ASD-TDR-7-945 (III)

# LINER FOR EXTRUSION BILLET CONTAINERS

Interim Technical Documentary Progress Report Nr ASD-TDR-7-945 (III)
1 February 1963 - 30 April 1963

Basic Industry Branch
Manufacturing Technology Laboratory
Aeronautical Systems Division
Air Force Systems Command
United States Air Force
Wright-Patterson Air Force Base, Ohio



ASD Project Nr 7-945

Shrink-fit assembly device for buildup of ceramic-coated liner and sleeve assemblies was tested and modified to develop desired temperatures and suitable heat distribution in sleeves which were heated. Nine different compositions of fiber metal reinforced ceramic compacts were produced for preliminary evaluation of suitability for extrusion liner use. Procedures were developed for welding short, hollow ceramic cylinders of high-strength metal carbides and borides to form a ceramic extrusion liner of suitable length. Preliminary extrusion testing of an alumina-coated liner was carried out, using SAE 4340 steel billets extruded to rod at 12:1 and 16:1 ratios.

(Prepared under Contract AF 33(657)-8784 by Armour Research Foundation, Chicago, Illinois, S. A. Spachner).

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## NOTICES

## FOREWARD

This Imterim Technical Documentary Progress Report covers the work performed under Contract AF 33(657)-8784 from 5 June 1962 to 5 December 1962. It deals with Phase II, "Performance Testing of New Liners." It is published for technical information only and does not necessarily represent the recommendations, conclusions or approval of the Air Force.

This contract with Armour Research Foundation, Chicago, Illinois, was initiated under Manufacturing Methods Project 7-945, "Liner for Extrusion Billet Containers." It is being accomplished under the Technical direction of T. S. Felker of the Basic Industry Branch, ASRCT, Manufacturing Technology Laboratory, Aeronautical Systems Division, Wright-Patterson Air Force Base, Ohio.

Dr. Sheldon A. Spachner of the Foundation's Metals and Ceramics Research Division is the metallurgist in charge. Others who cooperated in the research were Roy E. Reinholds and Edward H. Zempke, Project Technicians; Jack V. Smith, Tool Designer; Niru Parikh and Robert Hodson, who developed the fiber metal reinforced ceramic compacts for this effort; and Harry Schwartzbart, Assistant Director, Metals and Ceramics Research. This report has been given the Foundation number ARF-B244-9.

The primary objective of the Air Force Manufacturing Methods Program is to develop on a timely basis manufacturing processes, techniques and equipment for use in economical production of USAF materials and components. The program encompasses the following technical areas:

Rolled Sheet, Forgings, Extrusions, Castings, Fiber and Powder Metallurgy; Component Fabrication, Joining, Forming, Materials Removal; Fuels, Lubricants, Ceramics, Graphites, Nonmetallic Structural Materials; Solid State Devices, Passive Devices, Thermionic Devices.

Your comments are solicited on the potential utilization of the information contained herein as applied to your present or future production programs. Suggestions concerning additional Manufacturing Methods development required on this or other subjects will be appreciated.

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ABSTRACT - SUMMARY
Interim Technical Documentary Report

ASD-TDR-7-945(III)
May, 1963

# LINER FOR EXTRUSION BILLET CONTAINERS

S. A. Spachner
Armour Research Foundation

Shrink-fit assembly device for buildup of ceramic-coated liner and sleeve assemblies was tested and modified to develop desired temperatures and suitable heat distribution in sleeves which were heated. Nine different compositions of fiber metal reinforced ceramic compacts were produced for preliminary evaluation of suitability for extrusion liner use. Procedures were developed for welding short, hollow ceramic cylinders of high-strength metal carbides and borides to form a ceramic extrusion liner of suitable length. Disassembly tooling for rapid separation of shrink-fitted sleeves from a worn liner was designed, fabricated, and tested. Two complete 3-sleeve liner support assemblies were fabricated and tested. Preliminary extrusion testing of an alumina-coated liner was carried out, using SAE 4340 steel billets extruded to rod at 12:1 and 16:1 ratios. No coating wear was noted after extrusion of 3 billets. Required pressing force for SAE 4340 steel, heated to 2200°F and extruded at a 16:1 ratio, was only 200 tons.

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## LINER FOR EXTRUSION BILLET CONTAINER

### I. INTRODUCTION

The object of this effort is the development of improved extrusion liners for extrusion of billets in the 2000-3000°F temperature range. Liners are evaluated by extrusion of steel and refractory alloy billets.

Material classes under consideration for liner application are solid ceramic, ceramic-coated tool steel, metal fiber reinforced ceramics, and elevated temperature alloys. Effective utilization of such materials requires use of support tooling which prevents elastic stress or strain limit of liner material from being exceeded during peak extrusion loading, and which allows liner interchange to be effected in a minimum period of time. The support tool design which has been developed utilizes three or four tool-steel cylindrical sleeves which are successively shrink-fitted onto the liner and one another. Supporting sleeve wall thickness varies from 1/4 to 1/2 in. This relatively thin wall will cool rapidly, once it is removed from the heating furnace. Also, clearances between the hot-and-cold sleeves prior to shrink fitting are relatively small, in no case exceeding 0.006 in. Consequently, it was necessary to design and construct a device for rapid, accurate assembly of shrink-fitted sleeves. This work has been completed. Description of development activity, construction, and operating characteristics of the device is given in following sections.

Development of materials and tooling for this effort during this period covered the following:

a. Fabrication of 9 different compositions of fiber metal reinforced ceramic compacts for preliminary evaluation of suitability for extrusion liner use.

b.. Investigation of feasibility of fusing short, hollow, ceramic cylinders of high-strength metal carbides and borides to form a ceramic extrusion liner of suitable length.

c. Fabrication of 12 metal liners for ceramic coating use.

d. Fabrication of 2 complete 3-sleeve liner support assemblies.

e. Design and fabrication of disassembly tooling for rapid separation of shrink-fitted sleeves from a worn or damaged liner.

Evaluation tests of equipment and materials produced during this period were also carried out. This work consisted of the following:

a. Shrink-fit assembly device test by production of several 3-sleeve liner assemblies.

b. Disassembly tooling test by disassembling several shrink-fitted assemblies.

c. Preliminary extrusion testing of an alumina-coated extrusion liner by extrusion of SAE 4340 steel billets at temperatures of 2000 to 2200°F, at areal extrusion ratios of 12:1 and 16:1.

Activity concerned with production of materials and tooling and evaluation trials is further discussed in following sections.

## II. RESEARCH ACTIVITY

### A. Assembly, Test, and Modification of the Shrink-Fit Assembly Device

The shrink-fit assembly shown in Figure 3 of the first phase report, (Fig. 1) was assembled and tested. The heater block and liner-sleeve assembly transfer system operated satisfactorily. Use of a proportional temperature controller enabled $\pm$ 5 degrees F control at 1000°F, even though three 2-kilowatt heaters were used to heat the relatively low thermal mass heater block.

However, the heat transfer characteristic from heater block to heating sleeve proved to be both inadequate and undesirable. This system is required to heat a sleeve to a peak temperature of 1025°F with a + 0, -50degrees F maximum temperature differential. It was found that operation of the heater block at 1150°F developed a peak temperature of only 800°F in the upper section and generated a 160°F axial temperature gradient.

