, have been underestimated.

It now appears that both nickel and beryllium may be released from the alloy surface, go into solution, and be transported into the body.¹² In the case of beryllium, it has been suggested that the migration to the surface and subsequent dissolution may be a continuous process, and not prevented by a "protective" oxide layer as was once thought.¹² Moreover, the repercussions of these events are, as yet, not completely understood.

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The behavior patterns of nickel and beryllium are not restricted to the PFM alloys, and may also involve Ni-Cr-Be removable partial denture alloys. The mechanism of Ni and Be release is not limited to ion exchange by fluids in the gingival sulcus. The large surface area of removable partial denture frameworks apparently may also be subject to the same processes of nickel and beryllium dissolution into human saliva. The implication that there may be a cause and effect relationship between nickel-containing alloys and systems disease should be of even greater concern.¹¹

An interesting analogy develops when beryllium is compared to asbestos. Asbestos fibers are carcinogens,¹⁷ while beryllium is known to be responsible for causing cancer in occupationally exposed workers.⁵ Exposure to airborne asbestos fibers has been associated with lung cancer, pulmonary asbestosis, and fibrosis.¹⁷ The inhalation of dusts and fumes of beryllium and its compounds is the primary route of exposure,⁸ and chronic beryllium exposure is responsible for berylliosis. The effects of repeated exposure to asbestos are thought to be cumulative.¹⁷ A suspected beryllium end-product is beryllium hydroxide, "which is insoluble and unlikely to be cleared from the body; much the same as mercury."¹² The "effects of exposure to asbestos fibers may not manifest themselves immediately in the exposed worker."¹⁷ Beryllium disease may not cause any clinical symptoms for several years after exposure.¹⁷

The similarities between asbestos and beryllium exposure are strikingly similar, yet prevailing attitudes toward each are markedly different. Asbestos and asbestos-containing materials are not permitted in the dental laboratory. However, there are no similar restrictions on the routine use of beryllium-containing alloys at the present time, other than the recommended OSHA handling instructions and the contraindication of their use in nickel-sensitive patients.

In light of the known and suspected biological implications associated with nickel- and beryllium-containing alloys, the palladium-base precious metal alloy systems should be considered as alternatives to gold-base alloys. Refer to Sections 6, 7, and 8 for descriptions of the properties and handling characteristics of the high palladium-copper, the high palladium-cobalt, and the palladium-silver alloys.

Individuals interested in using non-precious alloys, particularly for removable partial denture frameworks, should consider the cobalt-chromium system. According to the 1985 A.D.A. Association Report:

"The potential for dermatologic and systemic effects that may occur in patients and dental personnel because of exposure to cobalt alloys must not be overlooked. Although sensitivity reactions may be of some concern, the toxicity potential of cobalt-chromium alloys appears to be insignificant."²

One other indication that the present non-precious alloy systems are not without problems is the program under way at the National Bureau of Standards to evaluate titanium cast crowns.²⁰ Titanium is the ninth most abundant material in the earth's crust, and "extremely biocompatible with the human body."²⁰ However, to make titanium crowns requires new casting investments (zirconia-based), and the use of an inert gas atmosphere in an especially

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designed electric-arc furnace.²⁰ Perfection of a titanium-base non-precious alloy system is probably not being sought solely for any anticipated financial benefit. Although existing non-precious alloys are already very inexpensive, alloy manufacturers and distributors might be able to improve profit margins with a titanium-base alloy. However, a major advantage, and one which is only mentioned in passing, may be the opportunity to offer a BIOCOMPATIBLE non-precious alloy.

Should a titanium-base alloy be available with workable supporting technology, we very well may see a change in attitude toward nickel and beryllium by the dental profession. Public perceptions also may impact these issues in the future.

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SECTION 13:

ECONOMIC CONSIDERATIONS OF DENTAL CASTING ALLOYS

13-1. FACTORS AFFECTING THE COST OF AN ALLOY

The total cost of an alloy to the consumer is based upon many factors-- not merely on the price per ounce of the material. Greater consideration should be given to the relative cost, per restoration, by including the ease of handling during processing. This factor would include all the man-hours required to produce a restoration from wax-up to final finish. This broader appreciation of the many technical aspects leading to a completed case helps establish a more equitable basis for comparison of different alloy systems.

For example, despite general training in the processing of the gold-base PFM alloys, additional experience is needed to accommodate the unique processing requirements of the non-precious alloys. Casting the nickel- and cobalt-base metals is a skill which has to be acquired, and which may be preceded by unsuccessful trial-and-error testing. Since the non-precious alloys are extremely hard, they require more time for adjusting and finishing. Careful attention to the wax-up is the method to reduce finishing time, but it is an area often overlooked. Consequently, the economy of a low-cost alloy can be offset by the added expenditure of additional finishing time. Miscasts and remakes, due to over-heating or mishandling an alloy, make these "economical" alloys more expensive than anticipated.

Some additional general considerations which can affect any alloy system, either precious or non-precious, include: price variations within an alloy system, the effect of alloy density on productivity, the value of weighing wax patterns, and the influence of ingot size on metal expenditure.

13-2. PRICE VARIATIONS WITHIN AN ALLOY SYSTEM

Pricing various alloys within a given alloy system is important. Costs can vary substantially for precious alloys within the same system. Even the non-precious systems will reflect substantial variations in price for the same quantity of alloy. Such distinctions may, in part, be attributed to the quality, level of testing, and research behind the development of an alloy. Participation in the American Dental Association Acceptance Program is very costly, and this expense will be reflected in the price of an alloy. If all factors are equal, an A.D.A. Acceptable alloy should be considered over an undesignated alloy, despite any anticipated savings.

It is equally important that price not be used as the sole criterion for alloy selection or substitution. Although two casting alloys may list the same constituents and the same percentage composition, the metals may NOT be of comparable quality. The purity of the elements in the alloy may differ, as may the sequence in which the ingredients are added to create the character of the final product. Such distinctions are not reflected on the alloy's package, just its price. Therefore, if you have proven success with a metal

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porcelain combination, do not agree to alloy substitutions without testing the compatibility of the new alloys with your dental porcelain.

13-3. THE EFFECTS OF ALLOY DENSITY ON PRODUCTIVITY

One of the added advantages of the non-gold base, alternative alloys is that they are lower in density than the high gold and gold-palladium metals. In other words, less metal can be used to cast restorations of equal volume. This fact has been particularly emphasized for the non-precious metals, but has application to the palladium-base alloys as well. In addition, many of the non-gold base metals can be waxed and cast routinely at 0.3- to 0.4-mm thicknesses. It is not uncommon for users of gold-base alloys to wax to 0.5 mm, cast, and then finish the metal down to their desired thickness. Aside from the obvious initial savings in the purchase price of a non-gold base vs. gold-base alloy, an added benefit of a lower density metal is a thinner, lighter weight casting requiring less alloy to be produced. Less metal per restoration can be translated into more castings per ounce and greater productivity.

13-4. THE BENEFITS OF WEIGHING WAX PATTERNS

Estimating the amount of alloy needed to cast a particular case is often guesswork without weighing the wax patterns. More importantly, cases sprued indirectly should be cast without a button to avoid competition with the connector bar as the reservoir area in the spruing system. This result can be obtained by weighing the sprue system and estimating the quantity of metal needed using a conversion table (Table 1, at the close of text). Precious alloys are available in 2-dwt, and sometimes 1-dwt, ingots as compared with the 2- to 4-dwt ingots of non-precious metals. Consequently, it is easier to cast with the correct quantity of metal when using a precious alloy. More importantly, the buttons of precious alloys are reusable, while some alloy manufacturers recommend using only virgin non-precious metal for each casting.

13-5. THE INFLUENCE OF INGOT SIZE ON METAL EXPENDITURE

It has been pointed out that large non-precious alloy ingots are of greater benefit to facilities which cast large single piece restorations or multiple unit cases. Smaller laboratories accustomed to casting single unit cases would find a non-precious alloy of 2 to 3-dwt size more advantageous. We have accepted the 2-dwt precious alloy ingot, but the 1-dwt ingot is much easier to work with, especially when wax patterns are weighed and indirect spruing is used. Casting with the correct volume of metal not only makes good sense, but is also economical.

13-6. A COMPARISON OF ALTERNATIVE ALLOY SYSTEMS

The prices of the precious and the non-precious alloys, respectively, are presented in the following Attachments 1 and 2. Consult each alloy manufacturer or distributor for current price information.

