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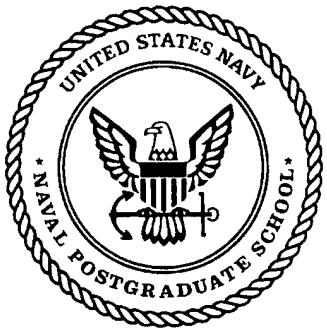

THESIS

QUALITY ASSURANCE FOR
1200 PSI STEAM BOILER MAINTENANCE
BY COMMERCIAL CONTRACTORS

by

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December 1995

Thesis Advisor: Paul J. Fields

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QUALITY ASSURANCE FOR 1200 PSI STEAM BOILER MAINTENANCE BY COMMERCIAL CONTRACTORS

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ABSTRACT

This thesis compares military, commercial, and international quality assurance standards and uses the framework of Dr. W. Edwards Deming's philosophy of management to evaluate and set appropriate quality assurance standards the Hellenic Navy should include in contracts with commercial contractors for 1200 psi steam boiler maintenance. The Hellenic Navy could experience long term benefits by implementing ISO 9002 quality assurance standards in all production and service contracts.

I. INTRODUCTION

A. BACKGROUND

This chapter identifies the role of Greece in the Balkans and the importance of implementing Total Quality Management (TQM) within the Hellenic Navy in order to maintain mission readiness to deter localized conflict in the Balkan region.

1. A Description Of The Greek Military Situation

Greece, also known as the Hellenic Republic, is a small country consisting of 50,944 sq. mi. (131,945 sq. km.), located in Southeastern Europe. Occupying the Southern Balkan Peninsula, it is bordered by the Adriatic Sea to the west, the Mediterranean Sea to the south, Turkey to the east, and Bulgaria, the former Republic of Yugoslavia, and Albania to the north. Thus the Hellenic Republic is in a very strategic position in the Mediterranean area, since it is located on the major shipping lanes that connect Europe with the Middle East.

Today the Balkan situation resembles a boiler-room ready to explode. After the collapse of the Soviet Union,

many countries which were behind the Iron Curtain found themselves free to revive historical differences among each other. This is especially true of the former Republic of Yugoslavia, which currently presents a challenge for peace in the Balkans. Old Moslem and Christian differences which are resurfacing may well spill over into the rest of the Balkan Peninsula and could eventually involve Greece and Turkey. This situation has forced Greece to be more vigilant about the integrity of its borders.

Another problem that Greece faces derives from border differences between Greece and Turkey involving claims to a twelve mile zone established by international agreements, which Turkey does not wish to recognize.

2. The Hellenic Navy

The Hellenic Navy was a pioneer in maritime warfare and has as a history that dates back for thousands of years. In the Naval Battle of Salamis (480 BC), a well organized, highly trained, but small Athenian Navy overcame the overwhelming advantage of the Persian fleet. This example of quality-over-quantity remains applicable today.

The Hellenic Navy has never been defeated. During World War II, when the rest of the country was occupied by the Axis powers, the Hellenic Navy remained free and joined

the Allied forces in Egypt. This success was due to constantly striving for quality and continuous readiness.

Historically, because of Greece's necessary dependency on its naval forces, the Hellenic Navy has exercised quality management and implemented the use of technology to respond to its tasks.

In order to modernize its fleet during 1991, Greece purchased a number of vessels from Europe and the United States. Four ADAMS class destroyers and three KNOX class frigates, which use 1200 psi steam boilers for their steam turbine propulsion plant, were purchased from the United States. Each ADAMS class vessel has four 1200 psi steam boilers and each KNOX class vessel has two 1200 psi steam boilers. A total of twenty-two 1200 psi steam boilers are in use today by the Hellenic Navy. Quality in maintenance of these boilers is the prime concern for readiness, safety, and cost reduction.

3. The Issue Of Quality In The U.S. Navy

During the last few years most organizations in the United States, including the U.S. Department of Defense (DoD), have adopted Edward Deming's philosophy concerning quality. Deming's approach to quality maintenance and control was first implemented successfully in Japan where

TQM was adopted to reduce expenditures, increase productivity, and maintain continuous improvement in the quality of goods manufactured.

In the fall of 1991, the Secretary of the U.S. Navy, H. Lawrence Garret III, speaking out on the "Need for Change" said:

> ... world events and the condition of our nation's economy provide intense pressure to reduce defense expenditures. At the same time the requirement to equip, maintain, and hold combat-ready forces is and will continue to be essential to the freedom of our nation. Maintaining naval strength under significantly reduced funding and manning levels demands that we became more efficient and effective, and we must do this with considerable urgency....
>
> Commitment to quality improvement is the way the naval service can maintain its effectiveness. It has been demonstrated in this country recently, and in Japan for over 40 years, that by improving quality, dramatic reductions in costs and increases in productivity can result. Shore commands that have initiated quality focused efforts have already shown significant improvements, and we have learned much from these successes. In November 1988, when I served as Under Secretary of the Navy, I became convinced that quality was the key to our survival. I talked with quality experts, industrial leaders, and members of our own shore commands who had initiated quality efforts. These organizations had bottom-line results to show that an emphasis on quality, on reduction of process variation, will lead to increased productivity and lowered costs." [Ref. 1]

This is a clear statement of the need for TQM in the U.S. Navy. The same statement could be made for the Hellenic Navy.

B. RESEARCH OBJECTIVE AND RESEARCH QUESTIONS

To increase mission readiness and reliability, it is important to implement quality assurance standards in every type of maintenance. This is especially true for 1200 psi steam boiler maintenance, since the steam pressure is very high and the boilers are used for a warship's main propulsion system. Thus, quality assurance to maintain system reliability is a significant consideration in Naval operations.

1. Research Objective

This thesis examines some of the quality assurance standards that are in use today by the U.S. Navy in its relations with commercial vendors. The objective of the research is to evaluate and set appropriate quality assurance standards the Hellenic Navy should include in contracts with commercial contractors for 1200 psi boiler maintenance.

2. Research Questions

a. Primary Research Question

What are the appropriate quality assurance standards the Hellenic Navy should include in contracts with commercial vendors for 1200 psi boiler maintenance?

b. Subsidiary Research Questions

1. What are the quality assurance requirements that the U.S. Government uses in boiler maintenance contracts with non-government shipyards?

2. What quality assurance standards are required of U.S. non-government shipyards concerning boiler maintenance?

3. What commercial quality assurance standards exist that could be used in boiler maintenance contracts?

C. SCOPE OF THE RESEARCH, ITS LIMITATIONS AND ASSUMPTIONS

This thesis presents an assessment of quality assurance standards implementation for contracting with commercial contractors for 1200 psi boiler maintenance.

Additionally, this thesis is written in such a manner that those unfamiliar with quality, quality assurance, and TQM concepts may utilize the research as a guidebook in those areas. This thesis may also be used to apply quality assurance standards to situations other than boiler maintenance.

D. METHODOLOGY

The research data were collected through a literature search and personal interviews.

The literature search included a thorough examination of information received through the Naval Postgraduate School Library, the Defense Logistics Studies Information Exchange (DSLIE), and review of text books in the subject area. This search provided a background on the basic terminology and concepts of quality management that apply to quality assurance systems, including quality assurance standards.

The author conducted five personal interviews of U.S. Navy personnel in charge of quality assurance and 1200 psi steam boiler inspection procedures at the San Diego Naval Station. These interviews provided a comprehensive understanding of the quality assurance standards and inspection procedures used by the U.S. Navy.

E. ORGANIZATION OF STUDY

This thesis is divided into six chapters. Chapter I is an introduction, which covers the background and purpose of the research. Chapter II defines the basic terminology and concepts of quality management, including quality assurance standards. Chapter III discusses the existing military, commercial, and international quality assurance standards. Chapter IV discusses quality assurance implementation at the San Diego U.S. Naval Shipyard. Chapter V compares and

analyzes quality assurance standards, and Chapter VI contains conclusions and recommendations.