The following procedures were carried out in an attempt to reduce this gradient and to increase the peak temperature in the liner, with the indicated result:

| Procedure | Result |
|---|---|
| Replacement of 10 in. long cartridge heaters in heater block with 5 in. long cartridge heater. | Location of peak temperature zone in heating sleeve was shifted and greatly reduced. Temperature gradient reduced to $\pm 60$ degrees F. |
| Axial displacement of heater block. | Location of peak temperature zone in heating sleeve was shifted and slightly reduced. Temperature gradient reduced to $\pm 50$ degrees F. |
| Construction of propeller fan inside furnace roof. | Location of peak temperature zone in heated sleeve was slightly shifted but not reduced. Temperature gradient reduced to $\pm 50$ degrees F. |
| Construction of centrifugal blower inside furnace roof. | Location of peak temperature zone in heated sleeve was slightly shifted but not reduced. Temperature gradient reduced to $\pm 35$ degrees F. |

It may be seen that all of the procedures employed involved movement of air, either by convection or agitation, and that all fell short of the desired goal. Consequently, an attempt was made to improve the heat transfer characteristic by providing additional heat to the outer surface of the sleeve which was to be heated.

This activity was accomplished by use of two semicylindrical heavy-wall steel plates in place of the furnace wall insulation. Plates were vertically bored to accommodate ten 1-kilowatt cartridge heaters, and then covered with thermal insulation on the outside. Temperature control was initially obtained by use of two separate controllers. When it was determined that heating characteristic of the two plates was sufficiently similar, control was obtained by use of two parallel-connected thermocouples and one controller.

Use of these heater plates in conjunction with the center heater block provided a rapid and effective means of sleeve heating. Temperature gradient location, and size, could be controlled by axial displacement of the center heater block relative to the heater plates. Optimum placement of the center heater block, 5 in. from the top of the heating sleeve, permitted sleeves to be heated to 1025°F in as little as 30 minutes, with a +0, -28 degrees F temperature gradient. Heating time was increased, but the temperature gradient remained the same, when the largest diameter sleeve was heated in place of the smallest diameter sleeve.

Determination of the time at which transfer was to be effected was the next consideration. The first procedures for determination of this time utilized 4 thermocouples, spaced equidistant from top to bottom of the sleeve, and held in place against the sleeve outer diameter by wire bands. Minimum sleeve temperature for the desired expansion was calculated. When all 4 thermocouples had attained this minimum temperature, transfer was effected. This procedure was found to be time-consuming and cumbersome. Consequently, a different means for detecting the desired expansion was developed.

First, the height of the center block heater in the heating sleeve was adjusted so that the coldest spot on the sleeve was at the sleeve base. One of the 4 sleeve support legs was then connected to a rod which, in turn, actuated a microswitch and signal light. Rod length could be varied by adjustment of a fine-pitch screw on its end. Procedure for actuation of the signal lamp at a desired expansion was as follows:

a. Sleeve to be heated was centered by adjustment of 3 of the 4 support legs.
b. A shim half the thickness of the desired expansion was inserted between the fourth support leg and sleeve.
c. Expansion rod screw was adjusted until signal light was turned on.
d. Shim was removed, and the 3 support legs adjusted for half the value of the required expansion.

This procedure worked very well. Microswitch resolution and repeatability was found to be within 0.001 in. Once the adjustment was made, the operator simply turned on the heaters, then actuated air transfer valves as soon as the signal lamp glowed. Temperature differential in base plate connecting the fourth support leg and microswitch was equal to that of the switch actuating rod, providing self-compensation for expansion of the base plate during heating.

An assembly drawing and photograph of the modified machine presently in use is shown in Figures 2 and 3. Operating characteristics are as follows:

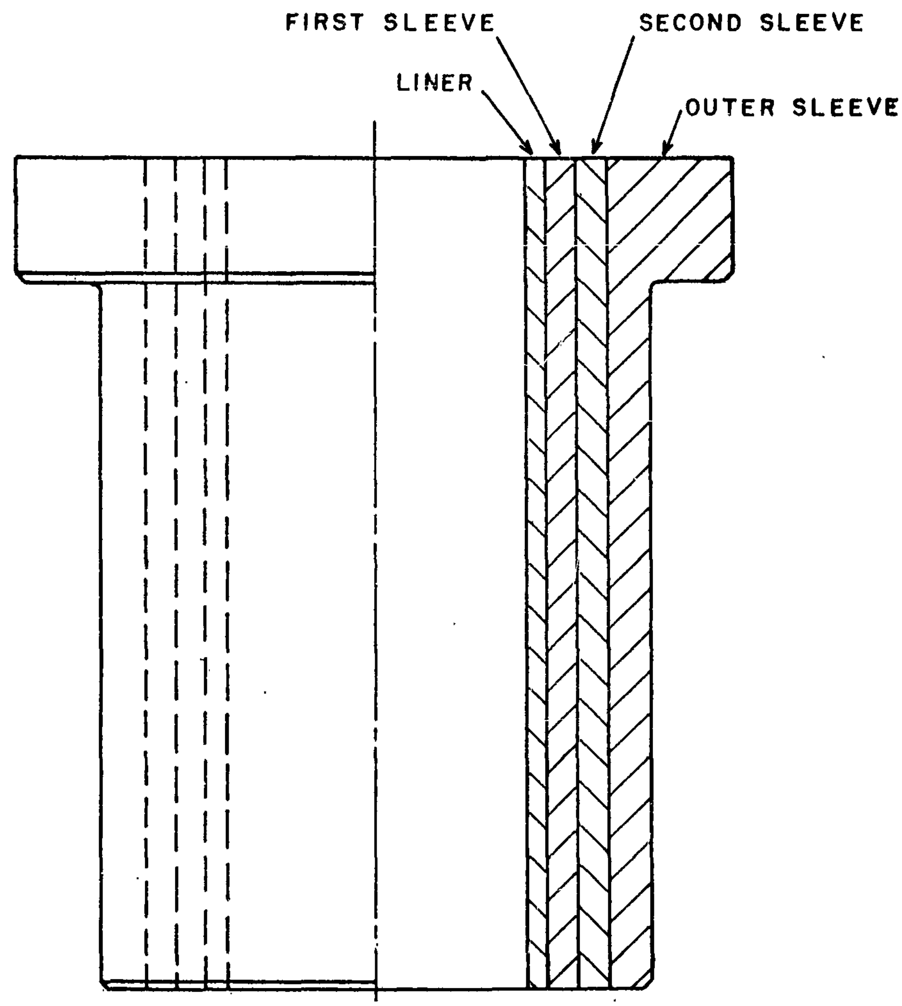


FIG. 1 CERAMIC COATED METAL AND ELEVATED TEMPERATURE METAL LINER-SLEEVE ASSEMBLY.