--SECTION 13: ATTACHMENT 1--

PRECIOUS ALLOY SYSTEMS PRICES
(As of February 3, 1986)

	<u>Price Per Ounce</u>	<u>Price Per Pennyweight</u>
a. HIGH PALLADIUM-COPPER:		
1). Athenium -	\$110.60	\$5.53
2). Deguplus 2 -	\$143.71	\$7.19
3). Naturelle -	\$122.00	\$6.10
4). PG-80+ -	\$147.54	\$7.38
b. HIGH PALLADIUM-COBALT:		
1). PTM-88 -	\$123.60	\$6.18
2). Supra AP -	\$121.00	\$6.05
c. PALLADIUM-SILVER:		
1). Bak-On SP -	\$110.05	\$5.50
2). Jel-5 -	\$96.40	\$4.82
3). Pors-On -	\$117.32	\$5.87
4). Will-Ceram W-1 -	\$86.80	\$4.34

[GOLD-BASE ALLOYS AND THEIR COMPARATIVE COSTS]

d. GOLD-PALLADIUM:		
Olympia -	\$296.20	\$14.81
e. GOLD-PLATINUM-PALLADIUM:		
Jelenko "O" -	\$423.40	\$21.17
f. MARKET PRICE OF GOLD:	\$346-348/oz price range	

--SECTION 13: ATTACHMENT 2--

NON-PRECIOUS ALLOY SYSTEMS PRICES

(As of September 1985)

	<u>Quantity</u>	<u>Purchase Price</u>	<u>Price Per Pennyweight</u>
a. NICKEL-CHROMIUM-BERYLLIUM:			
1). Bak-On NP -			
	1 oz @	\$ 20.50 per oz	\$ 1.03
	5-10 oz @	\$ 14.50 per oz	\$ 0.73
	50-100 oz @	\$ 8.00 per oz	\$ 0.40
2). Biobond II -			
	One 2-oz jar	\$ 28.00 per jar	\$ 0.72
	Five 2-oz jars	\$ 26.64 per jar	\$ 0.67
	Ten 2-oz jars	\$ 24.48 per jar	\$ 0.61
	One 25-oz jar	\$ 272.00 per jar	\$ 0.54
	Two 25-oz jars	\$ 252.00 per jar	\$ 0.51
	Four 25-oz jars	\$ 232.00 per jar	\$ 0.47
3). Litecast B -			
	Any quantity	\$ 12.00 per oz	\$ 0.60
4). Rexillum III -			
	Any quantity less than 100 oz	\$ 12.00 per oz	\$ 0.60
	(5-oz minimum order required)		

(Cont'd. on facing page)

—SECTION 13: ATTACHMENT 2—

NON-PRECIOUS ALLOY SYSTEMS PRICES

(As of September 1985--Cont'd. from previous page)

	<u>Quantity</u>	<u>Purchase Price</u>	<u>Price Per Pennyweight</u>
b. NICKEL-CHROMIUM (BERYLLIUM-FREE):			
Forte -	5 oz @	\$ 14.40 per oz	\$ 0.72
	25 oz @	\$ 12.80 per oz	\$ 0.64
	50 oz @	\$ 12.00 per oz	\$ 0.60
	100 oz @	\$ 11.20 per oz	\$ 0.56
	250 oz @	\$ 10.40 per oz	\$ 0.52
	500 oz @	\$ 9.60 per oz	\$ 0.48
	750 oz @	\$ 8.80 per oz	\$ 0.44

c. COBALT-CHROMIUM:

1). Cobond -

One 2-oz jar	\$ 28.80 per jar	\$ 0.72
Five 2-oz jars	\$ 26.64 per jar	\$ 0.67
Ten 2-oz jars	\$ 24.48 per jar	\$ 0.61
One 25-oz jar	\$ 272.00 per jar	\$ 0.54
Two 25-oz jars	\$ 252.00 per jar	\$ 0.51
Four 25-oz jars	\$ 232.00 per jar	\$ 0.47

2). Novarex -

Any quantity less than 100 oz	\$ 21.00 per oz	\$ 1.05
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(5-oz minimum order required)

SECTION 14:

LABORATORY SAFETY

14-1. GENERAL CONSIDERATIONS

The guidelines for safety in the dental laboratory are described in AFM 162-6.* The reader is encouraged to review that material in its entirety. Information presented in this Section focuses on factors directly related to the safe processing of dental casting alloys, particularly the non-precious metals containing nickel and beryllium.

14-2. PHYSICAL PROTECTION

Laboratory procedures, such as torch casting and finishing, require very specific precautions to protect the laboratory technician properly from any potential insult or injury. It is imperative that the following minimum safety measures be followed to ensure a reasonable level of caution and protection.

a. TORCH CASTING

Whenever torch-melting an alloy with a gas-oxygen system in an exposed environment, we recommend you wear the following safety equipment:

1). Welder's Goggles and Mask - Clear safety glasses may be satisfactory when casting the lower melting precious alloys. However, the non-precious alloys require hotter flames. Therefore, a dark protective lens is needed to prevent eye damage from the intensity of the flame, as well as any metal spills which might occur from a miscast. The welder's mask offers the most physical protection, since the entire face and neck are shielded, and a protective lens permits visualization of the molten alloy. The tinted lenses enable the dental technician to assess the character of the alloy and more readily estimate the appropriate moment to cast.

2). Insulated Gloves - While burnout temperatures of 1200-1300 °F (649-704 °C) may not appear to pose a threat, removal of an investment ring from a 1600 °F (871 °C) oven can potentially result in injury to the skin. The intense heat can not be averted by working quickly. Since the technician is more likely to drop the heated ring (or possibly remove the wrong one) in order to avoid being burned, the use of an insulated glove is essential. You may wish to purchase a non-asbestos glove, as offered for sale by: Lab Safety Supply, P.O.Box 1368, Janesville, WI 53547-1368.

3). Laboratory Coat - When casting, protect your outer clothing by wearing a laboratory coat. A coat provides an initial barrier against any molten metal which might become airborne during a miscast.

* Department of the Air Force, "The Dental Laboratory Environment," Ch. 2. Air Force Manual (AFM) 162-6. Washington, D. C.: U.S. Government Printing Office, 15 Nov 1982.

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4). Surgical Mask - If all you have available is a pair of welder's goggles, be sure to wear a surgical mask to decrease your exposure to vapors produced during casting, and to physically protect a larger area of the face.

b. ADJUSTING AND FINISHING.

The basic principles of physical protection apply to all the various stages of adjusting and finishing a PFM substructure. The concerns over the biocompatibility of nickel and beryllium reinforce the need to maximize safety, if these non-precious alloys are used.

1). Safety Glasses - Standard eyeglass frames with protective lenses offer limited protection, due to the large amount of unshielded area. Wear special goggles or safety glasses, shielded from below and laterally.

2). Surgical Mask - Whether removing a sprue, grinding, finishing, or polishing a restoration, wear a surgical mask to prevent the inhalation of airborne particles of metal and abrasive.

3). Laboratory Coat - Wear a laboratory coat, whenever grinding or finishing, to prevent the removal of metal and abrasive particles from the laboratory and possible transportation to your car or home.

14-3. HIGH-SPEED AIR EVACUATION

Whenever possible, avoid the use of a hand-held belt-drive dental laboratory engine for adjusting and finishing non-precious alloys containing nickel and beryllium. There is no substitute for good ventilation and high-speed evacuation to ensure maximum physical protection from any potentially harmful airborne particles. Use a high-speed lathe, or air-driven handpiece, which has a glass shield for added protection. However, do not regard the use of this equipment as a substitute for safety goggles, a surgical mask, and a laboratory coat.

14-4. HYDROFLUORIC ACID

The use of hydrofluoric acid is still mentioned in the directions for processing several PFM casting alloys. The acid is most frequently used to remove the oxide layer after oxidizing (degassing), or to strip porcelain from a metal substructure. By using pure, non-recycled 50- μ m aluminum oxide, the oxide layer can be removed mechanically with air abrasion. This change in technique eliminates the need to maintain this very hazardous material in our dental laboratories. Therefore, we strongly suggest that you DO NOT USE HYDROFLUORIC ACID in your laboratory. In fact, we recommend you eliminate it from your inventory, if you still have it on hand, to avoid any potential danger to laboratory personnel. If a hydrofluoric acid spill does occur, and contact is made with skin, flush the contaminated site liberally with water and apply a mixture of magnesium oxide (or milk of magnesia) and glycerin in paste form. Then immediately seek medical attention.

SECTION 15:

CONCLUSIONS

15-1. INTRODUCTION

This user testing program was undertaken as a pilot project to survey the many alloy systems presently being offered as alternatives to gold-base metals for PFM restorations. With its broad scope, such an effort could only examine the general behavior of the different materials, and had little time remaining for in-depth assessments of specific alloys or alloy systems.

The observations and findings of this project are included in the appropriate sections, but Section 15 summarizes the findings of the entire program. The reader is cautioned that the information in this Section represents both the objective and the subjective conclusions of the author. A comparison of materials with similar handling characteristics is most difficult and, often, quite subjective. As a result, an alloy or investment is evaluated on more than performance. Examples of some of the factors taken into consideration are: biocompatibility, ease of processing, porcelain compatibility, participation in the American Dental Association's Acceptance Program, the availability of local technical support, identification of ingots, ingot size, comparative costs, detailed written technical instructions, a TOLL-FREE hot line for prompt communication with the manufacturer, and general support to the Air Force effort.