II. DISCUSSION OF CONCEPTS

To set the context in which to identify appropriate quality assurance standards for the Hellenic Navy, this chapter defines the basic terminology and concepts of quality management, including quality assurance standards.

A. BASIC DEFINITIONS

1. "Reliability," "Maintenance," and "Readiness"

Reliability, maintenance, and readiness are interrelated concepts.

a. "Reliability"

Reliability is the probability of satisfactory performance during a given period of time and under specific operating conditions. When time to failure has an exponential probability distribution, reliability at a given time, t, is a function of one parameter; namely, the failure rate or equivalently, its reciprocal, the Mean Time Between Failures (MTBF). In the exponential case , the estimation of reliability of parts and assemblies is reduced to the estimation of the following:

- The failure rate of parts and assemblies. The number of times a part or assembly becomes inoperable within a specified period is its failure rate.
- The Mean Time Between Failures (MTBF) of a piece or equipment or component. MTBF is the reciprocal of the failure rate.

b. "Maintenance"

Maintenance consists of all actions necessary to maintain a system or product in, or restoring it to, an operational, reliable, safe, and serviceable condition [Ref. 2].

Maintenance includes the following procedures:

- *Preventive maintenance:* All scheduled maintenance actions such as service (cleaning, testing, etc.), periodic inspection, overhaul, and condition determination performed to retain a part in a specified condition and to prevent any unexpected damages.
- *Corrective maintenance:* All unscheduled repair and corrective actions performed after a part's failure.

c. "Readiness"

> Readiness is defined as the ability of military forces, units, weapon systems, equipment, and personnel to perform functions for which they have been designed, organized or trained. [Ref. 3]

Readiness means "operational availability" of the system. It is sometimes the proportion of time a system is in an operable state and available to perform its mission. This can be expressed as:

$$\text{Availability} = \frac{\text{MTBM}}{\text{MTBM+MDT}}$$

where: *MDT* = mean maintenance downtime,

MTBM = mean time between maintenance,

[Ref. 2].

2. Quality

There are several definitions of "quality".

- "Quality" means the composite of material attributes including performance features and characteristics of a product or service to satisfy a given need. [Ref. 7]
- "Quality" means freedom from deficiencies. In the eyes of customers, the fewer the deficiencies, the better the quality. [Ref. 4]
- "Quality" means appropriate product features. To the customer, more product features mean better quality. [Ref. 4]
- "Quality" means that throughout the life of the product or service it meets the needs and expectations of the customer at a cost that represents value to the customer. [Ref. 8]
- "Quality" means low-variability in the dimensions that the customer uses to measure the performance of the product. Low-variability in a product's performance relative to the customer expectations means high quality. [Ref. 9]

A concise definition that has achieved acceptance is: "Quality is customer satisfaction" [Ref. 5]. Customer satisfaction is achieved when a product or service not only meets some set of specifications, but also meets the customers' needs.

Customers for boiler maintenance consist of the fleet and the ship's crew. For the fleet, satisfaction means

reliability and readiness. For the crew, satisfaction means safety and easy, cost-effective maintainability.

3. Planning For Quality

Product quality does not just happen; it must be planned.

> "Quality planning is the activity of (a) establishing quality goals and (b) developing the products and processes required to meet these goals. ... Quality planners should follow quality disciplines to establish the desired goals and develop the process to meet those goals". [Ref. 4]

When planning for quality the planning manager has to comply with: governmental regulations, quality assurance standards, safety standards, reliability standards, budget requirements, operating schedules, readiness, etc.

In planning for quality boiler maintenance, the primary goal should be the safety of the people who operate the boiler. The steam pressure and temperature are very high, and, if steam escapes from an improperly repaired joint, this joint could rupture and cause the death or serious injury of the people who are near the boiler. In 1978 three Greek Navy personnel were killed when steam escaped from a relief valve into the boiler room during the performance of reliability tests after a standard overhaul. In 1989, faulty repairs caused the death of ten people on the USS IWO

JIMA. In planning for quality the secondary goals are component reliability and readiness.

Another objective during the planning phase is to assign tasks to specialists to perform and evaluate the process to control the quality during maintenance. The criteria for evaluating a contractor's quality control system should also be established in planning for quality. The officers who will audit and evaluate a contractors' quality control system, and determine quality assurance clauses and warranty coverage, should be named in the contract. The quality control manager, statistical analyst, quality assurance inspectors and feedback evaluators should be selected at this point also.

4. Control Of Quality

Control of quality is achieved through control of the operation to prevent defects.

> "Central to the process of quality control is the act of quality measurement: What gets measured, gets done. ... for quality control, measurement provides feedback and early warnings of problems". [Ref. 5]

Control of quality is the process of inspection, measurement, comparison and evaluation of actual performance relative to specifications and standards, thus identifying

and interpreting variances and taking corrective action or rejecting the product .

> Quality control is the regulatory process through which we measure actual quality performance, compare it with quality goals, and act on the difference. [Ref. 6]

Today in many companies and government agencies, the approach of quality control through inspection is extended in the concept Total Quality Management.

B. TOTAL QUALITY MANAGEMENT

1. Background

After World War II, some countries had the advantage of being the winners and others the disadvantage of being the losers. Japan was one of the big losers. The Japanese industrial base had been completely destroyed. The statement "Made in Japan" meant a poor quality product. [Ref. 1] The Japanese had to find a way to start with few resources to rebuild their industry and their nation. Dr. W. E. Deming was the man who taught the Japanese a way to rebuild their economy based on a philosophy known today as Total Quality Management (TQM). The main idea was that quality products would give the producer a competitive advantage in international markets.

Dr. Deming gave a lecture to Japanese CEOs about using statistics in manufacturing to achieve quality at reduced

cost. Dr. Deming's emphasis on quality through good management practices, a well-educated and trained work force, and the use of statistical techniques for quality control was adopted by Japanese companies and resulted in the very impressive comeback of the Japanese economy [Ref. 10].

2. T Q M Principles

Total Quality Management focuses on improving the manufacturing process instead of inspecting the product and scrapping or reworking rejects. The traditional position on quality control is compared with the Japanese (TQM) position in Table 1.

TQM means developing and maintaining the organizational activities to constantly improve quality in meeting customer expectations and emphasizing quality in every aspect of the entire organization. It uses statistical process control and management principles. "TQM emphasizes a commitment by management to have a company-wide drive toward excellence in all aspects of products and services that are important to the customer" [Ref. 8].

TABLE 1. Traditional Quality Management in the United States vs. Japan. [Ref. 8]

Traditional Position	Japanese Position
Quality is a function of how well the product or service meets the specifications.	Same as the U.S. position.
Quality depends on all departments - from purchasing to engineering design to production to shipping to service.	Same as the U.S. position.
The quality goal is to reach a preset percentage of defectives.	Accept no defects - insist on perfection.
Quality goals are set one fiscal year at a time.	Strive to improve quality consistently, not once a year, but all the time.
There is an optimal level of quality. Customers will not pay for a higher level.	Increasing quality all the time will increase market share and spur new market demand.
Control quality is done through inspections during production and through final inspection of completed lots.	Every production worker is responsible for inspection, even if this means stopping the assembly line to correct the observed defect.
Use statistical sampling methods to inspect large lots of completed products.	Inspect each piece as it is produced to catch defects before a whole lot is poorly made. Keep inventory low, using just-in-time concept.
Set acceptable quality levels (AQL) based on sampling tables such as MIL-STD-105D. These levels are stated in number of defects per 100 units produced.	Reject sampling tables, since no level of defects in acceptable. Express defects in number of defects per one million units produced.
Use a random sample, typically of size $n = 5$, to check for process stability.	Use a sample of $n = 2$, consisting of the first piece and last piece produced in each lot to assure stability.
The QC department is responsible for testing/inspection.	The QC department monitors quality, but also teaches and spreads QC information. Actual inspection by workers.
Rework of defective units is done on a separate rework line with its own staff.	Workers or groups correct their own errors, even if they have to stay late. (In reality, very few reworks are needed because of total quality control.)
Janitors keep workplaces clean.	Workers themselves are responsible for housekeeping of their work areas.