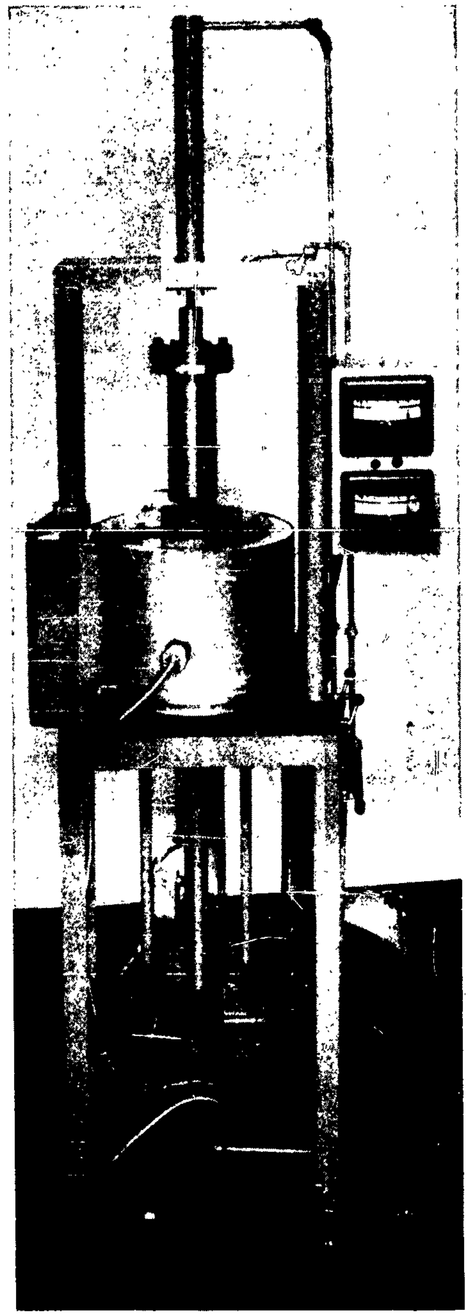

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**Fig. 2. Photograph of Shrink-Fit Assembly Device**

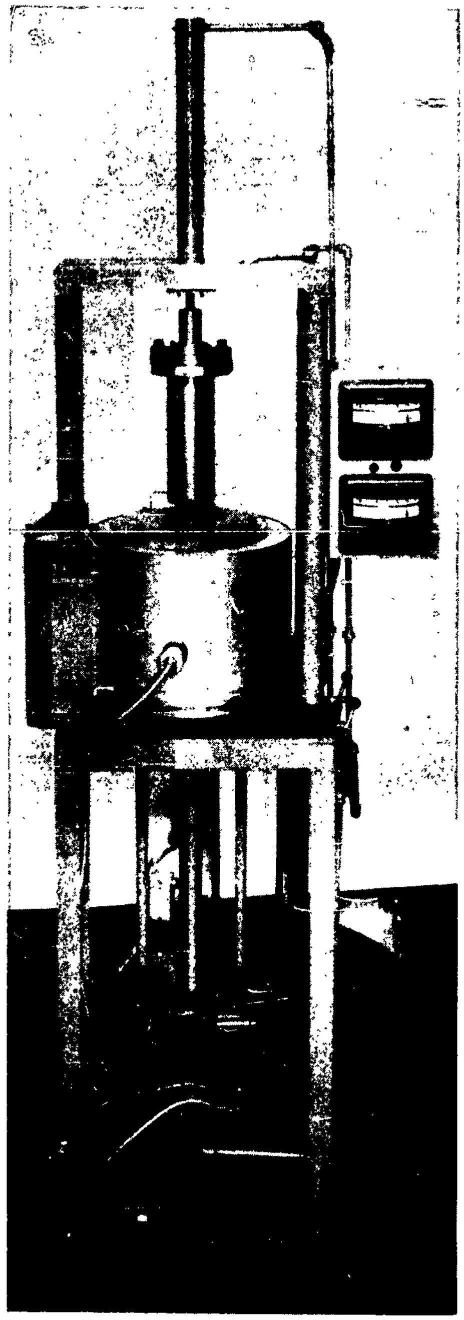

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**Fig. 2. Photograph of Shrink-Fit Assembly Device**

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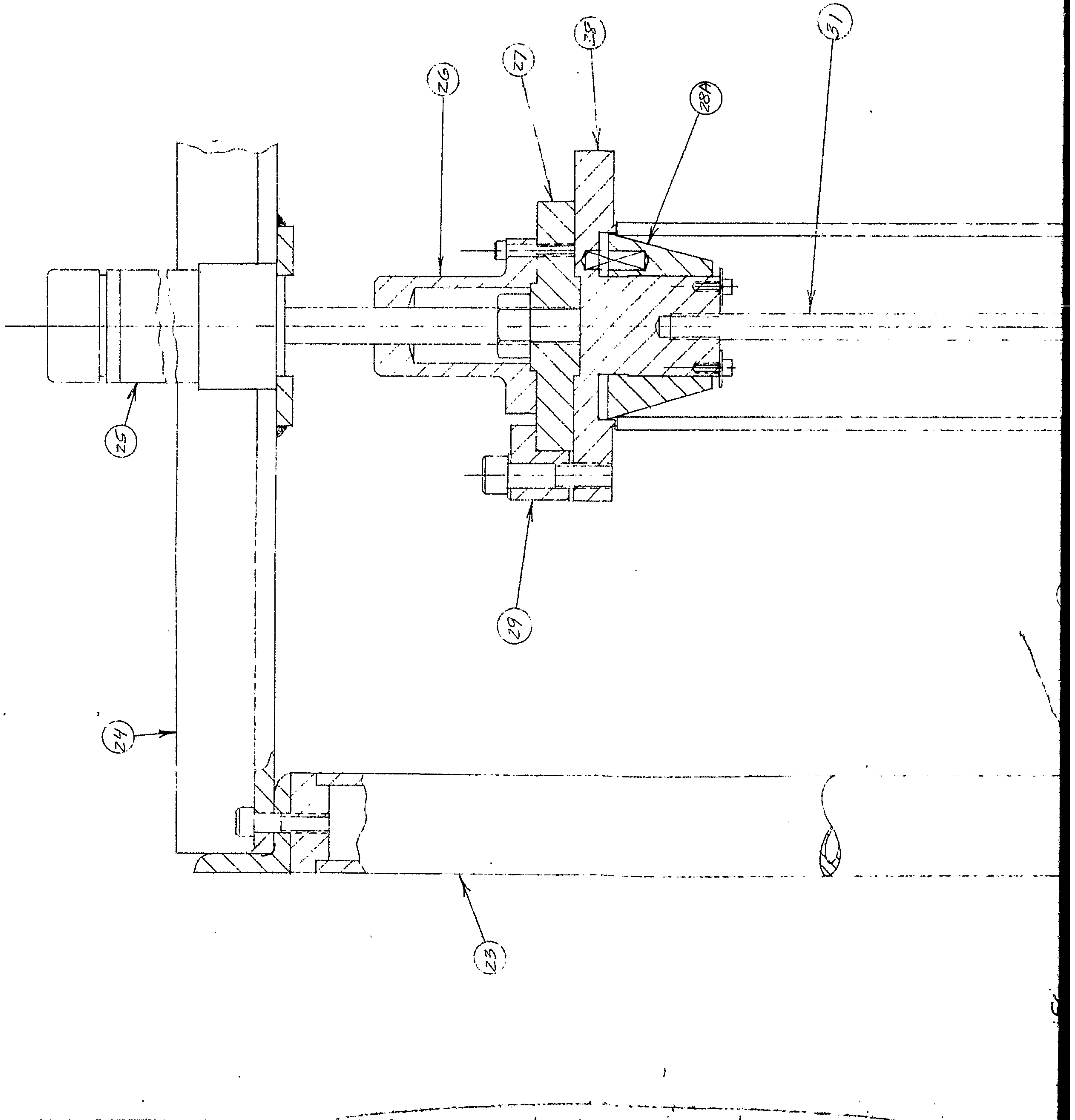