Moreover, recommendations are based on the findings of this pilot test and evaluation program, and may change as more is learned about the materials. While ease of laboratory processing is important, a restorative material must be safe, effective, and compatible with the oral environment (in vivo). Laboratory (in vitro) testing by manufacturers is not always a predictable indicator of success for a restorative material. Products sometimes fail to live up to expectations and marketing claims. Test and evaluation programs are helpful in separating fact from fiction. As an example, these conclusions have been revised to include information--regarding the biocompatibility of nickel and beryllium--which has appeared in the literature since the publication of Volume I. Such an update is necessary as new information is learned and made available.

Several products have been recognized in this project on the basis of their performance. Specific recommendations signify a high degree of confidence in the quality and in the benefit of a product. However, if no single product emerged as the best in its particular category, or serious concerns arose due to biocompatibility or processing difficulties, no recommendations were made.

THE READER IS REMINDED THAT THE OPINIONS EXPRESSED HERE ARE THOSE OF THE AUTHOR, AND THEY SHOULD NOT BE CONSIDERED OFFICIAL OR REPRESENTING THE DENTAL INVESTIGATION SERVICE, THE UNITED STATES AIR FORCE DENTAL CORPS, OR THE DEPARTMENT OF DEFENSE.

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15-2. PREFABRICATED WAX SPRUES AND CASTING RINGS

The use of prefabricated wax sprues has many advantages for facilities of all sizes, from the base laboratory to the ADL level. Technicians can reduce spruing time, be consistent in their technique, ensure location of the reservoir bar in the heat center of the casting ring, and produce high quality castings.

RECOMMENDATION: The Casting Oval System (Belle de St. Claire) is an excellent alternative to conventional round rings. It comes complete with prefabricated indirect wax sprues (Ready Sprues). With minor modifications to length of the reservoir bar, the Tri-Wax Sprues (Williams) can also be used with this casting system.

FOR SMALL-TO-MEDIUM SIZE WAX PATTERNS

The 6-gauge reservoir bar for both the small and large size Ready Sprues (Belle de St. Claire) may not provide adequate metal for all pattern sizes.

FOR MEDIUM-TO-LARGE SIZE WAX PATTERNS

The Tri-Wax indirect wax sprue has a 3-gauge reservoir bar which will provide ample metal for full metal crowns, large pontics, and medium-to-large partial veneer restorations.

NOTE: Some Belle de St. Claire products can be purchased at a discount from some mail-order dental supply companies.

15-3. PHOSPHATE-BONDED INVESTMENTS

The high melting and casting temperatures of porcelain alloys require the use of high-heat, phosphate- or silica-bonded investments, as opposed to the weaker gypsum-bonded materials.

Both the carbon and non-carbon containing phosphate-bonded types are widely used for precious and non-precious alloys. However, many consumers of non-precious alloys prefer the non-carbon variety to lessen any potential carbon contamination of the alloy. Opinions differ widely as to the relative risk of carbon exposure when burnout temperatures approach 1600 °F (871 °C) and heat soaking periods extend to 1-1/2 hr. Nonetheless, non-carbon varieties conveniently eliminate the carbon problem altogether.

Handling characteristics--such as working time, the smoothness and/or coarseness of the mix, interaction with wax pattern cleaners (debubblers), and factors like packaging and cost--are important features to be taken into consideration when evaluating investment materials.

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During the course of the evaluation, five phosphate-bonded investments were tested: two, of the NON-CARBON-containing type--HI-TEMP (Whip-Mix), and VESTRA-FINE (Unitek); and three, of the CARBON-containing type--BIOVEST (Dentsply), COMPLETE(Jelenko), and DEGUVEST HFG (Degussa).

a. NON-CARBON INVESTMENTS

Although generally recommended for the nickel-base alloys, non-carbon investments can be used with any alloy system. Their white color (no carbon present) makes them easy to identify and differentiate from the gray-black, carbon-containing investments.

VESTRA-FINE was unique among all the phosphate-bonded investment by virtue of its fine-grain powder and the smooth, creamy consistency of the resultant mix. The mixed VESTRA-FINE investment clung to the wax pattern very well, and provided more working time than did HI-TEMP. Even when the VESTRA-FINE special liquid was diluted with one-third distilled water, 6 min of working time were available for investing.

Another advantage of VESTRA-FINE was that after vacuum mixing, the technician could readily pour the investment into one or more casting rings without hurrying. An extended working time is particularly helpful to an inexperienced dental technician, and equally beneficial to an experienced individual investing multiple rings simultaneously.

Each small envelope of VESTRA-FINE contains 65 g of powder rather than 60 g, because of the fine particle size. Nonetheless, two 65-g packages mixed together, or one 130-g envelope, can fill 3 individual 1X casting rings. VESTRA-FINE investment appears strong enough to permit investment and burnout without a metal casting ring when maximum expansion is sought. Allow at least 1-hr setting time before removing the sprue former from the casting ring.

By comparison, HI-TEMP was observed to have a coarser consistency with less working time than VESTRA-FINE, but is also much less expensive.

In summary, the general handling characteristics of VESTRA-FINE were judged superior to those of HI-TEMP. Table 5 (at close of text) lists the government costs of both VESTRA-FINE and HI-TEMP.

RECOMMENDATIONS: VESTRA-FINE is a smooth investment with excellent working time, and is safe for use with any alloy system.

HI-TEMP is a satisfactory substitute, but it is not a fine-grain investment and does not offer the same handling characteristics as VESTRA-FINE.

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b. **CARBON-CONTAINING INVESTMENTS**

Some disagreement exists as to whether these investments should be used with the nickel-containing metals. Opponents contend that any carbon residue in the mold can potentially interact with nickel and embrittle the alloy. For example, the cobalt-chromium alloy Novarex contains carbide-forming elements, such as chromium, wolfram, and niobium. If these carbides are produced, the alloy can become harder. Nonetheless, others contend that, at burnout temperatures in the 1500-1600 °F (816-871 °C) range with 1- to 1-1/2-hr burnout times, the carbon is of little significance. They do not regard a CARBON-containing phosphate-bonded investment as potentially detrimental to the alloy.

Three of the five casting investments used were carbon-containing: BIOVEST, COMPLETE, and DEGUVEST HFG. Both BIOVEST and DEGUVEST HFG had very similar handling characteristics, although the special liquid dispenser for DEGUVEST HFG had a spout which permitted drop-by-drop measurements, and thus was the easiest container to use when dispensing the special liquid. BIOVEST was easier to divest than DEGUVEST HFG, but BIOVEST was also MORE expensive. COMPLETE, on the other hand, is the least expensive of these three investments, but appeared to release more gases. These gases resulted in the formation of more small nodules on the castings than did any of the other investments. In general, we found it necessary to decrease the mixing times slightly to retain the time for "holding" under vacuum and still have adequate working time.

Use of a clean mixing bowl, free of scratches, is strongly recommended to minimize influences on the setting time of the mixed investment. A test mix of a new investment is advisable to determine the mixing, holding, and working times which are appropriate for your laboratory equipment and personnel (Table 5, at close of text).

RECOMMENDATION: DEGUVEST HFG and BIOVEST were quite comparable, but Deguvest HFG was less expensive, and the special liquid dispenser was the best one we tested. However, BIOVEST is easier to divest.

15-4. THE HIGH PALLADIUM-COPPER ALLOYS

Four alloys from this particular group were evaluated: ATHENIUM (Williams); DEGUPLUS 2 (Degussa); NATURELLE (Jeneric); and PG-80+ (Unitek). Although these metals melt and cast like gold-base alloys and are economical, they have significant weaknesses.

Three problem areas with the high palladium-copper alloys, in general, are: the nature of the oxide layer (thick and dark oxide); and difficulties with pre-soldering, and with polishing.

The thick black to brown oxide has been observed to affect adversely the color of the final restoration. A graying of some dental porcelains may occur and be particularly noticeable with anterior restorations. Since the

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masking powers of opaque porcelains vary, this phenomenon may not occur with every porcelain system. Despite reports to the contrary, no bond failures were noted either clinically or in the dental laboratory. Bond strength, per se, was not considered a problem with any of the alloys tested.

Although the emphasis of this evaluation program was on the production of single unit restorations, several fixed partial dentures were fabricated. The area of greatest concern in partial denture construction appeared to be pre-soldering, based on this preliminary work with natural gas and oxygen. The temperature separation between the recommended pre-solders and the parent metals ranged from a mere 45 °F (7 °C) to 205 °F (96 °C). Even with a 170 °F (77 °C) separation, fixed partial dentures were inadvertently overheated, and melted because the solder would not flow. The inherent tendency to oxidize easily was also believed to have contributed to the problem.