The U.S. Navy refers to its use of TQM philosophy as Total Quality Leadership (TQL) and stresses the application of quantitative methods and the knowledge of people to assess and improve the following:

- Materials and services supplied to the organization,
- All significant processes within the organization, and
- Meeting the needs of the customer or end-user, now and in the future. [Ref. 1]

3. Deming's Approach

Deming's approach is based on implementation of fourteen points to help an organization make the changes required to implement a total quality management system. His fourteen points are shown in Table 2.

> The Fourteen Points are principles that apply to all organizations: From small organizations to large ones, from service industries to manufacturers. They apply to each division within a company. They apply to public and private organizations and to military and civilian organizations. [Ref. 13]

TABLE 2: Deming's Fourteen Points for Implementing Quality Improvement [Ref. 8]

1. Create consistency of purpose.
2. Lead to promote change.
3. Build quality into the product; stop depending on inspections to catch problems.
4. Build long-term relationships based on performance instead of awarding business on the basis of price.
5. Continuously improve product, quality, and service.
6. Start training.
7. Emphasize leadership.
8. Drive out fear.
9. Break down barriers between departments.
10. Stop haranguing workers.
11. Support, help, and improve.
12. Remove barriers to pride in work.
13. Institute a vigorous program of education and self-improvement.
14. Put everybody in the company to work on the transformation.

Through his fourteen points Deming emphasizes the following:

- Use statistics to localize problems early in the process and to minimize variances in quality at lower cost.
- It is better to prevent defects than detect defects. Build quality into the product and stop depending on inspections to catch problems.
- Inspect the process and fix the causes of defects so you can do it correctly the first time .

- Quality comes from planning, controlling the process, and continuously improving all aspects of the organization.
- Maintain a well-educated and trained work force.

To be effective an organization should implement all of Deming's fourteen points. An organization can start with the implementation of the points most important to it and, as success and efficiency are achieved, keep implementing the remained points for maximum success.

For steam boiler maintenance first priority should be given to points 2, 3, 4, 5, and 6. These points are the most applicable to the relationship between an organization and its suppliers.

Point 2: Lead to promote change.

This point basically means change the philosophy of doing business by adopting a philosophy that emphasizes quality.

> Adopting the new philosophy requires a paradigm shift in thinking and behaving in organizations. A paradigm shift is not about a gradual evolution; a paradigm shift means a major revolution in thinking. The people of the 15th century had to make a paradigm shift to realize and accept that the earth was round instead of fiat. This one realization affected their thinking about a host of other issues: Travel and navigation, movement of stars, gravity, and even the place of humanity in the cosmos. Now WE have to make a paradigm shift to accept a new philosophy of doing

business. This new philosophy will transform the way we think about every aspect of our work lives. The Fourteen Points are the transformational tools to ease the required paradigm shift. [Ref. 13]

At the present time;

> The Department of the Navy is affected by the general economic conditions in the United States and the worldwide changes. It is also experiencing radically declining budgets and personnel. We cannot afford waste or rework at any level. We must adopt a philosophy that emphasizes quality. The DON must provide the best defense possible within the budget provided by Congress. [Ref. 10 and 13:p. 7-8]

Point 3: Build quality into the product; stop depending on inspections to catch problems.

Deming states that inspection of a final product to find defects is too late and that fixing is too costly. He proposes a change in the inspection function to inspect the process and refine the inspector (his knowledge, training and abilities). Quality comes from process improvement. It is better to build quality into the product the first time. The best way to improve quality is to reduce process variation.

Deming also points out that, as a practical matter, a certain amount of inspection will always be required [Ref. 10]. For example, producing integrated circuits or

measuring medical dosages require 100% inspection. Safety considerations fall into this same category. Releasing an overhauled aircraft without flight tests would be foolhardy [Ref. 13: p.7-12]. This is also true for a steam boiler after maintenance. Hydrostatic tests to 150% of the operating pressure should take place with inspection showing no leakage.

Point 4: Build long-term relationships based on performance instead of awarding business on the basis of price.

In this point Deming states that contract awards should be based on best value of the product instead of lowest price by the lowest bidder. "In the Navy, we need to work more closely with contractors and suppliers and educate them about quality requirements." [Ref. 13]. If the quality received by the lowest bidder is not the expected quality then it will cost much more in the long run for rework or replacement.

This point also encourages an organization to "reduce the number of suppliers to reduce variation" [Ref. 13]. Awarding the contract each time to a different bidder will

increase variances which may cause problems in the systems where these products are used. For example, for a specific diesel engine, if an organization buys spare cylinder liners and pistons from different suppliers each time, there could be small variances in piston and liner diameters which could cause serious problems in oil consumption and the regular operation of the engine.

Point 5: Continuously improve product, quality, and service.

According to Deming, an organization must have a program of continuous quality improvement to remain competitive.

> For example, what is considered effective weaponry today may be unacceptable tomorrow due to equipment innovations. This points up the need for continuous improvement. [Ref. 13]

The leaders of an organization should constantly and forever improve the systems they control and push information up the chain of command to help higher levels identify barriers that stand in the way of continuous improvement [Ref. 10]. Customer feedback is vital to identifying needed improvements.

Point 6: Start training.

Changing and improving an organization's process cannot be achieved without training. "Employees must know how to do their jobs. You cannot perform a job well if you don't know how or why the job is to be done". [Ref. 13]

> Changing organization systems without providing training will not lead to continuous improvement. Organizations sometimes offer no or little formal training. Many organizations institute on-the-job training which means new workers learn their jobs from other co-workers or predecessors who themselves may have never been properly trained. Deming notes that this way of training contributes to greater variation in the process. On the other hand, the training should not end as long as performance is not yet in statistical control and there is something to be gained. [Ref. 10]

For steam boiler quality maintenance:

- Inspectors should be trained and retrained to inspect the boiler and determine the tests needed to be done.
- Employees should be trained and retrained to perform repair work. For example:. a welder must know what kind of electrode to use and how to do the welding on a particular tube.

C. QUALITY ASSURANCE

1. Definitions Of Quality Assurance

Quality assurance is the activity that provides protection against quality problems through early detection

and correction of defects and failures, warning of variances from specifications and providing the opportunity to correct deficiencies as early in the process as possible. Other definitions for quality assurance are the following:

> Quality assurance is a planned and systematic pattern of all actions necessary to provide confidence that the item or product conforms to established technical requirements [Ref. 7].

> Quality assurance is the activity of providing the evidence needed to establish confidence, among all concerned, that the quality-related activities are being performed effectively [Ref. 5].

The quality assurance department in an organization is responsible for activities such as quality planning, quality control, and quality audits. It establishes quality assurance procedures to the monitor performance to control variances.

The government needs to assure that it will receive a product that performs as it was designed. As important as it is for the contractor to receive payment for the service that has been performed, it is equally important for the government to receive the product quality it paid for. Well organized quality assurance departments and quality assurance provisions in the contract are helpful to protect the rights of both the government and the contractor.

2. Quality Assurance Standards

Necessary quality control procedures and quality acceptance criteria have been established between organizations as quality assurance standards. The scope of standardization is to document accepted practices to provide a common means for clear communication between organizations. The quality assurance standards are intended to ensure that the supplier meets the buyer's specified requirements during all phases of production or service. Specific quality assurance standards should be written in the contract.

The implementation of quality assurance standards will help accomplish the following:

a) For the supplier:

- establish measurable criteria to determine when tasks are performed correctly,
- create a successful quality control management strategy,
- increase customer confidence with company products and manufacturing practices,
- increase customer satisfaction to create a competitive edge for the company, and
- reduce testing and administrative costs.

b) For the buyer:

- increase mission reliability,
- reduce testing costs and time invested in product feasibility studies,

- increase buyer confidence about the goods acquired, and
- provide more efficient source evaluation and selection.