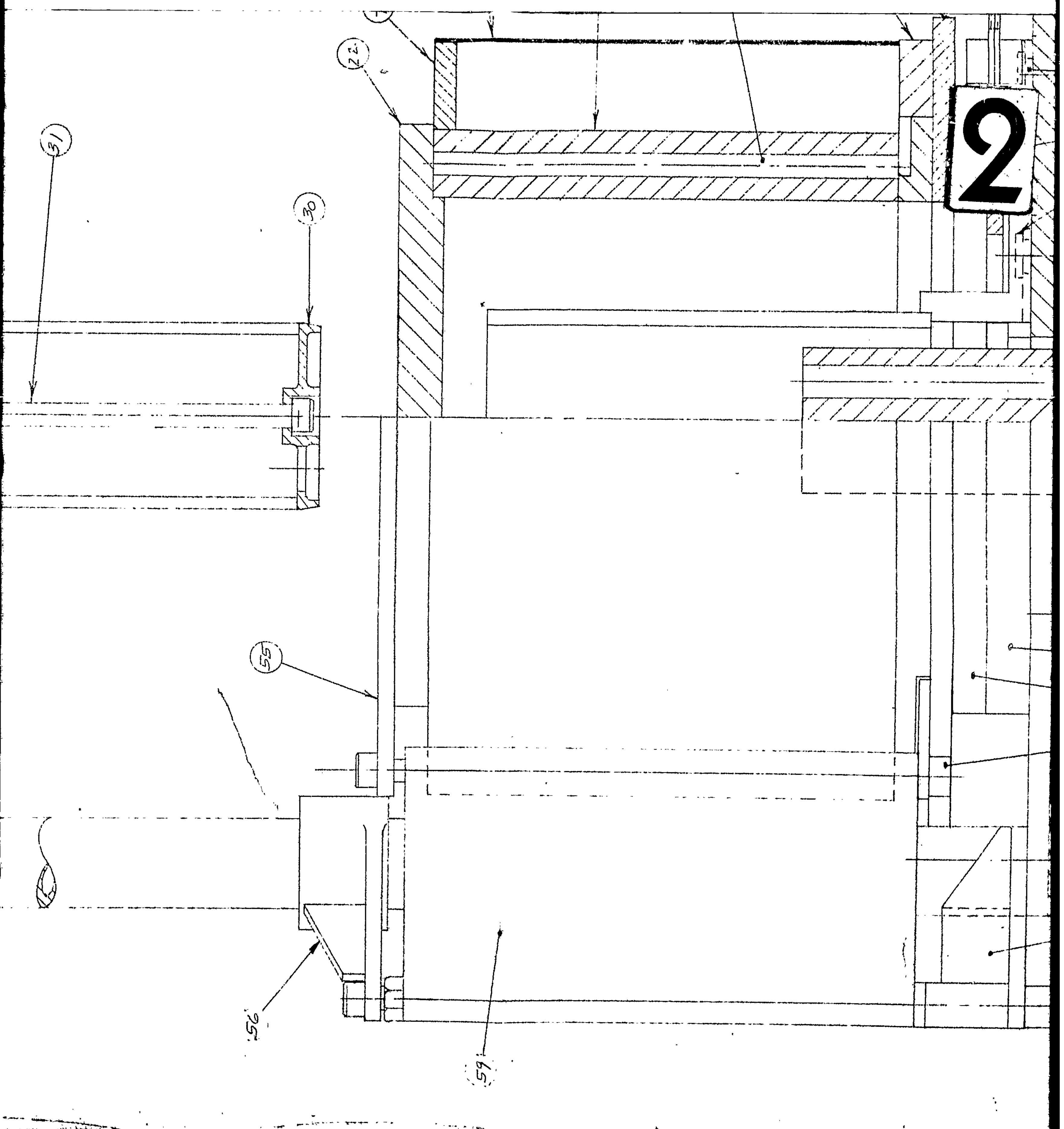

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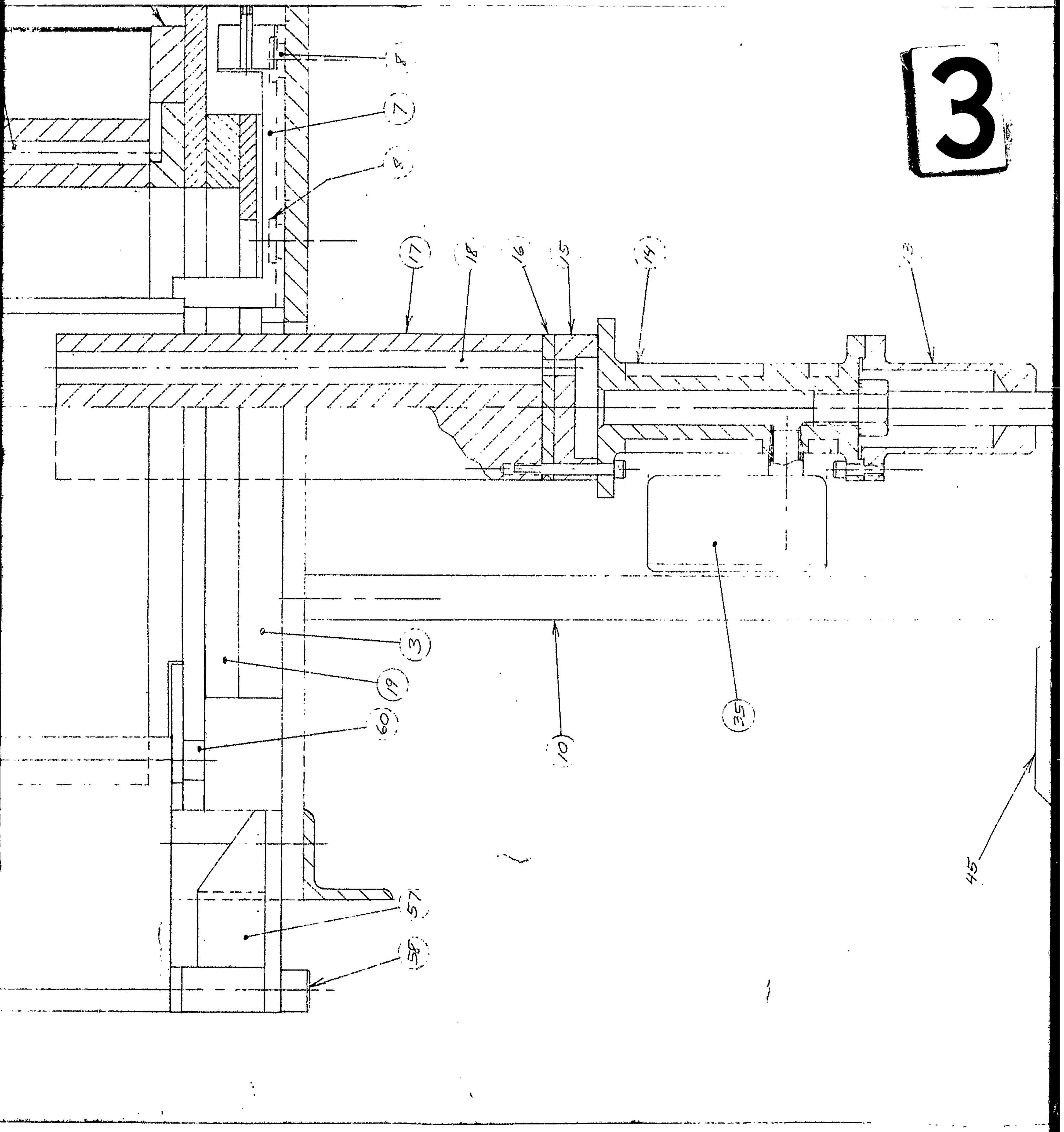