Obtaining a high, even luster to the final restoration is not always possible. Some attribute this particular problem to the presence of surface oxides. Others say it's a result of dealing with a two-phase alloy, or the presence of microporosity. In order to achieve a final polish, any surface oxide layer (extraneous oxidation) has to be mechanically removed for the parent metal to be reached. This procedure has not always been so easy to accomplish, and portions of a restoration with a large surface area (metal occlusals/linguals) could not always be made to produce a uniform high shine. Since full metal crowns made from high palladium-copper alloys are easy to polish, but heat-treated (fired in a porcelain furnace) units are not, the oxide theory may be found to be at the heart of the issue. In any regard, polishability can be a problem, demand more time than anticipated, and render a less than ideal final polish.

None of the high palladium-copper alloys tested should be considered as substitutes for gold-base alloys, such as Olympia (Jelenko). Although the high palladium alloys may be of supplemental value, they should be recognized as possessing certain limitations not found with alloys such as Olympia. Porcelain "graying" and pre-soldering failures can require remakes which would eliminate any potential savings from using an alternative alloy.

RECOMMENDATION: No single alloy proved superior to the other members of this group. These general recommendations pertain to all high palladium-copper alloys.

- a. Obey the Laws of Casting, and follow the recommended procedures for processing lower density alloys.
- b. Assess the masking power of your opaque porcelain, since the thick, dark oxide may influence shade fidelity.
- c. Limit initial restorations to posterior units where color is less critical, in the event porcelain "graying" occurs.

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- d. Perform pre-soldering laboratory tests to ascertain your ability to solder these alloys, prior to undertaking a clinical case which involves a fixed partial denture.
- e. Evaluate the polishability of several test castings with metal occlusals or linguals after heat-treating the alloys (firing in a porcelain furnace).
- f. Do not consider the addition of small percentages (1-3%) of noble metals, such as gold and platinum, as important to the properties of these alloys.

15-5. THE HIGH PALLADIUM-COBALT ALLOYS

Two high palladium-cobalt alloys were included in the study: PTM-88 (Jelenko), and SUPRA-AP (Jeneric). These alloys are similar to the high palladium-copper metals, with the exception that cobalt is substituted for copper.

Instead of a thick, dark black to brown oxide, the cobalt-containing group produces a cobalt blue oxide layer. Porcelain "bluing" reportedly may occur, if the masking power of the opaque porcelain is not sufficient, to handle the oxides. This occurrence presents a similar clinical problem associated with the high palladium-copper alloys--a lack of shade fidelity in some instances.

No fixed partial dentures were fabricated from these alloys, and no preliminary pre-soldering testing was attempted. However, the formation of oxides on the glazed porcelain surface was observed after cementation with one alloy (PTM-88). In view of that event, no additional clinical cases were produced with that particular metal.

Like their copper-containing counterparts, the high palladium-cobalt alloys are not substitutes for gold-base metals such as Olympia (Jelenko).

RECOMMENDATION: Aside from the post-cementation oxide formation by PTM-88, no distinction could be made between SUPRA-AP and PTM-88.

15-6. THE PALLADIUM-SILVER ALLOYS

Four palladium-silver alloys were examined: BAK-ON SP (Johnson & Johnson); JEL-5 (Jelenko); PORS-ON (Degussa); and WILL-CERAM W-1 (Williams). Both BAK-ON SP and PORS-ON contain a higher percentage of palladium, and less silver, along with tin and indium, for oxide development. On the other hand, W-1 and JEL-5 are composed of less palladium and more silver, and contain tin but no indium. The tin and indium-containing alloys produce a bluish-violet oxide layer, while the oxidized tin-only metals generate a light gray oxide film. The oxide layer from both palladium-silver categories is much lighter in color

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than the oxidation with either the high palladium-copper or high palladium-cobalt groups. Yamamoto has recommended using 30% hydrochloric acid to selectively remove dark oxides from various precious and non-precious alloy and leave only the "white" tin oxide.¹ He contends that this procedure improves bond strength and lessens the likelihood of porcelain discoloration. These acid treatment procedures are unnecessary with palladium-silver alloys containing tin but no indium. The naturally occurring oxide is a "white" or light gray color which looks almost transparent. Unfortunately, few people know much about palladium-silver alloys other than the discoloration problem associated with certain shades of some dental porcelains.

The palladium-silver alloys also melt easily and cast well, much like gold-base metals. They polish readily and yield a high luster, equal if not superior to a gold-palladium alloy. No fixed partial dentures were fabricated with any of the palladium-silver alloys, so pre-soldering was not studied.

The ease of melting, good castability, thin light-colored oxide layer, good bond strength, and excellent polishability made this alloy system superior to the other palladium-base alloys and all the non-precious systems.

If any alloy system might rival the handling properties and features of the gold-base metals, it would be the palladium-silver alloys. Their major limitation is the potential discoloration of some dental porcelain by the substantial quantity of silver. However, both Will-Ceram (Williams) and Artis-Tech (Rx Jeneric) porcelains are reportedly resistant to porcelain discoloration. The cost of the palladium-silver alloys is often 30% less than that of the high palladium metals, and 60% less than gold-palladium alloys. At least two palladium-silver alloys are A.D.A. "ACCEPTABLE": WILL-CERAM W-1 (Williams), and JELSTAR (Jelenko).

RECOMMENDATION: No single alloy proved more outstanding than all the others. However, a lighter oxide was produced by WILL-CERAM W-1 and JEL-5, which contained tin and no indium.

- a. Obey the Laws of Casting, and adhere to the recommendations for processing lower density alloys.
- b. The study of Pd-Ag alloys should be continued and expanded for fixed partial dentures, and for pre- and post-soldering testing.
- c. Facilities using Will-Ceram or Artis-Tech porcelains are advised to examine the palladium-silver alloys before experimenting with either high palladium-copper or high palladium-cobalt metals.
- d. The problems of porcelain discoloration by silver should also be examined to ascertain the capabilities and limitations of these alloys with dental porcelains in Air Force inventories.
- e. Of all the alternative alloy systems evaluated, palladium-silver appears to offer the most potential for obtaining economy without sacrificing quality.

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15-7. THE NICKEL-CHROMIUM-BERYLLIUM ALLOYS

Four alloys were examined in this group: BAK-ON NP (Johnson & Johnson); BIOBOND II (Dentsply); LITECAST B (Williams); and REXILLIUM III (Jeneric). More recent reports have provided additional evidence that nickel-base alloys containing beryllium may be more potentially harmful to our patients and to our dental laboratory technicians than previously believed.

Consequently, no recommendations will be made for any nickel-containing alloys.

RECOMMENDATION: NONE

The noteworthy characteristics of each of the foregoing alloys are summarized here:

LITECAST B - Is A.D.A. "ACCEPTABLE"; has ingot identification; field technical support is available; TOLL-FREE phone number; low ingot weight; medium burnout temperature (1500 °F/ 816 °C) low oxygen casting pressure; and least expensive (minimum orders), but highest Vickers hardness number (335).

REXILLIUM III - Is A.D.A. "ACCEPTABLE"; TOLL-FREE phone number; lowest reported Vickers hardness number (255), but NO ingot identification; the highest burnout temperature (1600 °F/ 871 °C), second highest ingot weight (3.5 dwt per ingot); highest oxygen casting pressure (30); and among the most expensive (minimum orders).

BIOBOND II - Is A.D.A. "Provisionally Acceptable"; has ingot identification; field technical support available; second highest burnout temperature; low oxygen casting pressure; low cost (minimum orders); high Vickers hardness number (310); and a TOLL-FREE phone number; but the ingots were large-- a factor which leads to rapid accumulation of spent metal (buttons) in smaller laboratories.

BAK-ON NP - Is A.D.A. "Provisionally Acceptable"; has ingot identification; field technical support reportedly available; lowest burnout temperature (1450 °F/788 °C); low ingot weight; medium oxygen casting pressure; and low Vickers hardness number (260); but has no TOLL-FREE phone number, and is more EXPENSIVE in minimum orders.

NOTE: Large ingots are more of an advantage to bigger laboratories, or facilities accustomed to multiple unit castings. A large ingot will have a lower surface area of oxide to volume ratio as compared with several smaller ingots, or a small ingot and a button. However, smaller laboratories, more accustomed to single unit castings, benefit more by using the smaller ingot.

15-8. THE NICKEL-CHROMIUM BERYLLIUM-FREE ALLOYS

Only one alloy was evaluated from this particular group: FORTE (Unitek). This system offers no real advantages over the nickel-chromium-beryllium alloys, other than the elimination of potential health risks associated with beryllium.

Since this alloy is not etchable (no nickel-beryllium phase), a technique to provide mechanical retention is required if used for the etched resin-bonded retainer (Maryland Bridge) restoration. More importantly, these are still nickel-base alloys, and thus subject to the same biocompatibility issues associated with the nickel-containing alloys in general.