There are many different quality assurance standards in existence. For example, there are military standards, commercial standards, and international standards.

III. QA STANDARDS

A. MILITARY QUALITY ASSURANCE STANDARDS

The existing standards used in DoD contracts concerning quality assurance are:

- MIL-Q-9858A: Quality program requirements,
- MIL-I-45208: Inspection system requirements,
- MIL-STD-105E: Sampling and inspection procedures, and
- MIL-STD-109: Quality assurance definitions.

In addition to the above military quality assurance standards the following Naval SEA Systems Command (NAVSEA) technical manuals are referred to in boiler maintenance contracts as guidelines for specific work:

- NAVSEA S9221-D2-MMA-010: Steam Generation Plant Inspection (non-nuclear) technical manual,
- NAVSEA S9086-GY-STM-010/CH-221: Naval Ships' Technical Manual" chapter 221 Boilers, and
- NAVSEA S9221-C1-GTP-010/020 "Repair and Overhaul Main Propulsion Boilers".

1. MIL-Q-9858A: Quality Program Requirements

This specification directs suppliers on what they must consider when conforming to this specification, and it requires approval of the company's quality program by the government. The following two paragraphs provide a perspective for this specification:

> 1.2 Contractual Intent. This specification requires the establishment of a quality program by the contractor to assure compliance with the requirements of the contract. The program and procedures used to implement this specification shall be developed by the contractor. The quality program, including procedures, processes and product shall be documented and shall be subject to review by the Government Representative. The quality program is subject to the disapproval of the Government Representative whenever the contractor's procedures do not accomplish their objectives. The Government, at its option, may furnish written notice of the acceptability of the contractor's quality program.
>
> 1.3 Summary. An effective and economical quality program, planned and developed in consonance with the contractor's other administrative and technical programs, is required by this specification. Design of the program shall be based upon consideration of the technical and manufacturing aspects of production and related engineering design and materials. The program shall assure adequate quality throughout all areas of contract performance; for example, design, development, fabrication, processing, assembly, inspection, test, maintenance, packaging, shipping, storage and site installation. [Ref. 12, p.13]

A careful analysis of MIL-Q-9858A leads one to conclude that the drafters of this specification were seeking to close as many legal challenges to their idea of quality

programs as possible. The goal of using the existing supplier quality assurance program to fulfill quality requirements of the Government becomes lost in all the government oversight and inspections, required to conform to this specification. The end result is a requirement on the part of the Government to be constantly inspecting the quality assurance program to ensure compliance with all the various parts of this specification. Thus MIL-Q-9858A becomes an attempt to "inspect quality into the product" rather than build it in using good quality processes that stress improving the existing production system. [Ref. 12, p.15]

An evaluation for its relation to TQM and a comparison with international standards is examined in Chapter V.

2. MIL-I-45208: Inspection System Requirements

This specification contains fewer requirements than specification MIL-Q-9858A, and the contractor may use the requirements of this MIL-Q at his option if he is already complying with it. MIL-I-45208 contains details for the inspection system that will follow the contract to assure quality of procurement and provide an attempt to cover as many contingencies as possible. It includes scenarios for a change to a product within the specification, amendments and

revisions. MIL-I-45208 requires that the contracting officer be notified in the event that an amendment or revision is implemented. According to these requirements a contractor cannot follow revisions until they are formally added to a contract. [Ref. 12 and 20]

3. MIL- STD-105E

MIL-STD-105E establishes sampling procedures and plans to be used in inspections. It is based on the random sampling of events for specified attributes. An attribute is a feature of a service which either matches or fails to match a standard.

The user must determine a proportion of defectives and then specify an acceptable quality level (AQL). Given the AQL, the inspection level, the lot size, and the number of inspections to be done, MIL-STD-105E provides a sampling plan. This plan is applicable to the inspection of end items, components and raw materials, materials in process, supplies in storage, maintenance activities, etc.

4. MIL-STD-109

The purpose of MIL-STD-109 is to promote the common use of words and phrases pertaining to quality and related programs, thus improving clarity in communications. This standard provides a standardized interpretation of quality

assurance terms and definitions used in specifications, standards, technical manuals, contracts, and quality control inspection and related documents.

B. COMMERCIAL QUALITY ASSURANCE STANDARDS

In addition to NAVSEA technical documents and other military standards, the following commercial quality assurance standards are also in use:

- The Code of Federal Regulations (CFR) part 46: Shipping,
- The American Society of Mechanical Engineers (ASME) Boiler and Pressure Vessel Code, and
- The National Board Inspection Code (NBIC).

The standards most often referenced in steam boiler construction, repair and maintenance are the ASME and NBIC standards, which are both internationally recognized.

1. The Code Of Federal Regulations (CFR)

This is a standard mainly used for ship's under the United States Coast Guard jurisdiction. This standard requires inspection by a Marine Coast Guard inspector prior to any boiler repair work to provide safety during the maintenance process. It also requires inspection after maintenance to ensure that the completed work is in a safe and satisfactory condition.

2. The American Society Of Mechanical Engineers, Boiler And Pressure Vessel Code

The American Society of Mechanical Engineers (ASME) Boiler and Pressure Vessel Code establishes rules of safety governing the design, fabrication and inspection during construction of boilers. There is no provision in this standard for boiler maintenance.

3. National Board Inspection Code

The National Board of Pressure Vessel Inspectors is an organization comprised of the Chief Inspectors of states and cities of the United States and provinces of Canada. It is organized for the purpose of promoting greater safety to life and property by securing concerted action and maintaining uniformity in the construction, installation, inspection and repair of boilers and other pressure vessels and their appurtenances. Uniformity of requirements assures acceptance and interchangeability among jurisdictional authorities[1] who are responsible for the administration and enforcement of the various sections of the (ASME) Boiler and Pressure Vessel Code. The National Board Inspection Code

[1] Jurisdiction or Jurisdictional Authority: "Any city of the United States having a population of 1 million (1,000,000) or more, any sate of the United States that has adopted and does administer one or more sections of the ASME Boiler and Pressure Vessel Code as a legal requirement".

(NBIC) is implemented in jurisdictions that have adopted and administer a boiler and pressure vessel safety law.

The purpose of the NBIC is to maintain the integrity of such boilers after they have been placed into service by providing rules and guidelines for inspection after installation, repair, alteration and re-rating, thereby helping to ensure plant integrity and safety.

This code provides guidelines and recommends procedures for use by the authorized inspector of ASME/National Board manufactured and stamped boilers during fabrication. It also provides inspector qualification requirements.

The NBIC is based mostly on acceptance inspections and specifies final inspections after repair or maintenance work. It does not present any contractor's quality control requirements except welder qualification. It could provide in some limited cases, an inspection guide for Navy boiler maintenance. However, the inspection procedures presented in the NAVSEA technical manuals are more appropriate for boilers which have been manufactured under military specifications. Additionally the Navy has its own inspectors to verify the adequacy of a contractor's quality control system in order to avoid oversight and excessive acceptance inspections.

C. INTERNATIONAL QUALITY ASSURANCE STANDARDS (ISO 9000)

Many quality system standards have been developed and are available world-wide. The ISO 9000 series is a set of quality assurance standards created to provide uniformity among the European Community. The ISO 9000 standards have been adopted as national standards by most industrialized nations, and have the potential of improving free trade world-wide. These standards stress process control and are a step toward continuous improvement. In 1970 the ISO committee was formed with the following objectives:

1) To study a means of assessing the conformity of products, processes, services and quality systems to appropriate standards or other technical specifications.