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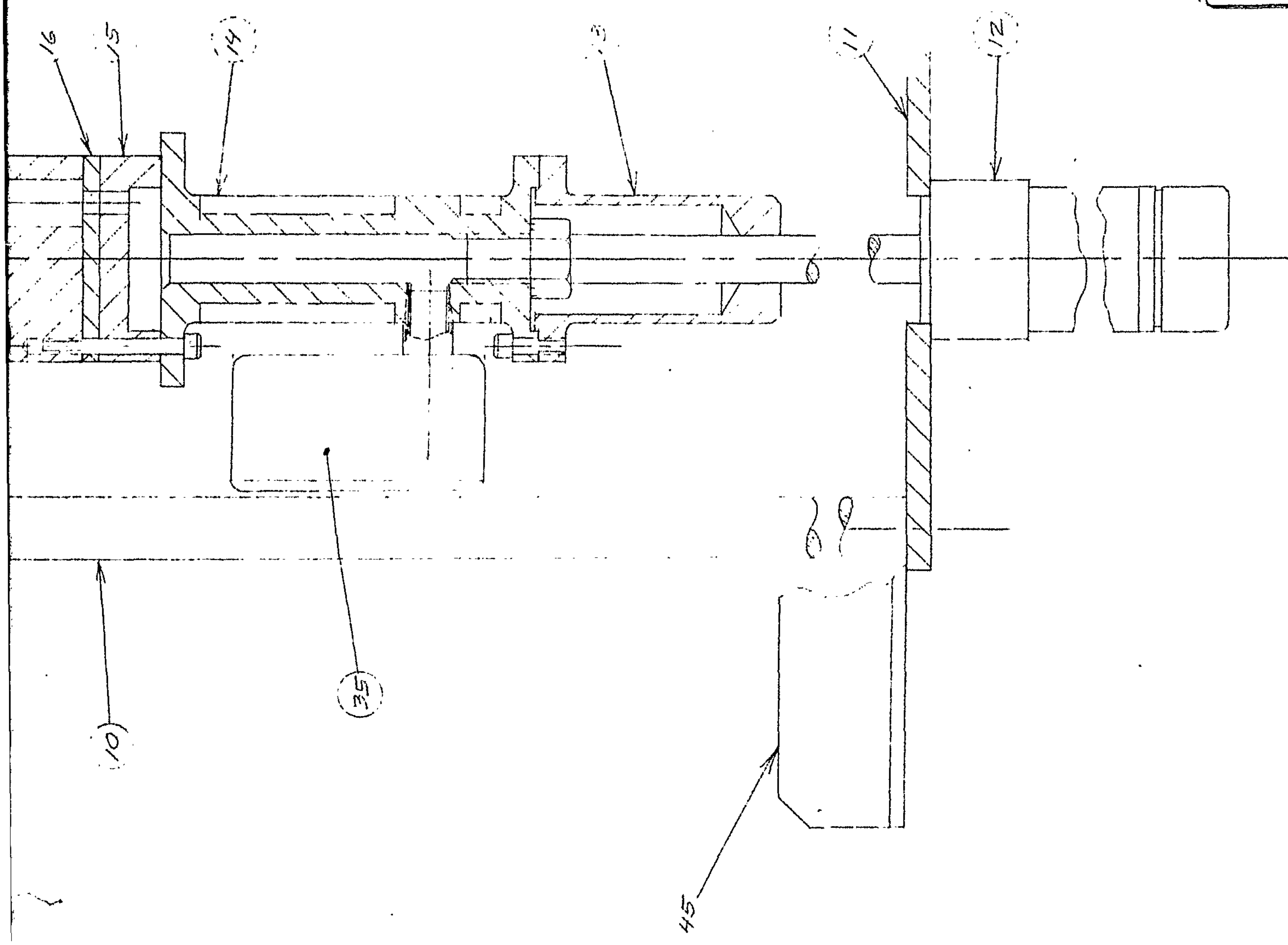

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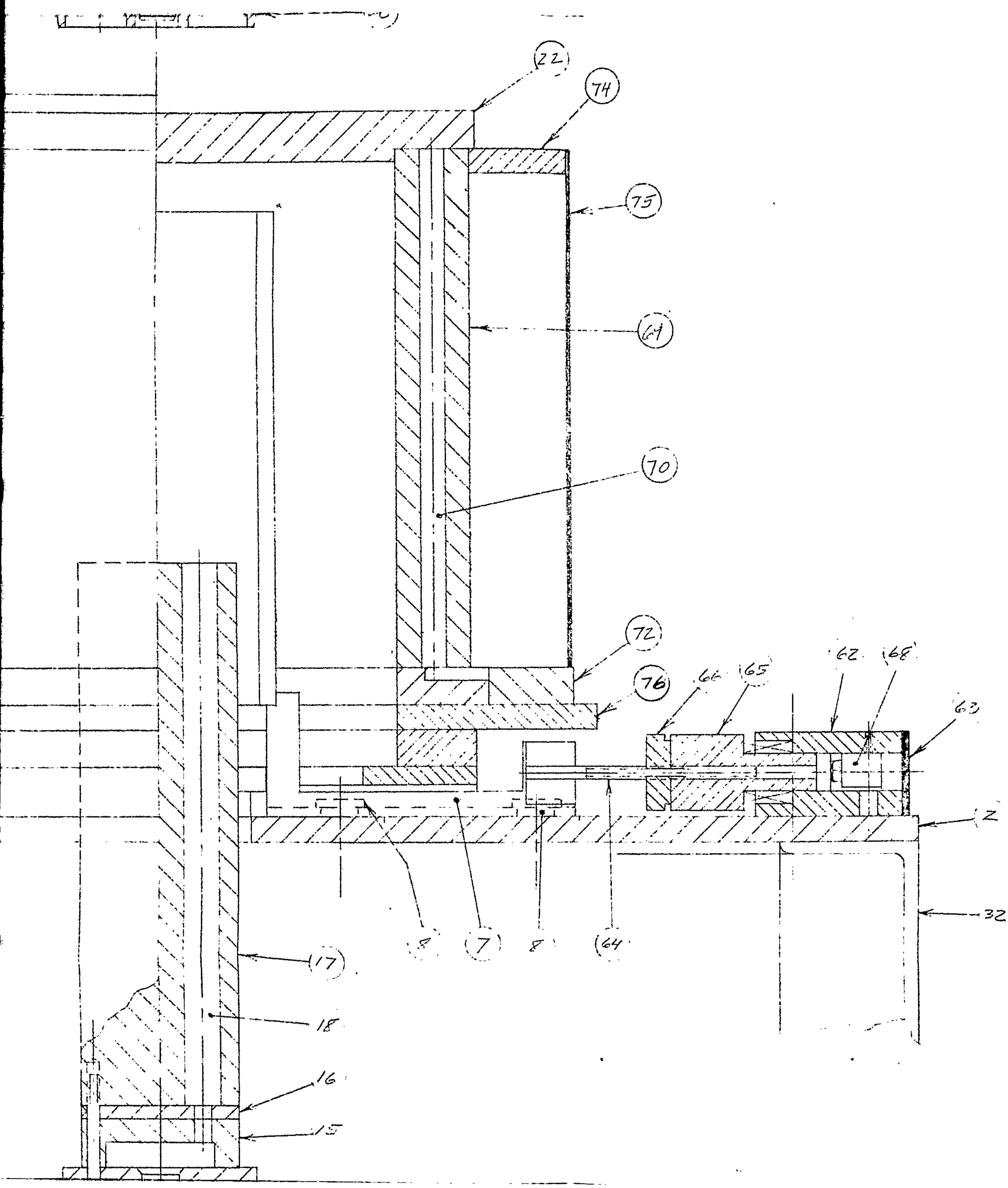

(64)

# 6

Shrink Press
General Section
Detail D-1

[illegible]

a. Sleeve Heating Time

Varies between 30 minutes and 2 hours, depending upon diameter and mass of liner.

b. Maximum Sleeve Temperature Gradient

Twenty-eight degrees Fahrenheit, (±14 degrees F) in the 800-115-°F temperature range. This gradient is obtained when sleeve is within 150 degrees F of the peak temperature desired, and remains constant above this point.

c. Range of Expansion Sensing Adjustment

Range is from 0.001 in. to 0.060 in. Microswitch resolution and repeatability is within 0.001 in. Diameter sensing rod of microswitch contacts heating sleeve at coldest point on sleeve, assuring that expansion sensing is made at point of smallest diametral expansion.