RECOMMENDATION: NONE

15-9. THE COBALT-CHROMIUM ALLOYS

Two alloys were obtained for evaluation of the only non-nickel, non-beryllium, non-precious alloy system: COBOND (Dentsply), and NOVAREX (Jeneric). These alloys were both more difficult to process than either of the nickel-base groups. They produce a thick, dark oxide layer which may range in color from brown to greenish-black. This thick oxide is unlike that seen with the high palladium alloys, and must be managed if porcelain-metal bond failures are to be prevented.

The cobalt-chromium alloys have not gained sufficient popularity to rival the nickel-base metals, because they are more demanding technically. In the event the price of palladium increased markedly to render the palladium-base alloys unattractive from a cost standpoint, then attention should be directed toward mastering the technical considerations associated with the cobalt-chromium system. With the availability of relatively low cost, precious alternatives like palladium-silver, the cobalt-chromium metals remain far less attractive for the PFM restoration.

RECOMMENDATION: NONE

The noteworthy characteristics of both of these alloys are summarized here:

COBOND - Is designated "PROVISIONALLY ACCEPTABLE" by the A.D.A., and has ingot identification, a lower burnout temperature, and a lower oxygen casting pressure; is LESS expensive; field technical support is available; has TOLL-FREE phone number; but COBOND has a high Vickers hardness number (320).

NOVAREX - Has no A.D.A. designation; no ingot identification; no field technical support; a high burnout temperature (1600 °F/871 °C); a high oxygen casting pressure; and a 5-oz minimum order, but lower ingot weights and lower Vickers hardness number (275).

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15-10. OTHER ITEMS OF INTEREST

While the focus of this project was on dental casting alloys for the PFM restoration, several adjunctive products were brought to our attention and examined. We felt such items might be of general interest, so they have been included in this special section:

- a. **CASTING OVAL SYSTEM** (Belle de St. Claire) - This casting system included an oval ring, oval sprue former, prefabricated wax sprues, and a non-asbestos ring liner (ceramic type). As discussed in Section 4, the system is effective, easy to use, efficient, and helpful in producing excellent castings. Three sizes of indirect sprues and rings are available (small, large, and extra large). The reservoir bar is 6-gauge for the small and large sizes, and 8-gauge for the extra large size. A special cradle is available for adaptation to several brands of casting equipment.
- b. **COLOR TRU LIQUID BINDER** (Forsyth Dental Center) - This new liquid for dental porcelain is an organic liquid binder. It has the unique property of permitting visualization of the color of the porcelain mixture before it fired. Although its handling properties are much different from conventional liquids, it has the potential to be of particular help to the dental technicians in developing internal color.

Color Tru is a new product and has not been tested as thoroughly as conventional liquids. In addition, its handling properties are quite different from those of distilled water, so expect a short period of adjustment to its unique properties.

- c. **FLEXIBLE CLEARANCE GUIDE** (Belle de St. Claire) - What the calipers are to wax and metal, the Flexible Clearance Guide is to the tooth preparation. The flexible guide has 6 clearance gauges (0.5, 1.0, 1.5, 2.0, 2.5, and 3.0 mm). It can be used for intraoral or laboratory measurements of the distance between the prepared tooth (or die) and the opposing dentition. It is autoclavable, but use paper autoclave bags rather than plastic materials.

This product has both laboratory and clinical application, and may prove helpful in identifying instances of underpreparation.

- d. **RPS-REINFORCED PORCELAIN SYSTEM** (Williams Gold) - This system of prefabricated wax pontics is designed for pontics with full porcelain veneer restorations. Numerous single unit pontics were made and no cracking, crazing, or fracture of the pontics was noted either in the laboratory or clinically. The individual units may be modified to convert them to metal occlusals or linguals, if porcelain occlusion is not desired. The main advantages of the RPS system are the elimination of the solid pontic and reduction of the "heat sink" factor, plus conservation of metal.

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- e. **TRI-WAX SPRUES** (Williams Gold) - Tri-Wax sprues are prefabricated wax patterns for both direct and indirect spruing. The large direct sprue has a 1-gauge reservoir ball, and the small direct sprue has a 2-gauge ball. The single indirect pattern has a 3-gauge reservoir bar with 7-gauge feeders, and is most useful for large metal crowns, pontics, and large metal occlusal restorations.

- f. **VESTRA-FINE INVESTMENT LIQUID** (Unitek) - The special liquid for the Vestra-fine investment can be mixed with shoulder porcelains to give rigidity to the porcelain. In some situations, such as multi-unit cases, having a more rigid material for the direct-lift porcelain margin technique can be helpful.

15-11. REFERENCES

- 1. Yamamoto, M.: Metal-Ceramics, Principles and Methods of Makoto Yamamoto, Chicago, Ill., Quintessence Publishing Co.

T A B L E S :

1. WAX PATTERN TO ALLOY WEIGHT CONVERSION CHART
2. PROPERTIES OF HIGH PALLADIUM-COPPER ALLOYS COMPARED WITH THOSE OF A GOLD-PALLADIUM ALLOY
3. PROPERTIES OF HIGH PALLADIUM-COBALT ALLOYS COMPARED WITH THOSE OF A GOLD-PALLADIUM ALLOY
4. PROPERTIES OF PALLADIUM-SILVER ALLOYS COMPARED WITH THOSE OF A GOLD-PALLADIUM ALLOY
5. CASTING INVESTMENTS FOR PORCELAIN-FUSED-TO-METAL ALLOYS

TABLE 1. WAX PATTERN TO ALLOY WEIGHT CONVERSION CHART

CONVERSION CALCULATION METHOD: Weigh your wax pattern(s) with the entire sprue system before investing. Record that weight either in grams (g) or pennyweights (dwt), and multiply that number by the specific gravity (density) of the alloy that you plan to use. Refer to the conversion table below for approximations of PRECIOUS and NON-PRECIOUS alloys. If you elect to use plastic sprues, then multiply the estimated weight of the alloy by a factor of 0.33, and add that value to obtain your final weight. The best method is to add 2-3 g of additional metal for an adequate button. The estimated weight of alloy is given in pennyweights and grains, so that the number 5¹² represents 5 dwt and 12 grains, or 5 1/2 dwt (1 dwt = 24 grains).

PRECIOUS ALLOY CONVERSION TABLE
(Assumes a specific gravity of 11 g/cc)

Weight of the wax pattern	0.2	0.4	0.6	0.8	1.0	1.2	1.4	1.6	1.8	2.0	2.2	2.4	2.6	2.8	3.0	3.2	3.4	3.6	3.8	4.0	4.2	4.4	4.6	4.8
g	0 ³	0 ⁶	0 ⁹	0 ¹²	0 ¹⁵	0 ¹⁸	0 ²¹	1	1 ³	1 ⁶	1 ⁹	1 ¹²	1 ¹⁵	1 ¹⁸	1 ²¹	2	2 ³	2 ⁶	2 ⁹	2 ¹²	2 ¹⁵	2 ¹⁸	2 ²¹	3
dwt																								
Use dwt of alloy	1 ⁹	2 ¹⁸	4 ³	5 ¹²	6 ²¹	8 ⁶	9 ¹⁵	11	12 ⁹	13 ¹⁸	15 ³	16 ¹²	17 ²¹	19 ⁶	20 ¹⁵	22	23 ⁹	24 ¹⁸	26 ³	27 ¹²	28 ²¹	30 ⁶	31 ¹⁵	33

NON-PRECIOUS ALLOY CONVERSION TABLE
(Assumes a specific gravity of 8 g/cc)

Weight of the wax pattern	0.2	0.4	0.6	0.8	1.0	1.2	1.4	1.6	1.8	2.0	2.2	2.4	2.6	2.8	3.0	3.2	3.4	3.6	3.8	4.0	4.2	4.4	4.6	4.8
g	0 ³	0 ⁶	0 ⁹	0 ¹²	0 ¹⁵	0 ¹⁸	0 ²¹	1	1 ³	1 ⁶	1 ⁹	1 ¹²	1 ¹⁵	1 ¹⁸	1 ²¹	2	2 ³	2 ⁶	2 ⁹	2 ¹²	2 ¹⁵	2 ¹⁸	2 ²¹	3
dwt																								
Use dwt of alloy	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24

TABLE 2. PROPERTIES OF HIGH PALLADIUM-COPPER ALLOYS COMPARED WITH THOSE OF A GOLD-PALLADIUM ALLOY

Gold-Palladium	High Palladium-Copper			
Olympia*	ATHENIUM	DEGUPLUS 2	NATURELLE	PG-80+
200 Brinell 200 Vickers	N/A 222	240 260	320 350	244 253
13.5 g/cc	11.0	11.5	10.6	10.7
2320-2380 OF (1271-1304 °C)	2120-2330 OF (1160-1277 °C)	2111-2354 OF (1155-1290 °C)	2140-2175 OF (1171-1191 °C)	2150-2340 OF (1177-1282 °C)
2450 OF (1343 °C)	2430 OF (1282 °C)	2550 OF (1399 °C)	2350 OF (1288 °C)	2600-2800 OF (1427-1538 °C)
115,000 psi	123,000	118,900	185,000	105,000
20%	25	30	10	20
83,000 psi	76,100 (0.1% offset)	83,380 (0.2% offset)	160,000 (0.2% offset)	90,000 (0.2% offset)
N/A	N/A	N/A	16,000 psi	15,000
Phosphate	Phosphate	Phosphate	Phosphate	Phosphate
1300 OF (704 °C)	1500 OF (816 °C)	600 OF; 1560 OF (316 °C; 849 °C) (two-stage)	1500 OF (816 °C)	600 OF; 1550 OF (316 °C; 843 °C) (two-stage)
\$ 296.20	\$ 110.60	\$ 143.71	\$ 122.00	\$ 147.54