2) To prepare international guides relating to the testing, inspection and certification of products, processes and services, and to the assessment for acceptance. [Ref. 12]

In 1976 the ISO TC 176 technical committee was formed to address specific questions of quality assurance and quality management. In 1987 the committee issued five quality assurance models:

- *ISO 9001: Quality Systems* model for quality assurance in design and development, production, installation and servicing. This is a specific model for companies that perform all phases of the

manufacturing process from design to final product and is the most comprehensive of the ISO standards.

- *ISO 9002: Quality Systems* models for quality assurance in production and installation. This is a specific model for manufacturing companies that perform all phases of manufacture except design of the product.
- *ISO 9003 Quality Systems* model for quality assurance in final inspection and test. This model provides specifics for end-item inspection procedures.
- *ISO 9004: Quality Management and Quality System Elements Guidelines.* This reference document explains the philosophy and underlying purpose of ISO 9000.
- *ISO 9000: Quality Management and Quality Assurance Standards Guidelines for Selection and Use.* This document clarifies the relation between different quality concepts and is based on an approach to quality assurance modeled along the TQM principles.

The ISO 9001, 9002, and 9003 are contractual quality standards while the ISO 9000 and 9004 are guideline standards. An analysis and assessment of the ISO 9000 series standards applicability to boiler contracts is examined in Chapter V.

IV. SAN DIEGO NAVAL STATION AND QA

This chapter describes interviews the author conducted at the San Diego Naval Station and the San Diego Fleet Training Center in June 1995. The interviews addressed the implementation of quality assurance in 1200 psi boiler maintenance.

A. INTERVIEW PREPARATIONS

Telephone contacts were made first to identify who was responsible for boiler maintenance and boiler QA. An appointment was made with LCDR Werkman, Officer in charge in the engineering department of the Fleet Training Center. A survey questionnaire was developed and faxed in advance to BTCS(SN) Thomas Adams, course coordinator for Steam Generating Plant Inspector Certification (SGPIC). The author selected interview questions which met the criteria of being: (1) open-ended in nature and (2) reflective of the primary and secondary research questions listed Chapter I. A copy of the survey is included in Appendix A. The questionnaire was intended to prepare the interviewees to

answer questions about the QA procedures and standards implemented for 1200 psi boiler maintenance.

B. INTERVIEWS

The author visited the Fleet Training Center and the Naval Station in San Diego CA from 30 May through 2 June 1995. Personal interviews were confirmed with five representatives. Specific questions were asked of each interviewee depending on their specialty. The advantages of personnel interviewing were in the detailed information received by probing the respondents during the interviews.

The first interview was with BTCS(SW) Thomas Adams, course coordinator for Steam Generating Plant Inspector Certification (SGPIC). The interview was about boiler maintenance documentation and included personnel training and qualification procedures.

The next interview was with the BTCS Cayas, course coordinator for QA training. He explained the scope and the reasons for the emphasis on QA training.

The third interview was with BTCS John, Steam Generating Plant Inspector (SGPI), at Shore Intermediate Maintenance Activity (SIMA) San Diego. The emphasis of this interview was on inspections and quality control procedures for boiler maintenance.

The final interviews were with the two supervisors for shipbuilding and repair: Mr. Clemans, the boiler planner; and Mr. Russo, the head of advance planning. These interviews discussed the Naval Station's assignments for boiler maintenance to commercial contractors and the QA standards that are included in the contracts.

C. INTERVIEW RESULTS

The interviews provided background information about the U.S. Navy's QA program and information about inspection frequency, inspection procedures, and boiler overhaul procedures. Information about QA in boiler repair and tube procurement was also obtained.

1. Background of The U S Navy's QA Program

The need for a QA program for ship maintenance in the U.S. Navy was recognized in 1962 after the USS THRESHER sank. After the Navy implementing a QA program for submarine maintenance there was a significant reduction in accidents and an increase in readiness for all U.S. Navy ships. In 1967 a formal program was established to provide for the routine inspections of all conventional steam generating plants by qualified Steam Generating Plant Inspectors (SGPIs).

In 1982 a new QA program was implemented at SIMA San Diego for ashore based facility, and a QA team was set up to supervise it.

In 1989, when the USS IWO JIMA completed a boiler repair at a Bahrain shipyard, an untrained Petty Officer (PO) gave the shipyard brass nuts instead of steel nuts for a boiler's main steam valve. The valve exploded and ten people were killed. This improper QA boiler maintenance prompted the U.S. Navy to establish an even stricter and more effective QA program for U.S. ship maintenance.

In 1990, the Navy recognized that there was an additional need for systematic industrial inspections by qualified Certified Industrial Boiler Inspectors (CIBIs) of all conventional steam generating plants in areas not normally covered by SGPIs. It was noted that the training and certification of all SGPIs and CIBIs needed to be closely monitored and standardized to ensure that all Navy steam generating plants receive professional inspections. For this reason the Chief of Naval Operations issued an instruction which delineated the specific requirements for their training and certification, so that all levels of command could achieve the desired standards and improve overall fleet readiness.

In 1992, a new QA program was established based on Total Quality Leadership (TQL) to help avoid mistakes. The primary goals were accident and cost reduction along with an increase in readiness. To establish and administer this shipboard QA program, the Commander Naval Surface Force Atlantic and Pacific Fleet issued the "Forces Afloat Quality Assurance Manual" with the following goals:

- to assign responsibilities and coordination channels within the revised shipboard quality assurance organization, and give QA guidelines to everyone involved in maintenance activity;
- to familiarize U.S. Navy personnel with QA practices that will save lives;
- to provide efficient supervision of work done; and
- to delineate shipboard procedures for inspection, stowage, issue, and record keeping requirements.

In order to achieve these goals, the U.S. Navy has modified the existing periodic inspections by providing NAVSEA technical manuals which describe specifications, limits, and frequency of inspections.

2. Inspection Frequency

Periodic inspections are performed in order to maintain the boiler in a desired condition. Naval certified SGPIs perform periodic inspections in accordance with the NAVSEA S9086-GY-STM-010/CH-221 technical manual. Section 2 page 9 of this manual declares the frequency of periodic inspections and boiler maintenance (whichever occurs first following the last inspection) as follows:

a. Routine Inspection

A routine inspection is performed every 18 months to check the state of the boiler. To provide scheduling flexibility, this inspection may be performed as early as 12 months or as late as 24 months after the previous inspection. This inspection shall be performed by a certified Steam Generating Plant Inspector (SGPI). [Ref. 15]

b. Unscheduled Inspection

An unscheduled inspection is performed:

- During the next upkeep or repair period following a serious contamination incident;
- Prior to further steaming if, as a result of a serious contamination incident, boiler water conductivity is greater than the specified limit;

- According to other Naval Sea Systems Command (NAVSEA) program requirements; or
- Whenever the Engineer Officer considers an inspection necessary. [Ref. 15]

c. Strength and Integrity Inspection

This inspection is performed every 60 months. The inspection should be scheduled to coincide with Chief of Naval Operations (CNO) inspections at depot level ship overhaul. To provide scheduling flexibility, the boiler strength and integrity inspection may be performed as early as 48 months or as late as 72 months after the last strength and integrity inspection. Every effort should be made to conduct this inspection within 60 months of completion of the previous strength and integrity inspection. [Ref. 15]

3. Inspection Procedures

The inspection procedures are established in accordance with the NAVSEA S9221-D2-MMA-010 "Steam Generation Plant Inspection (non-nuclear)" technical manual. This manual provides information to help in conducting a proper inspection. It lists areas to be inspected, common conditions and defects, recommended actions, and other important information. In this manual there are no special

QA provisions. It emphasizes that thoroughness is the most important aspect of a boiler inspection.

During these periodic inspections the Naval Inspectors statistically select tubes and piping points on which to perform non-destructive inspections. They determine which parts or tubes need repair or replacement. For example, if there are some tubes in good condition, but they are leaking in the connections with the drums, the assignment is to re-roll the generating tubes or weld the superheater tubes but not to replace them. If there are significant deficiencies in the tubes, they need replacement.