The shrink-fitting procedure employed in assembly of all liner-sleeve combinations is as follows:

a. Sleeve to be heated is positioned so that its centerline is directly beneath centerline of suspended inner sleeve assembly, or liner.

b. Microswitch assembly is adjusted to actuate neon lamp when sleeve expands required amount.

c. Sleeve temperature for required expansion is calculated. Both temperature controllers are set 150 degrees F above this value, and heaters are energized.

d. When signal lamp lights, electric power is turned off. Actuation of the lower air cylinder drops the center block heater out of the heated sleeve. Actuation of the upper air cylinder drops cold sleeve assembly inside heated sleeve.

e. Sleeve assembly is allowed to remain inside furnace shell approximately 60 seconds, while sleeves seize, to avoid personnel injury in event of a fracture in outer sleeve. Liner-and-sleeve assembly is then lifted by upper air cylinder.

f. Next sleeve to be shrink-fitted onto assembly is placed in heating position, and procedures a. through e. are repeated.

## B. Development of Materials and Tooling

### 1. Fabrication of 9 Different Compositions of Fiber Metal Reinforced Oxides and Carbides - by N. M. Parikh and R. L. Hodson

The purpose of this work was to prepare specimens of fiber metal-oxide and fiber metal-carbide composites for evaluation in the hot compression tests. Because the specimens are to contact materials at temperatures in the order of 3000°F, the components were selected such that their melting points would exceed these temperatures. Another basis for the selection of the specimen components was the relative chemical stability of the metal fibers in contact with the oxide or carbide matrices at fabrication temperatures as well as at the test temperatures. Using these criteria, the systems selected were:

a. $Al_2O_3$, MgO, $ZrO_2$, and $SiO_2$, all reinforced with molybdenum fibers.

b. TiC, TaC, ZrC, VC, and CbC, all reinforced with tungsten fibers.

The method used to prepare the specimens involved the impregnation of fiber metal felts with fine powders of the oxides and carbides, followed by hot pressing in graphite dies. The fibers used were cut from spooled wires to approximately 1/4 in. lengths. The molybdenum wire used was 0.002 in. diameter, and the tungsten wire was 0.005 in. diameter. The molybdenum fibers were hand cut, and consequently had to be "kinked" in a Waring Blender to assure good mechanical interlocking when felted. The tungsten wires were cut out in a hammer mill, and the fibers were naturally kinked as a result of the action of the hammer mill.

Fibers were felted through a No. 20 screen into a glass tube of the desired specimen diameter (1 in.) and were then compacted to about 30% of theoretical density (70% porosity). The tube containing the felt was then placed in the impregnation apparatus shown in Figure 4. Apparatus consists of a vacuum flask, Buchner funnel, water aspirator, glass tube containing the felts, slurry container, and vibrator. The oxide or carbide powders (-325 mesh) were made into thin water-base slurries to which about 1% of a wetting agent (Aerosol OT) was added, and were then placed in the slurry container at the top of the glass tube. The apparatus below the slurry container was evacuated with the aspirator, and the slurries were then allowed to fill the tube to a depth of some 4 to 5 inches above the top of the felts. The vibrator was started to keep the powders suspended while the water was drawn off through the filter in the Buchner funnel. This, in effect, causes layers of powder to form at the bottom of the felts and continuously build up until the felts are completely filled with the powders.

Neg. No. 18877

**Fig. 4. PHOTOGRAPH OF IMPREGNATION APPARATUS**

Impregnated felts were then dried and transferred to graphite pressing dies which, in turn, were induction heated. Oxide compacts were heated to 2200°C and carbide compacts to 2350°C. When the hot pressing temperatures were reached, pressing pressures of 3000 psi were applied in all cases.

The specimens which have been prepared are listed in Table I. Because each specimen was prepared individually, it was not possible to maintain close compositional control within each set. Large variations are to be found in sets No. 1 and 8. These are due to the somewhat erratic impregnation behavior of the materials $Al_2O_3$ and VC. The amounts of these materials accepted by the felts were found to vary by 8 to 12 volume per cent for reasons which are not clear at this time.

2. Solid Ceramic Liner Procurement

a. Investigation of Feasibility of Fusing Short, Hollow, Ceramic Cylinders of High-Strength Carbides and Borides to Form a Ceramic Extrusion Liner of Suitable Length

Prior search of the technical literature had indicated that carbides of boron, titanium, and zirconium, and titanium diboride might be particularly suitable for extrusion liner use. The Norton Co. has had experience in the fabrication of many different parts from such materials, and has developed procedures for obtaining specific combinations of mechanical strength and thermal shock resistance. Consequently, this company was contacted to determine their interest in producing ceramic extrusion liners of approximately 3 5/8 in. inner diameter, 7 1/4 in. high, with a 1/4 in. wall.

The Norton Co. expressed interest in the possible use of such materials for extrusion liners, but indicated that such hollow cylindrical bodies could, at present, be produced in lengths of 4 in. only; because of the sintering properties of these materials, production of longer single lengths did not appear likely in the foreseeable future. It did, however, appear possible to the company's laboratory division that the 4 in. cylinders could be satisfactorily fused to produce an 8 in. cylinder which would be monolithic, as far as compressive strength and thermal shock properties were concerned.

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## TABLE I

## LIST OF SPECIMENS PREPARED BY HOT PRESSING OF IMPREGNATED FIBER FELTS

| Set No. | Specimen No. | Composition Volume % | Composition Weight % | Hot Pressing Temperature, °C | Hot Pressed Density, % of Theoretical |
|---|---|---|---|---|---|
| 1 | 1 | $72Al_2O_3$-28Mo | 48.5$Al_2O_3$-51.5Mo | 1600 | 100 |
| | 2 | 59.5$Al_2O_3$-40.5Mo | 36.5$Al_2O_3$-63.5Mo | 1600 | 93 |
| 2 | 3 | 74MgO-26Mo | 50MgO-50Mo | 1600 | 100 |
| | 4 | 74MgO-26Mo | 50MgO-50Mo | 1600 | 98 |
| 3 | 5 | 84$ZrO_2$-16Mo | 74$ZrO_2$-26Mo | 1600 | 87 |
| | 6 | 83$ZrO_2$-17Mo | 72$ZrO_2$-28Mo | 1600 | 86 |
| 4 | 7 | 91$SiO_2$-9Mo | 70$SiO_2$-30Mo | 1600 | 93 |
| | 8 | 89$SiO_2$-11Mo | 65$SiO_2$-35Mo | 1600 | 88 |
| 5 | 9 | 82TiC-18W | 49.5TiC-50.5W | 2200 | 87 |
| | 10 | 78TiC-22W | 46.4TiC-53.6W | 2200 | 94 |
| 6 | 11 | 76TaC-24W | 72TaC-28W | 2350 | 89 |
| | 12 | 76TaC-24W | 72TaC-28W | 2350 | 88 |
| 7 | 13 | 75.5ZrC-24.5W | 52ZrC-48W | 2350 | 90 |
| | 14 | 79.5ZrC-21.5W | 55.5ZrC-44.5W | 2350 | 85 |
| 8 | 15 | 74.5VC-25.5W | 45VC-55W | 2200 | 100 |
| | 16 | 66.5VC-33.5W | 35.5VC-64.5W | 2200 | 97 |
| 9 | 17 | 77CbC-23W | 57.8CbC-42.2W | 2350 | 84 |
| | 18 | 74.5CbC-25.5W | 54.1CbC-45.9W | 2350 | 83 |