1. HARDNESS:

Brinell
Vickers

2. DENSITY

3. MELTING RANGE

4. CASTING TEMP.

5. ULTIMATE TENSILE
STRENGTH

6. PERCENTAGE (%)
ELONGATION

7. YIELD STRENGTH

8. BOND STRENGTH

9. INVESTMENT

10. BURNOUT TEMP.

11. COST per oz.
(February 3, 1985)

* J.F. Jelenko & Co., Armonk, NY 10504.
N/A = Information not available

TABLE 3. PROPERTIES OF HIGH PALLADIUM-COBALT ALLOYS COMPARED WITH THOSE OF A GOLD-PALLADIUM ALLOY

	High Palladium-Cobalt	
	PJM-88	SUPRA-AP
1. HARDNESS:		
Brinell	210	250
Vickers	235	265
2. DENSITY	11.0	11.45
3. MELTING RANGE	2120-2340 °F (1160-1282 °C)	2275-2375 °F (1246-1302 °C)
4. CASTING TEMP.	2450 °F (1343 °C)	2475 °F (1357 °C)
5. ULTIMATE TENSILE STRENGTH	115,000 psi	130,000
6. PERCENTAGE (%) ELONGATION	20%	20
7. YIELD STRENGTH	83,000 psi	90,000 (0.2% offset)
8. BOND STRENGTH	N/A	N/A
9. INVESTMENT	Phosphate	Phosphate
10. BURNOUT TEMP.	1300 °F (704 °C)	1600 °F (871 °C)
11. COST per oz. (February 3, 1986)	\$ 296.20	\$ 123.60
		\$ 121.00

* J.F. Jelenko & Co., Armonk, NY 10504
N/A = Information not available.

TABLE 4. PROPERTIES OF PALLADIUM-SILVER ALLOYS COMPARED WITH THOSE OF A GOLD-PALLADIUM ALLOY

	Palladium-Silver				
	Gold-Palladium Olympia*	BAK-ON SP	JEL-5	PORS-ON	W-1
1. HARDNESS:					
Brinell	200	220	170	220	N/A
Vickers	200	240	187	240	242
2. DENSITY	13.5 g/cc	10.7	10.7	11.0	11.06
3. MELTING RANGE	2320-2380 OF (1271-1304 OC)	2320-2410 OF (1271-1321 OC)	2116-2341 OF (1158-1283 OC)	2261-2318 OF (1238-1270 OC)	2165-2320 OF (1185-1271 OC)
4. CASTING TEMP.	2450 OF (1343 OC)	2450 OF (1343 OC)	2500 OF (1371 OC)	2350 OF (1288 OC)	2420 OF (1327 OC)
5. ULTIMATE TENSILE STRENGTH	115,000 psi	96,000	96,000	185,000	94,100
6. PERCENTAGE (%) ELONGATION	20%	15	15	10	11
7. YIELD STRENGTH	83,000 psi	69,000 (0.2% offset)	N/A	160,000 (0.2% offset)	68,100 (0.1% offset)
8. BOND STRENGTH	N/A	15,200 psi	N/A	16,000 psi	N/A
9. INVESTMENT	Phosphate	Phosphate	Phosphate	Phosphate	Phosphate
10. BURNOUT TEMP.	1300 OF (704 OC)	1450 OF (788 OC)	600 OF; 1560 OF (316 OC; 849 OC) (two-stage)	1500 OF (816 OC)	1500 OF (816 OC)
11. COST per oz. (February 3, 1986)	\$ 296.20	\$ 110.05	\$ 96.40	\$ 117.32	\$ 86.80

* J.F. Jelenko & Co., Armonk, NY 10504.
N/A = Information not available.

TABLE 5. CASTING INVESTMENTS FOR PORCELAIN-FUSED-TO-METAL ALLOYS

A. PHOSPHATE-BONDED
(Non-Carbon)

Name of Investment	Package Size	Quantity	Bulk Price	Unit (package) Price
1. VESTRA-FINE (Unitek) [Powder and liquid sold separately]	65-g	25	\$ 40.00	\$ 1.60
	(Starter kit-includes powder & liquid)	144	\$ 52.40	\$ 0.36
	65-g 16-oz liquid	4 x \$5.20 ea.	\$ 20.80	\$ 0.15
2. HI-TEMP (Whip-Mix) [Powder and liquid]	60-g	24	\$ 12.95	\$ 0.54
	60-g	144	\$ 51.45	\$ 0.36

B. PHOSPHATE-BONDED
(Carbon-Containing)

1. BIOVEST (Dentsply)	60-g	96	\$ 57.30	\$ 0.60
	(Sold in boxes of 96 or 4-lb cans)			
2. DEGUEST HFG (Degussa)	60-g	33	\$ 16.69	\$ 0.51
	(Sold in boxes of 33 envelopes only)			
3. COMPLETE (Jejenko)	60-g	24	\$ 11.50	\$ 0.48
	60-g	144	\$ 47.85	\$ 0.33

A P P E N D I X E S:

- A. THE CASTING ALLOYS TESTED
- B. THE PARTICIPATING MANUFACTURERS
- C. CENTIGRADE-FAHRENHEIT CONVERSION CHART
- D. GLOSSARY OF TECHNICAL TERMS

APPENDIX A:

THE CASTING ALLOYS TESTED

(Listed by alloy system)

1. HIGH PALLADIUM-COPPER ALLOYS:
 - a. ATHENIUM (Williams): 74% Palladium and 14.5% Copper, 5% Indium and 6.5% Tin, Gallium and unspecified grain refiners
 - b. DEGUPLUS 2 (Degussa): 80% Palladium, ?% Copper, 1% Gold, 1% Platinum, and ?% Gallium
 - c. NATURELLE (Jeneric): 79% Palladium, 10% Copper, 2% Gold, 9% Gallium, and Aluminum, Zinc, and Ruthenium
 - d. PG-80+ (Unitek): 79.5% Palladium, ?% Copper, 1% Gold, ?% Gallium, and unspecified grain refiners.

2. HIGH PALLADIUM-COBALT ALLOYS:
 - a. PTM-88 (Jelenko): 88% Palladium, 4% Cobalt, and 8% Gallium
 - b. SUPRA-AP (Jeneric): 83% Palladium, 6-8% Cobalt, 7% Gallium, and 4% Indium

3. PALLADIUM-SILVER ALLOYS:
 - a. BAK-ON SP (J & J): 58% Palladium, 31% Silver, 6% Tin, 4% Indium, and 1% Zinc
 - b. JEL-5 (Jelenko): 54% Palladium, 38.5% Silver, 7% Tin, and 0.5% Gallium
 - c. PORS-ON (Degussa): 58% Palladium, 30% Silver, ? Tin, ?% Indium, and ?% Zinc
 - d. WILL-CERAM W-1 (Williams): 53.5 % Palladium, 37.5% Silver, 8.5% Tin, 0.5% Indium, and unspecified trace elements

4. NICKEL-CHROMIUM-BERYLLIUM ALLOYS:
 - a. BAK-ON NP (J & J): 77% Nickel, 13% Chromium, 1.8% Beryllium, 1.8% Titanium, and 1.4% Aluminum
 - b. BIOBOND II (Dentsply): 80.7% Nickel, 13.5% Chromium, 4% Vanadium, and 1.8% Beryllium
 - c. LITECAST B (Williams): 77.5% Nickel, 12.5% Chromium, 4% Molybdenum, 1.7% Beryllium, and 4.3% Al, Fe, and Si
 - d. REXILLIUM III (Jeneric): 74-78% Nickel, 12-15% Chromium, 4-6% Molybdenum, and 1.8% Beryllium

5. NICKEL-CHROMIUM BERYLLIUM-FREE ALLOYS:

FORTE (Unitek): 64% Nickel, 22% Chromium, 9% Molybdenum, 4% Columbium, 1% Iron, plus Tantalum

6. COBALT-CHROMIUM ALLOYS:
 - a. COBOND (Dentsply): 65-68% Cobalt, 25-27% Chromium, and 4-6% Molybdenum and unspecified trace elements
 - b. NOVAREX (Jeneric): 55% Cobalt, 25% Chromium, 11% Wolfram, 5% Ruthenium plus Aluminum, Yttrium, Zirconium, and Niobium.