4. Boiler Overhaul Procedures

The quality assurance for boiler maintenance is based on implementation of the above procedures. This is achieved by implementing quality control procedures during the maintenance or overhaul cycle. It begins at the start of the availability inspection (SAI) and finishes with the completion of availability inspection (COI).

a. Start of Overhaul Availability Inspection

The boiler inspection starts with an overhaul/ availability inspection (SOI/SAI). The SOI/SAI and strength and integrity inspection is a joint inspection by Carderock Division Naval Surface Warfare Center (CDNSWC), the

overhauling agency, the Type Commander (TYCOM), and the ship personnel.

Within the SAI, the Naval inspectors identify the work to be completed. The quality assurance during inspections is dependent on the inspectors' knowledge and experience. In this manner, repair work can be carried out to verify the continued safe operation of the boiler. If the Naval inspector finds an operational deficiency, he will decide whether or not it will operate safely until the next inspection. If he decides in the negative, it will have to be repaired immediately.

Generally, a non-destructive tube evaluation is performed concurrently with the SOI/SAI. This requires additional Naval activity or TYCOM personnel trained in the use of currently authorized boiler tube non-destructive examination (NDE) equipment. Currently authorized equipment includes (BTIU), remote visual scopes, laser optic tube inspection system (LOTIS), remote field eddy current (RFEC) and immersion ultrasonic test (UT). The procedure to determine the need for tube renewal in main propulsion boilers is in the Boiler Inspection Manual. On the basis of observed conditions and results of the NDE evaluation,

sample tubes for destructive evaluation may be required and will be identified by the CDNSWC inspector. [Ref. 15]

Quality control during maintenance involves the Naval Inspector, the TYCOM, the ship quality assurance officer, and the ship quality assurance coordinator, and is conducted according to the Forces Afloat Quality Assurance Manual.

b. Tube Renewal

Examination of boiler tubes to determine the need for replacement relies on a combination of inspection techniques and inspection tools including visual examination of tube ends, optical examination of tube internal surfaces, metallurgical examination, ultrasonic techniques, laser-optic techniques, eddy current techniques, hydrostatic tests, and tube removal with destructive testing. These methods are used to determine tube wall thinning, pitting depth, pitting frequency, corrosion deposit thickness, failure mode, tube seat integrity, and bell anomalies such as end pitting and splitting. Nondestructive examination and testing is used whenever possible. Decisions for general tube renewal, however, may require some tube removal to gain conclusive data to support the decision. [Ref. 15,221-2.9]

Tube failures in generating banks generally occur in the outer half of the tube nest because of external

corrosion just above the water drums. When such failures have occurred, either in operation or under hydrostatic test, or during examination by non-destructive testing or by destructive sampling, and the tube thickness is less than half the original thickness, the affected tubes and those requiring removal for access shall be replaced. The existence of slight scattered pitting, even when the tube thickness in the pits is less than half the original thickness, does not necessarily require complete re-tubing of the boiler. Tubes are evaluated according to procedures in the boiler inspection manual. [Ref. 15,221-2.9]

c. Completion of Overhaul/ Availability Inspection

The intent of the boiler Completion of Overhaul/Availability Inspection (COI/CAI) is to ensure that all work authorized at the SOI/SAI has been satisfactorily completed. This is a joint inspection by CDNSWC, the repair activity, and TYCOM personnel. The COI/CAI should be performed when approximately 90 percent of all boiler work has been completed. Within the CAI the same inspectors who did the initial inspection check that work was carried out properly and completed satisfactorily.

d. Hydrostatic Tests

The object of boiler hydrostatic tests is to prove either the tightness of all parts of the boiler or the strength of the boiler and its parts. The tests apply to and include the entire boiler pressure vessel, including the first or most proximate valve on each connecting line to the boiler. Hydrostatic test pressures for a particular boiler can be determined by reference to the design and operating data listed in the boiler technical manual. [Ref. 15, 221-2.16.1]

Hydrostatic test acceptance criteria and related repair guidance have been established for tube joint leakage. The first hydrostatic test of newly installed rolled tubes is at 125 percent of rated operating pressure, and if dry, followed by the 100 percent test to confirm tightness. Tubes leaking at the 125 percent test shall be re-fitted to the joint. Each subsequent hydrostatic test of the re-fitted joint is at 100 percent. If the joint is not absolutely dry, it should be re-fitted using the proper equipment and re-tested at 100 percent hydrostatic test pressure for 15 minutes after which joint tightness shall be re-evaluated. After two re-fits, the joint may be considered acceptable if only dampness but not

leakage (weep, spray, or trickle) is present at the joint. [Ref. 15 ,221-2.16.6]

5. QA In Boiler Repair and Tube Procurement

a. Boiler Repair

Most repair and replacement boiler work at the San Diego Naval Station is done by the private sector. The Naval inspectors determine the assignments and do the final acceptance. In order to assure that the work is completed satisfactorily, in addition to the previous QA procedures, quality assurance standards and specifications are written into the repair contracts governing work performed in the private sector. The most commonly invoked written QA specifications are the MIL-Q-9858A, "Quality Program Requirements", the MIL-I-45208, "Inspection system requirements", and the MIL-STD-105E "Sampling Procedures and Tables for Inspection by Attributes" [Ref. 16].

b. Tube Procurement

The Naval supply center is responsible for tube procurement. In order to accept the tubes, inspections are performed to ensure that high-quality formed tubes are manufactured from the proper military specification tubing. The inspection points and methods for each tube type are

described in NAVSEA S9221-C1-GTP-010/020 "Repair and Overhaul Main Propulsion Boilers", Chapter II "Quality Assurance". The number of tubes selected for inspection is in accordance with MIL-STD-105E, level III - AQL 1.5 for economizer tubes and level I - AQL 1.5 for generating and superheater tubes respectively.

However original manufacturers have begun to upgrade the methods and procedures of manufacturing new boiler tubes including QA requirements and non-destructive tests. They tag tubes made to their upgraded procedures with the letter "Q", followed by the month and year of manufacture. These tubes are exempt from the inspection requirements.

V. ANALYSIS OF QA STANDARDS

This chapter compares the International Standard ISO 9002 and the Military Standards MIL-Q-9858A and MIL-I-45208 to TQM principles and demonstrates which of them is closer to TQM in order to identify the requirements to use in contracting with private sector suppliers.

A. COMPARISON OF ISO 9002 TO TQM

From the various international standards the most appropriate for boiler maintenance is ISO 9002, because:

- ISO 9000 and ISO 9004 standards are used only as guidelines for the implementation of ISO 9001, ISO 9002, and ISO 9003 standards.
- ISO 9003 is based on the procedures of final inspection and testing, which is contradictory to TQM principles.
- ISO 9001 is almost the same as ISO 9002 with the addition of design prerequisites. In maintenance activities, design standards are not required.

ISO 9002 can be compared with TQM by considering Deming's points 2, 3, 4, 5, and 6:

1. Point 2: Lead To Promote Change

Adaptation to change is basic in ISO 9002 and it is tied to Deming's point 2. Both of them emphasize quality and are able to adapt procedures that can apply their standards to a changing environment. A company that chooses to be registered within ISO 9001 or ISO 9002 standards can promote change toward quality improvement emphasizing quality in all its development and maintenance stages.

2. Point 3: Build Quality Into The Product

The majority of ISO 9002 requirements are in accordance with Deming's point 3 the most important of Deming's points, which emphasizes building quality into the product. Following this point, the ISO 9002 standard in paragraphs 4.1 and 4.8 [Ref. 18] provides for building quality into the product. Paragraph 4.1.2.1 requires responsibility of all personnel who manage, perform, and verify work affecting quality. There are also provisions to take actions to prevent the occurrence of product nonconformity and to identify and record any product quality problems.

Paragraph 4.8 of this standard requires that the supplier must monitor and control suitable processes which

directly affect quality of the final product/service. It also requires written criteria for workmanship where possible. Another fundamental tool for controlling the process is in paragraph 4.18 which requires the supplier to use appropriate statistical techniques to verify process capability and product characteristics.