Accordingly, arrangements were made with the Norton Co. to perform a series of experiments and mechanical evaluations which would determine the practicability of attempting to produce extrusion liner cylinders by the fusing of 4 in. cylindrical lengths. Experiments were carried out on carbides representative of the class selected and on titanium diboride.

Experimental results were encouraging. The Norton Co. believes that fusing, or welding, of cylinders can be carried out without an appreciable loss of compressive strength or thermal shock resistance in the weld area. Consequently, arrangements have been made to procure cylinders of those materials possessing optimum combinations of mechanical shock resistance and mechanical strength.

b. Solid Ceramics Selected for Extrusion Liner Evaluation

Selection of the best probable ceramics for extrusion liner evaluation was made after consideration of ceramics manufactured by all known industrial ceramics manufacturers in the U. S. and by selected European companies. Material selection was based on consideration of availability in the sizes required, mechanical strength, elastic modulus, thermal expansion characteristic, thermal shock resistance, and relative cost. The properties of the materials selected and ordered for this effort which are of particular interest for extrusion container design are listed in Table II.

| Coating | Application Process |
|---|---|
| Alumina | Rokide flame spray |
| Stabilized zirconia | Rokide flame spray |
| Alumina | Plasma arc |
| Stabilized zirconia | Plasma arc |
| Alumina and gradated nickel | Plasma arc |
| Zirconia and gradated nichrome | Plasma arc |

Liner inner diameter and the type of surface finish are determined by the coating. Rokide process coatings require a coarse thread cut on the liner inner diameter. Since the coating thickness is between 0. 030 and 0. 035 in., liner inner diameter must be overcut a similar amount. In practice, a 0. 045-0. 050 in. coating is applied. Liner inner diameter is then ground to size.

## TABLE II

## MECHANICAL PROPERTIES OF SELECTED EXTRUSION LINER CERAMICS

| Material | Manufacturer | Compressive Strength, kpsi | Young's Modulus, mpsi | Liner Thermal Expansion Coeff., per °F |
|---|---|---|---|---|
| No. 352 Alumina | Int. Lock Joint Pipe Co. | 340 | 48.0 | $3.98 \times 10^{-6}$ |
| Lucalox | Gen. Electric Co. | >300 | 56.1 | $3.83 \times 10^{-6}$ |
| Zirconium carbide | Norton Co. | 250 | 49.3 | $3.55 \times 10^{-6}$ |
| Titanium diboride | Norton Co. | 325 | - * | $2.55 \times 10^{-6}$ |
| Titanium carbide | Norton Co. | 350 | 45.0 | $4.21 \times 10^{-6}$ |

* Value will be determined.

Plasma arc coatings are considerably thinner, ranging from 0.003 to 0.010 in. in thickness. Plasma arc liners are overcut on the inner diameter by an amount equal to the sum of the coat thickness on each wall. Surface is then grit blasted prior to spraying. In all cases, liner hardness must be held below $R_c 50$ to permit effective surface roughening prior to spraying. Liner support tooling has been designed with this in mind. Support tooling exerts sufficient compressive stress on liners to prevent plastic strain at peak extrusion loads for liners of a $R_c$ 44-46 hardness.

To assure final liner inner diameter will be the size desired, two liner-3-sleeve assemblies are produced, using one Rokide process coated liner and one plasma arc process coated liner which have not been ground to final size. Liner coatings are then ground to size in the stressed condition. Following grinding, sleeves are removed from liners, and liner inner diameters are measured. These measurements are removed from liners, and liner inner diameters are measured. These measurements serve as a standard for grinding the other liners. This procedure serves as a check on the calculated liner diametral contraction due to shrink fitting. It has been established that calculated and experimentally determined values lie within 2 to 3% of one another, or within 0.0005 in. on a 0.016 in. diametral contraction. Since liners are ground to a 0.002 in. tolerance, use of the calculated value will not seriously interfere with liner utility. However, experimental determination of liner inner diameter does appear desirable, because it has the effect of reducing diametral tolerance by 30%.

All liner machining is complete. Rokide process liners have already been coated and ground to size. Liners to be plasma arc coated are currently being processed. Two liners have been prepared for each process (12 liners) to enable extrusion evaluation to proceed without delay in event of failure of a particular coating.

4. Tooling for Disassembly of Liner-Sleeve Assemblies

Since it is to be expected that some of the extrusion liners to be evaluated will fail or wear greatly during extrusion trials, provision must be made for rapid removal of liner-sleeve assembly from the container, and for disassembly of the supporting sleeves from the liner. Supporting sleeves are then shrink-fitted on another liner while a second liner-sleeve assembly is being evaluated. Removal of a liner-sleeve assembly from the container is readily accomplished by a jack placed underneath the container, since a slip fit exists between the third supporting sleeve and the container sleeve. Separation of the liner from the liner-sleeve assembly shown in Figure 4 must be accomplished by successively pressing off the outer sleeves. Differential heating cannot be used because wall thickness of the sleeves and heat transfer characteristic of the extrusion liners are such that the required temperature differential between liner inner surface and sleeve outer surface cannot be attained. Even if the required differential could be obtained, removal of sleeves by pressing would still be a much faster method than sleeve removal by differential heating.

Tooling for liner-sleeve disassembly is of relatively simple design. It consists of three concentric sleeves, a two-piece stem, and 3 stem heads of different diameter. Disassembly operations are carried out as follows:

a. Liner-sleeve assembly is removed from the container by use of a jack, built into the shear slide.

b. Shear slide is shifted to place a plane solid surface beneath container.

c. An alloy-steel tube is placed in the container sleeve. Tube length is equal to container height. Tube outer diameter is slightly less than the inner diameter of container sleeve. Tube inner diameter is slightly greater than the inner diameter of the third sleeve.

d. The 3-sleeve liner assembly is placed on top of the alloy-steel support tube and centered.

e. A stem head whose diameter is slightly less than inner diameter of the third sleeve is placed on top of the liner-sleeve assembly and centered by means of a pilot diameter.

f. Stem head is pushed 10 in. by the press, pushing liner-first-second sleeve assembly out of the third sleeve.

g. All liner-sleeve parts are removed from the press. A second alloy-steel tube is placed inside the first tube. Inner diameter of the second tube is slightly greater than inner diameter of second sleeve. Liner-first-second sleeve assembly is placed on top of this alloy steel tube and centered.

h. Steps e. and f. are repeated, using a stem head whose diameter is slightly less than inner diameter of the second sleeve.

i. Steps b. through f. are repeated, using an alloy steel tube whose inner diameter is slightly greater than inner diameter of first sleeve, and a stem head whose diameter is slightly less than inner diameter of first sleeve.