APPENDIX B:

THE PARTICIPATING MANUFACTURERS

<u>Manufacturers and addresses</u>	<u>Products</u>
1. Belle de St. Claire 16146 Valerio Street Van Nuys, California 91406	Casting Oval System Ready Sprues Flexible Clearance Guide
2. Degussa Dental, Inc. 21-25 44th Avenue Long Island City, New York 11101	Deguplus 2 (High Palladium-Copper) Pors-On (Palladium-Silver)
3. Dentsply International, Inc. 570 West College Avenue P. O. Box 872 York, Pennsylvania 17405	Biobond II (Nickel-Chromium-Beryllium) Cobond (Cobalt-Chromium) Shademate Porcelain
4. J. F. Jelenko & Co. 99 Business Park Drive Armonk, New York 10504	PTM-88 (High Palladium-Cobalt) Jel-5 (Palladium-Silver) Jelenko Porcelain
5. Rx. Jeneric Gold Co. Jeneric Industries, Inc. 125 North Plains Industrial Road P. O. Box 724 Wallingford, Connecticut 06492	Naturelle (High Palladium-Copper) Supra-AP (High Palladium-Cobalt) Rexillium III (Nickel-Chromium-Beryllium) Novarex (Cobalt-Chromium) Artis-Tech Porcelain
6. Johnson & Johnson Co. Dental Products Co. Ceramco, Inc. 20 Lake Drive, CN 7060 East Windsor, New Jersey 08520	Bak-On SP (Palladium-Silver) Bak-On NP (Nickel-Chromium-Beryllium)
7. Unitek Corporation 2724 South Peck Road Monrovia, California 91016	PG-80+ (High Palladium-Copper) Forte (Nickel-Chromium Beryllium-Free) Crystar Porcelain
8. Vident 5130 Commerce Drive Baldwin Park, California 91706	Vita Porcelain
9. Williams Gold Refining Co. 2978 Main Street Buffalo, New York 14214	Athenium (High Palladium-Copper) Will-Ceram W-1 (Palladium-Silver) Litecast B (Nickel-Chromium-Beryllium) Will-Ceram Porcelain RPS System Tri-Wax Sprues

APPENDIX C:

CENTIGRADE-FAHRENHEIT CONVERSION CHART

°C	°F	°C	°F	°C	°F
		610	1130	1010	1850
0	32	620	1148	1020	1868
50	90	630	1166	1030	1886
100	212	640	1184	1040	1904
300	572	650	1202	1050	1922
310	590	660	1220	1060	1940
320	608	670	1238	1070	1958
330	626	680	1256	1080	1976
340	644	690	1274	1090	1994
350	662	700	1292	1100	2012
360	680	710	1310	1110	2030
370	698	720	1328	1120	2048
380	716	730	1346	1130	2066
390	734	740	1364	1140	2084
400	752	750	1382	1150	2102
410	770	760	1400	1160	2120
420	788	770	1418	1170	2138
430	806	780	1436	1180	2156
440	824	790	1454	1190	2174
450	842	800	1472	1200	2192
460	860	810	1490	1210	2210
470	878	820	1508	1220	2228
480	896	830	1526	1230	2246
490	914	840	1544	1240	2264
500	932	850	1562	1250	2282
510	950	860	1580	1260	2300
520	968	870	1598	1270	2318
530	986	880	1616	1280	2336
540	1004	890	1634	1290	2354
550	1022	900	1652	1300	2372
560	1040	910	1670		
570	1058	920	1688		
580	1076	930	1706		
590	1094	940	1724		
600	1112	950	1742		
610	1130	960	1760		
620	1148	970	1778		
630	1166	980	1796		
640	1184	990	1814		
650	1202	1000	1832		

CONVERSION FORMULAS:

$$^{\circ}\text{C} = 5/9 (^{\circ}\text{F} - 32)$$

$$^{\circ}\text{F} = 9/5 (^{\circ}\text{C}) + 32$$

APPENDIX D:

GLOSSARY OF TECHNICAL TERMS

- AIR-ABRADING - The finishing of a metal or porcelain surface with an abrasive material (aluminum oxide, glass beads, sand, etc.) under pressure.
- AIR-FIRING - The process of sintering (firing) in a porcelain furnace without a vacuum.
- ALLOY - A substance which possesses metallic properties and is composed of two or more chemical elements, of which at least one is an elemental metal comprising the majority of the mixture.
- APPLIED GLAZE - An artificial glaze applied to the dental porcelain surface and air-fired in an oven for a specified period of time.
- AUTOGLAZE - Refer to "Self-Glaze."
- BASE METAL - A non-precious metal which is non-noble and has little intrinsic value (e.g., chromium, copper, nickel, tin, and zinc). Base metals are added to high noble metal alloys to produce the oxide layer for porcelain bonding.
- BOND - A term used to describe the attachment or union between dental porcelain and the metal substructure.
- BRINELL HARDNESS - A measure of the hardness of a material obtained in a laboratory test, in which a hardened steel ball is pressed into the polished surface of a material under a measured load. The amount of indentation is computed according to the load, and assigned a Brinell hardness number (BHN). Thus, the smaller the indentation, the harder the material and the higher the Brinell number.
- CARAT - The carat of an alloy is determined by the parts of pure gold in the alloy of 24 parts. The term is, therefore, never used to describe non-gold base alloys.
- CASTING TEMPERATURE - A temperature which is usually 100-150 °F above the melting or fusing range of an alloy. This higher temperature compensates for heat loss during the casting procedure.
- CERAMO-METAL - One of several alternative designations to describe the PFM restoration. However, the term "ceramo" might incorrectly imply that dental porcelain is a ceramic, and actually it is a non-crystalline glass.
- COLOR - While the gold in gold-base alloys imparts a yellow color, the non-gold base systems possess a platinum or white color which may take on a reddish tint if sufficient copper is present.

—APPENDIX D—

- CONDUCTIVITY - The property of transferring thermal (heat and cold) and electrical energy. Gold, silver, and copper are examples of good thermal conductors. Base metal alloys are poor thermal conductors--a property which can be beneficial to pulpal tissues.
- COPING - A designation for the metal substructure of a single unit PFM
- CORROSION - This term refers to the process in which the surface of a metal restoration actually undergoes deterioration through a reaction with its environment.
- CRUCIBLE (CASTING) - The container in which alloys are melted for casting. High-heat zircon-alumina or quartz crucible are recommended for PFM alloys, and clay crucibles should be limited to Type III gold alloys.
- DEGASSING - The process of heat-treating a PFM substructure believed to release entrapped gasses and burn off organic surface impurities (refer to "Oxidation").
- DELAMINATION - A term used to describe a porcelain-metal bond failure when the porcelain is removed cleanly from the metal surface.
- DENSITY - The density, or specific gravity, is the weight of a substance as compared with the weight of exactly the same volume of water. The standard used is that 1 cc of water (at 4 °C) is equal to 1. The density of pure gold is 19 g/cc, while many of the non-precious alloys have a density between 7.75 and 8.5 g/cc.
- DEVITRIFICATION - The return of some of the dental porcelain components to a crystalline form caused by repeated firing and overfiring, and resulting in an increase in cloudiness (opacification).
- DUCTILITY - The property of a metal which permits it to be drawn into a wire without breaking. While gold and silver are very ductile, nickel and chromium are not.
- ELASTIC LIMIT - Refer to "Modulus of Elasticity."
- ELONGATION - The "percentage of elongation" refers to the amount an alloy will increase in length when drawn from a zero load to its breaking point. Thus elongation is a measure of the ductility of a metal or an alloy, and the higher the percentage the GREATER the ductility. The lower the percentage, the LESS likely the metal margins can be burnished.
- ETCHING - Process by which surface metal is electrolytically or chemically removed (usually with acids) to create microscopic three-dimensional relief for micro-mechanical retention. A composite cementing medium is permitted to flow into the etched metal surface to provide mechanical retention of the prosthesis.