In addition to developing preventive actions, in paragraph 4.9 this standard anticipates both in-process and final inspection requirements. This is in accordance with Deming's point 3 which points out that a certain amount of inspection will always be required. The aim of in-process inspection and testing is to identify deficiencies as early as possible. Taking corrective actions and improving process actions will avoid excessive costs in correcting final defects.

This standard also requires final inspection and testing in accordance with the product's quality plan or documented procedures. This is especially true for steam boilers. After boiler maintenance a certain amount of inspection and hydrostatic tests are required for safety reasons. Therefore, according to Deming's point 3, ISO 9002 covers the entire process that a contractor must complete to achieve an acceptable final product.

3. Point 4: Build Long-Term Relationships Based On Performance

Paragraphs 4.3 and 4.5 of ISO 9002 [Ref. 18] are in accordance with Deming's point 4. These paragraphs require that the contractor ensure that its subcontractors maintain effective quality control systems and have the capabilities to meet contractual requirements including quality. These two paragraphs make it clear that the contractors' relationship with their suppliers must be based on performance and the best value approach instead of selecting the lowest price by the lowest bidder.

The organization which selects ISO 9000 registered contractors follows Deming's point 4 by selecting its contractors based on quality considerations.

4. Point 5: Continually Improve Product, Quality, And Service

Paragraphs 4.2, 4.13 and 4.15 of ISO 9002 [Ref. 18] are in accordance with Deming's point 5. Paragraph 4.2 requires that timely consideration must be given to the updating of quality inspection and testing techniques, including new instrumentation. Additionally, the standard will be reviewed for possible updates and/or changes at least every

five years. This provision demonstrates ISO's dedication to continual improvement.

Paragraph 4.15 of ISO 9002 states that "quality records shall be maintained to demonstrate achievement of the required quality and the effective operation of the quality system" [Ref. 18]. Additionally, paragraph 4.13 of this standard explains how procedures for corrective actions help to eliminate potential causes of deficiencies.

The records, documentation, and statistics for quality required by this standard ensure that the contractor will have significant data to implement a continual quality improvement program.

5. Point 6: Training

ISO 9002 includes a provision which requires that all personnel performing activities affecting quality should receive training. Paragraph 4.17 of this standard stipulates that the contractor must provide training and education for all personnel whose job may affect quality of production and services. It also requires that personnel performing specific assigned tasks must be qualified on the basis of appropriate education, training and/or experience. Also, this paragraph requires that trained personnel should be assigned for verification activities.

ISO 9002 cannot be achieved without proper training. First, employees must be trained on how to do their jobs with emphasis in quality. Then they can apply what they have learned in the work environment, in order to assure a quality final product.

6. Summary

The intent of ISO 9002 is simple. It is that a basic quality system assures customers that suppliers are able to provide quality products and services. ISO 9002 also provides for continual improvement. Documenting the quality system clarifies critical process measurements, facilitates process improvement, and increases customer satisfaction.

Although ISO 9002 is not a TQM guide, it is a QA standard that provides minimum contractual requirements for a quality product or service to meet customer expectations.

> "ISO 9002 requirements certainly belong to a Total Quality process. They cannot take place of a Total Quality effort because they do not necessarily have to deal with issues of leadership, strategic planning, bench-marking , or employee empowerment. Those issues are more central to Total Quality. ISO 9002 does, however, provide a comprehensive approach to documenting quality processes and assessing their performance." [Ref. 21]

The ISO 9004 is closer to TQM principles. Although not intended for certification purposes, it is useful as a guideline model for an effective TQM system implementation.

B. COMPARISON OF MIL-Q-9858A AND MIL-I-45208 TO TQM

Generally these two military standards rely on inspection of the product to promote quality. On the other hand, TQM focuses on in-process inspection and continuous quality improvement. The main idea is that MIL-Q-9858A, MIL-I-45208 and TQM each support quality, but they use different procedures in achieving this goal. The following paragraphs describe the main differences among the procedures used by the military standards and TQM.

1. Comparison Of MIL-Q-9858A To TQM

The majority of the MIL-Q requirements refer to product inspection and correction of discrepancies [Ref. 19] rather than process correction for improvement. This approach is not consistent with TQM principles, and Deming's point 3.

Although the standard provides that "The program shall assure quality throughout all areas" [Ref. 19], it does not have specific provisions for process improvement or continuous quality improvement actions.

MIL-Q requires the use of MIL-I-45208, which is based on the final inspection process rather than the "quality built into the product" development. This concept is different from TQM's main purpose.

Although, MIL-Q requires well defined responsibilities for the personnel involved in product quality, it does not provide requirements for personnel training programs.

MIL-Q recognizes the need to update inspection and testing techniques, but it does not provide guidelines for the update of the inspection process in order to assure quality.

The MIL-Q instructions are intended to serve for supervising, inspecting, and managing work. On the other hand, TQM emphasizes training, responsibility, and involvement of all the personnel in the quality process, and less on supervising.

In MIL-Q, the contractor's acceptance of purchases from its suppliers is based on inspection. This ensures that the manufacturer has to make a product that meets specification requirements. According to Deming's point 4, the suppliers should maintain an adequate quality control program and contracts should be awarded based on the product with the best quality.

The above imply that the MIL-Q-9858A specifications do not follow TQM principles.

2. Comparison Of MIL-I-45208 To TQM

This standard contains fewer requirements than MIL-Q-9858A and is based entirely on product inspection, correction of the final product, and acceptability or non-acceptability concepts. The following three paragraphs are the basis for this standard:

> 3.1 Contractor Responsibilities. The contractor shall provide and maintain an inspection system which will assure that all supplies and services submitted to the government for acceptance conform to contract requirements. ... The contractor shall perform or have performed the inspections and tests required to substantiate product conformance to drawing, specifications and contract requirements, and shall also perform or have performed all inspections and tests otherwise required by the contract.
>
> 3.2.3 Corrective Action. The contractor shall take prompt action to correct assignable conditions which have resulted in the submission to the government of supplies and services which do not conform to (1) the quality assurance provisions of the item specification, (2) inspections and tests required by the contract, and (3) other inspections and tests required to substantiate product conformance.
>
> 3.7 Nonconforming Material. The contractor shall establish and maintain an effective and positive system for controlling nonconforming material, including procedures for the identification, segregation, presentation and disposition of reworked or repaired supplies. Repair of nonconforming supplies shall be in accordance with documented procedures acceptable to the government. [Ref. 19]

Additionally this specification requires that the subcontracted or purchased supplies shall be subjected to

inspection, rather than the subcontractor maintaining an adequate quality control program.

All the above imply that the MIL-I-45208 specifications are different from the principles of TQM.

3. Summary

Both of the above military standards do not comply with the TQM principles. MIL-Q-9858A provides a detailed approach to quality assurance by specifying the procedures for contractor and government testing and oversight. MIL-I-45208 also is based on inspections and detailed accounting of quality by the supplier, however it contains fewer specifications.

C. COMPARISON OF ISO 9002 TO MIL-STDS

ISO 9002 is based on TQM principles that achieve quality through process improvement while the military standards are based on inspection, testing, and oversight as the means of identifying problems and defects. ISO 9002 addresses Deming's points 2, 3, 4, 5, and 6 while the military standards do not.

The military specifications emphasize inspection to detect defective final products. The ISO 9002 standard takes an overall approach and provides management with a

control structure for the problems they are seeking to resolve.

The ISO 9002 standard, as a step in TQM, is intended to provide for continual improvement in quality. It contains a comprehensive set of generic requirements for the quality system of the supplier, and provides objective criteria to verify the existence of key elements in the total quality management approach. [Ref. 21]

Finally, the major advantages of ISO 9002 over military standards are the following:

- it emphasizes in-process inspection to maintain a system, that corrects the causes of defects;
- it emphasizes process improvement;
- it requires personnel training; and
- it specifies subcontractor selection based strictly on quality.