Liner-sleeve disassembly operations may be carried out at room temperature or elevated temperatures with equal ease, when using ceramic coated metal liners or elevated temperature metal liners. Disassembly operations require considerably less force at 600°F when solid ceramic liners are used. This is due to the relatively low thermal expansion coefficient of the ceramic liner, compared to that of the metal supporting sleeve. Cooling to room temperature causes the metal sleeves to shrink more tightly about the ceramic, developing higher interfacial pressures between all liner and sleeve surfaces.

## C. Evaluation Trials

### 1. Shrink-Fit Assembly Device

Some difficulty was encountered in transferring cold sleeve assemblies into the heated sleeve, if both hot and cold parts had sharp corners. A slight mismatch between centerlines of the parts would then result in a bouncing of the cold sleeve before it settled into the heater sleeve. Premature sleeve seizure could then result. This difficulty was remedied by use of a 1/32 in. radius on the outer diameter of the cold sleeve assembly, and a 10 degree, 1/4 in. long conical entry on the inner diameter of the heated sleeve. All sleeve assemblies could then be smoothly transferred without any audible scraping. Transfer time, in all cases, was approximately 1 second.

Assembly of 6 liner-sleeve combinations has demonstrated that this apparatus operates reliably and efficiently.

### 2. Liner and Sleeve Disassembly Tooling

Operation of the sleeve disassembly tooling was tested by separation of shrink-fitted liner assemblies. First, tests were made with a liner and sleeve assembly which had been shrink-fitted together without the use of a lubricant between the shrink-fitted surfaces. Disassembly was effected within a few minutes by use of the tooling for this purpose. However, galling did occur in several places, cutting grooves ranging from 0.002 to 0.010 in. in depth. Groove width ranged from about 0.005 to 0.030 in.

Consequently, a second liner-sleeve assembly was made, using "Molykote G"* lubricant between the two sleeves. This lubricant was applied by lightly wiping the outer surface of the cold sleeve with a paper towel dipped in the lubricant. Disassembly procedures were repeated after the two sleeves had been shrink-fitted together and allowed to cool to room temperature. This time, only very fine galling grooves were observed, less than 0.001 in. in depth or width. Required separation force for sleeves coated with Molykote G proved to be somewhat less than for an uncoated sleeve. Yet, no difficulty was encountered with liner or sleeve pushout during extrusion, when a 1000-ton force was applied to the stem. Sustained operation of the extrusion container at 800°F did not appear to reduce intersurface lubricity. Therefore, it appears that this lubricant is highly satisfactory as an antigalling agent for the type of liner-sleeve assemblies developed for this project.

3. <u>Preliminary Extrusion Testing of Rokide Process Alumina-Coated Liners</u>

Five extrusion trials were made using SAE 4340 steel billets. Container temperature was maintained at 600°F. Billets were coated with Corning No. 0010 glass, then heated in the 80 kw induction furnace mounted on the side of the press. Billet temperatures were monitored by a Leeds and Northrup "Ray-O-Tube" connected to an AZAR recorder. Five to seven minute soaking times were employed for all billets. Both billets and graphite follower blocks were machine-transferred to the extrusion container. Billet transfer time averaged 3 seconds, follower block time 2 seconds. Prior to extrusion, alumina-coated liner was lubricated with Fisk-lube 604.** It was noted that this lubricant smoked, but did not burn prior to extrusion, at the relatively low container temperature employed for this test.

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* Molybdenum disulfide base lubricant produced by the Alpha Molykote Corporation.

** Product of Fiske Bros. Refining Company

The first billet was extruded at a temperature of 2200°F through a rod die of 12:1 areal reduction ratio. The ramspeed accumulator control valve was set to develop a ram speed of 500-600 in. /min. against a force of approximately 400 tons. (Breakthrough pressure was anticipated to be approximately 80,000 psi, requiring a force of 400 tons for extrusion of a 3.5 in. diameter billet.)

Breakthrough pressure did not reach this value. Required pressing force proved to be less than 300 tons. Examination of the extrusion liner after extrusion disclosed no apparent damage to the liner, but did show that the container lubricant had built up a hard, shiny surface over the length of the liner. Consequently, the extrusion trial was repeated, using a 16:1 ratio die to increase calculated extrusion resistance to 400 tons. The coating built up by the container lubricant apparently further reduced friction, for the extrusion force, instead of rising, dropped to 200 tons. The press ram accelerated rapidly because of the relatively low billet resistance, causing the stem to impact the die and deliver a sizeable shock to the press foundation as the 1000-ton force impacted on die, stem, and liner.

Die and stem heat, as would be expected, were damaged beyond repair. However, no apparent damage was sustained by liner, supporting sleeves, or container. A two-inch long strip of alumina coating did spall from the liner when the deformed die was ejected, but this could have been expected.

All sleeves were removed from the liner and measured to determine whether or not this unintentional very high shock loading had caused any permanent deformation in the sleeves. Only the outer diameter of the third sleeve showed any measureable deformation. The 6.62 in. outer diameter of this sleeve expanded 0.0004 in. or 0.006%. This expansion is considered negligible.

Hence, it has been established that the liner-sleeve assembly designed for ceramic-coated metal and elevated temperature metal liner use is at least as rugged as the extrusion liners in present industrial use.

Damaged tools were replaced, extrusion speed control valve was reset for a lower ram speed, and sleeve assembly was fitted with a second alumina-coated liner while the first liner was being recoated. This time, ram speed stayed constant in the 500-600 in./min range during the extrusion stroke, but again, pressing force did not rise over 200 tons as the billet extruded through the 16:1 ratio die. This test was repeated. Results were similar. Finally, billet temperature was dropped from 2200 to 2000°F to increase billet resistance. This time, extrusion force rose to 500 tons, due to increased billet strength and decreased lubricity of the No. 0010 glass lubricant. Examination of the alumina liner coating showed it to be in excellent condition after these three extrusion trials.

## III. FUTURE ACTIVITY

A. Rokide process alumina and stabilized zirconia-coated liners will be evaluated by extrusion of TZM alloy to rod and "T" section.

B. Plasma arc coatings will be applied, ground, and evaluated by extrusion trials.

C. Metal fiber reinforced ceramic compacts will be evaluated by application of a forging and/or extrusion load.

D. Fabrication of sleeve assemblies for support of solid ceramic liners will continue.

## IV. CONTRIBUTION PERSONNEL

The following personnel contributed to this project in the indicated capacities:

| | | |
|---|---|---|
| 1. | S. A. Spachner | Project Leader |
| 2. | J. V. Smith | Project Tool Designer |
| 3. | R. E. Reinhold | Project Technician |
| 4. | E. H. Zempke | Project Technician |
| 5. | N. M. Parikh | Project Supervisor for preparation of fiber metal reinforced ceramics |
| 6. | R. L. Hodson | Project Engineer for preparation of fiber metal reinforced ceramics |

## V. PROJECT LOGBOOK

Data pertaining to this project are recorded in ARF Logbook No. C13291.

Respectfully submitted,

ARMOUR RESEARCH FOUNDATION OF
ILLINOIS INSTITUTE OF TECHNOLOGY

S. A. Spachner
Senior Scientist

Approved by:

H. Schwartzbart, Assistant Director
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