—APPENDIX D—

- EXTRANEEOUS OXIDATION - Oxidation which forms on non-porcelain bearing areas of the metal substructure (i.e. metal, occlusal/lingual, metal collar, etc.).
- FINENESS - Alloy fineness is the parts per 1000 which are gold. This term is used to describe gold-base (not non-gold base alloys).
- FLEXIBILITY - The amount of bending movement, or distortion, an alloy can withstand and still be able to return to its original shape without evidence of distortion. An alloy which possesses a low modulus of elasticity but a high yield strength will offer greater flexibility.
- FRAMEWORK - A designation for the metal substructure of a PFM fixed partial denture, as well as a removable partial denture casting.
- GALVANISM - The production of small electrical currents in the mouth as a result of contact by restorations of dissimilar metals (e.g., gold onlay opposing an amalgam restoration). Galvanism may cause tooth sensitivity.
- GASSING - The release of entrapped gases, formed by a metal substrate during a firing procedure, which results in voids or bubbles in the opaque or body porcelains.
- GLAZE - Refer to "Applied-," "Auto-," or "Self-Glaze."
- GRAINS - A metal is made up of microscopic components called crystals or grains. Each grain represents an individual unit, but thousands represent a polycrystalline structure and make up the metal. An alloy composed of many small similar grains is often referred to as a "micro-fine homogeneous metal." It will exhibit better physical and mechanical properties than a macro (large) grain heterogeneous (mixed) alloy. Manufacturing and handling of the alloy by the technician can and will affect the grain structure.
- GRAIN GROWTH - Overheating an alloy, or subjecting it to prolonged heating, may permit the grains or crystals of the metal to merge, thus forming even larger grains. Large grain alloys are weaker than small or micro-fine grain metals. Slow cooling after casting can permit such grain growth.
- GRAINS (WEIGHT) - Precious metals are frequently weighed to calculate the volume of metal used to produce a given restoration. Since 24 grains are in each pennyweight, and 20 pennyweights in each troy ounce, then 480 grains are in each ounce. In metric measurements, 1 grain equals 200 mg; 24 grains equal 1.5552 g; and 480 grains, or 31.1035 g, equal one troy ounce.
- GRAMS (WEIGHT) - The gram (g) is the basic unit of weight in the metric system, with 28.3495 g in each avoirdupois ounce and 31.1035 g in each troy ounce.

—APPENDIX D—

- HARDNESS - The resistance of an alloy to surface penetration is referred to as its "hardness"; as hardness increases, resistance to surface wear also increases. Values for hardness are most often reported as either a Vickers or a Brinell hardness number (VHN or BHN), with a VHN designation being used more frequently.
- INVESTMENT (GYPSUM) - Investments consist of a binder and a refractory material; and, with gypsum investment, plaster is the binder and silica is the refractory. Beauty-Cast and Cristobalite are examples of such investments. In general, gypsum investments should not be heated to temperatures higher than 1292 °F (700 °C) for fear of investment breakdown and alloy contamination.
- INVESTMENT (PHOSPHATE) - These investments do not contain a gypsum binder (plaster), but substitute a phosphate (ammonium phosphate)-- a metallic oxide (magnesium oxide) with a silica refractory material. These investments are capable of withstanding temperatures much higher than the gypsum investments, and are considerably stronger. Examples of the carbon-containing investments are: Biovest, Complete, and Deguvest HFG; and, of the non-carbon investments: Hi-Temp and Vestra-fine.
- INVESTMENT (SILICA) - The binder for the silica-bonded investments is a silica gel which reverts to silica (Cristobalite) on heating.
- LIQUIDUS - The temperature above which an alloy is entirely molten.
- LIQUIDUS RANGE - The temperature range from the time the alloy becomes semi-liquid until it is fully molten, without overheating the metal and burning off any trace elements.
- MALLEABILITY - The ability to withstand permanent deformation without rupture under compression, as compared with ductility--which is a measure of a metal under a tensile (pulling) load.
- MECHANICAL PROPERTIES - The properties of an alloy or a metal which reveal its elastic or inelastic behavior when a loading force is applied. Such properties would include percentage elongation, hardness, ultimate tensile strength, and yield strength.
- MELTING RANGE - Alloys do not melt sharply at a specific temperature, but over a 50 - 200 °F temperature range. The lower limit indicates the initial melt, and the upper limit represents a complete melt when the alloy is totally fluid.
- METAL-CERAMIC - One of several terms to identify the PFM restoration, although dental porcelain is a glass as opposed to a true "ceramic."
- MODULUS OF ELASTICITY - A measure of the rigidity or stiffness of an alloy; the higher the "modulus," the more difficult to deform it. A gold alloy might possess a modulus of elasticity between 13 and 15 X 10⁶ psi.

—APPENDIX D—

- NATURAL GLAZE - Refer to "Self-Glaze."
- OUNCE (AVOIRDUPOIS) - One ounce is equal to 28.3496 grams.
- OUNCE (TROY) - One ounce is equal to 20 pennyweight or 31.1035 grams (refer to TROY WEIGHTS).
- OXIDE LAYER - The colored film which forms on a PFM alloy after the metal has been heat treated. The oxides on the porcelain-bearing areas are used to bond the dental porcelain to the metal substructure.
- OXIDATION - The process of heat-treating a PFM alloy to produce an oxide layer for porcelain bonding. Whether the oxidation firing is accomplished in air or a vacuum depends on the requirements of the particular alloy system. There is no standard oxidation procedure, and manufacturers specify the technique for each of their alloys.
- PENNYWEIGHT - A pennyweight represents 1/20th of a troy ounce, and is composed of 24 grains. The abbreviation "dwt" is used synonymously with pennyweight. In metric terms, 20 dwt represent one troy ounce, or 31.1035 g.
- PFM - The accepted abbreviation for "porcelain-fused-to-metal."
- PHYSICAL PROPERTIES - These are the properties inherent in a metal or an alloy; e.g., its casting temperature, density, and melting range.
- POROSITY - Refers to the presence of holes, voids, and pits, either within a material or on its surface.
- POST-SOLDERING - The soldering of PFM components after the application of porcelain.
- PRE-SOLDERING - The soldering of PFM components before the application of porcelain.
- PROCESSING - Refers to the steps, or procedures, involved in the production of a PFM restoration--from wax-up to the application of dental porcelain, and includes the final finish.
- PROPORTIONAL LIMIT - The amount of stress a metal or an alloy will withstand before it will permanently deform. This limit is an indication of the relative strength and toughness of a material.
- QUENCH - To immerse a heated alloy or invested casting in water to prevent atomic diffusion (e.g., to prevent a certain constituent in the alloy, which is soluble at a high temperature but less so at a lower temperature, from precipitating out of solid solution).
- RESILIENCY - The ability of an alloy to spring back to its original shape or form after receiving a sudden blow. An alloy with a high yield strength and low modulus of elasticity will possess greater resiliency.

—APPENDIX D—

- SAG RESISTANCE - The ability of the cast form of a fixed partial denture to resist distortion during soldering and repeated firings at elevated temperatures. This ability is of particular concern with long-span PFM fixed partial dentures in which multiple pontic areas are unsupported. In general, the lower density alloys with higher Brinell and Vickers hardness numbers offer greater "sag resistance," due to their increased strength.
- SELF-GLAZE - A naturally occurring glaze obtained by air-firing dental porcelain to a recommended temperature for a specific period of time.
- SINTERING - Another term to describe the "firing" of dental porcelain.
- SOLIDUS - The temperature at which a metal or an alloy begins to melt (incipient melting point).
- SOLUBILITY - The ability of a material to be dissolved in another material (solvent). Palladium is known to dissolve gases readily, especially hydrogen, while silver has an affinity for oxygen. Consequently, importance lies in properly mixing and evacuating all phosphate-bonded investments, and in not over-oxygenating the flame when casting.
- SPECIFIC GRAVITY - Refer to "Density."
- TARNISH - The formation of a discoloration or other alteration to the surface finish of a metal restoration in the mouth. Food items (such as eggs and fish, rich in sulfur) can form copper or silver sulfides. Pigment-producing bacteria, iron, mercury-containing drugs, along with absorbed food debris can also result in the formation of stains or discoloration on dental restorations.
- TOUGHNESS - Concerns the ability of an alloy to withstand sudden blows or shocks which may stress the alloy beyond its yield strength, yet not beyond its breaking strength. Generally, those alloys with a high percentage of elongation and a high ultimate tensile strength possess greater toughness.
- TROY WEIGHTS - One troy ounce is made up of 20 pennyweight (dwt), and each pennyweight contains 24 grains of metal. All precious metal weights should be recorded in both pennyweights and grains.
- ULTIMATE TENSILE STRENGTH - Refers to the greatest amount of tensile stress an alloy can withstand before it will fracture.
- VACUUM-FIRING - The firing of dental porcelain in a furnace in which the air or atmosphere has been removed to create a denser porcelain restoration (less air between porcelain grains).

—APPENDIX D—

VICKERS HARDNESS - Unlike the Brinell test, the Vickers hardness test uses a pyramid-shaped diamond instead of a steel ball. The Vickers hardness number (VHN) is calculated the same way as the Brinell test. Also, the higher the value, the greater the hardness, although the Vickers number for an alloy is usually greater than its Brinell hardness number, solely because of the testing method. Therefore, compare similar test results when evaluating different alloys.

VITRIFICATION - The formation of a glass, or glass-like, structure by fusion due to heat. A formal definition is: "the development of a liquid phase which, on reaction or cooling, provides a glassy phase."

VOLATILITY - The vaporizing of a substance into a gas which can occur when melting an alloy, particularly if it is inadvertently overheated. This vaporization can realloy the metal, and actually change the properties of the alloy before it is even cast.

YIELD STRENGTH - The greatest amount of stress a metal or alloy can withstand, and retain its original shape or form when the stress is removed.

END

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