D. BENEFITS OF USING ISO 9002 QA STANDARD

1. Benefits for The Government

The benefits for the government as a customer in contracting with ISO 9002 registered suppliers are the following:

- common contractual language,
- better value products or services,
- less oversight,
- contractual requirements met,
- improved readiness, and
- easier and faster source selection.

2. Benefits for The Companies

The benefits for the ISO 9002 registered companies are the following:

- common contractual language,
- improved process,
- less re-work,
- fewer customer audits,
- greater competitive advantage,
- access to global markets,
- improved productivity, and
- better trained work force.

E. ISO 9002 IMPLEMENTATION FOR 1200 PSI BOILER MAINTENANCE

ISO 9002 is applicable to boiler maintenance for the following reasons. ISO 9002 is a generic standard that can be used for all production and service activities. It is a non-prescriptive standard that does not specify how a firm's quality assurance processes must occur, but mandates that a company define appropriate quality standards, document its processes and prove that it consistently adheres to both.

In boiler maintenance, there are some critical parts (e.g., valves, atomizers, nuts, bolts, etc.) that are difficult to inspect or it may be impossible to detect defects after work is completed.

An appropriate QA system requires that all personnel involved be highly trained and knowledgeable and ensures quality workmanship throughout the entire process, not just based on inspections after work is completed. ISO 9002 does these things.

F. THE U.S. POLICY OF ISO 9000 IMPLEMENTATION

Secretary of Defense William Perry's new directions since June 1994 require that Program Managers use specifications and standards for guidance only. The Under Secretary of Defense is directed to develop a plan for

canceling these specifications and standards, transferring to non-government standards, and converting them to performance based specifications. [Ref. 22]

DOD is pushing for ISO 9000 quality management and assurance certification to help achieve its acquisition reform objectives. Acquisition officials and program managers are encouraged to employ ISO standards for all programs procured under MIL-Q-9858A and MIL-I-45208. New programs that meet ISO 9000 will qualify for military procurement without any additional military standards. For companies in the defense arena this provides further incentive to become ISO qualified. DOD's support of the standard will make ISO 9000 a universal standard that all suppliers will have to meet.

Effective in fiscal year 1996 the Naval Sea Systems Command (NAVSEA) policy for quality systems states that:

> 3.1 Contractor shall establish, document, and maintain a Quality System to ensure product conformance to job order specifications. The system shall meet the requirements of ANSI/ASQC Q9002 or equivalent ISO. MIL-I-45208 may be used until canceled. [Ref. 23]

Third party registrar certification is not yet required.

G. SUMMARY

ISO 9002 is the preferable standard to follow. Compliance with its specifications can assure high quality in 1200 psi boiler maintenance.

VI. CONCLUSION AND RECOMMENDATIONS

A. CONCLUSION

Since standardization of quality assurance systems has the potential of significantly reducing quality inspection efforts, the buyer and the seller should agree on an acceptable quality control method. The key is the definition of requirements and their communication by the buyer to the supplier to create a confident atmosphere.

Since many quality system standards are available, a significant benefit of using a recognized and accepted international quality standard that consolidates all system elements is that one basic standard can be referred to by all potential users. In addition, since it would be difficult and cost ineffective for an organization to maintain many quality assurance systems, using one quality assurance system would reduce administrative and testing costs.

Using ISO 9002 in contracting for 1200 psi boiler maintenance would emphasis preventing deficiencies during maintenance, rather than detecting and correcting final

defects. The ISO standards force the contractor to establish a quality control management system covering the entire process to achieve an acceptable end product. A high quality reliable end product can save testing cost and time and prevent schedule delays and conflicts between the buyer and supplier.

B. RECOMMENDATIONS

RECOMMENDATION 1: Implementation of ISO 9002 by the Hellenic Navy for 1200 psi steam boiler maintenance is the most appropriate quality assurance standards based on TQM. ISO 9002 is appropriate for every type of maintenance and repair activities as well as for shipbuilding. By adopting ISO 9002 the Hellenic Navy would experence long-term improvements which would help achieve high quality in maintenance, readiness, and safety.

RECOMMENDATION 2: As there are no contractors in the shipbuilding industry in Greece that are ISO 9001 or ISO 9002 registered, the Hellenic Navy must encourage all contractors to achieve ISO certification by showing them the benefits to both the Navy and their own company. ISO certification would also help commercial contractors become more competitive in all their activities with enhanced quality and reduced costs. As the Greek shipyards perform

work for international shipping companies, the ISO certification would help them identify opportunities for improving their operations, and, as a consequence, help them improve product quality to establish themselves as a world-class industry.

RECOMMENDATION 3: As a temporary measure the Hellenic Navy should accept contractors that have taken the initial steps towards ISO registration. Future contracts should require that the contractors establish, document, and maintain a quality system that meets the requirements of ISO or equivalent until registration can be completed. The Hellenic Navy auditor should perform routine audits to determine the progress made by the contractors towards full implementation of the ISO 9002 standards.

C. SUGGESTIONS FOR FUTURE RESEARCH

Studies in the area of quality have no boundaries. Some recommended areas for further research include:

1. Perform a pareto analysis to examine the difference in administrative and oversight costs for contractors using ISO 9002 versus contractors using military quality assurance standards, or for the same contractor that previously used military standards and now is using ISO 9002 quality assurance standards.

2. Conduct research at ISO 9002 registered shipyards to determine if they have experienced quality maintenance improvements and/or cost reductions.

3. Perform a comparison of third party ISO 9000 series registration organizations to determine if there exist any differences in the registration process, registration cost, experience of the auditors, and reputation of the registrars.

4. Investigate the issues associated with having one government activity that certifies third party registration services.

5. Conduct research to determine the relationship between quality and productivity in steam pressure vessel maintenance.

It is hoped that this thesis will be a motivator for other research efforts to expand and enhance quality in all maintenance activities in order to increase the level of quality in the Hellenic Navy's warships. It is also hoped that the proposed quality assurance standards and procedures will benefit other services of the Hellenic military.

APPENDIX A

LIST OF INTERVIEW QUESTIONS

1. A general brief for 1200 psi boilers maintenance.
2. What is the documentation and your existing policy for 1200 psi steam boilers maintenance?
3. How often do you make inspections and what inspections do you make before and what after the maintenance? What is the mean time to failure (MTTF)?
4. Do you follow a quality assurance program for 1200 psi steam boilers maintenance?

   If YES

   a. When did you start the program?
   b. What feedback did you have?
   c. How did you implement this program?
   d. What quality assurance standards do you use for boiler maintenance?
   e. What are the discreet factors and what are the desired parameters associated with those factors for a 1200 psi steam boiler maintenance plan?
   f. What is your training program?
5. What problems were resolved after implementation of the quality assurance program (failure rates, rejection rates, ship availability, deficiency reports, safety incidents, etc.) ?

6. Are there any civilian contractors who do boiler maintenance? Who are they and what quality assurance standards are included in the contracts?

APPENDIX B

ISO 9002 QA STANDARD

A copy of the ISO 9002 QA standard is included on the following 11 pages.

BS 5750 : Part 2 : 1987
ISO 9002-1987
EN 29002-1987
UDC 658.562.3

British Standard

Quality systems

Part 2. Specification for production and installation

[ISO title : Quality systems — Model for quality assurance in production and installation]

Systèmes qualité
Partie 2. Production et installation — Spécifications

Qualitätssicherungssysteme
Teil 2. Qualitätssicherungs-Nachweisstufe für Produktion und Montage

Contents

National foreword

This Part of BS 5750, having been prepared under the direction of the Quality, Management and Statistics Standards Committee, supersedes BS 5750 : Part 2 : 1979, which is withdrawn. It is identical with ISO 9002-1987 'Quality systems – Model for quality assurance in production and installation', published by the International Organization for Standardization (ISO).

The requirements of this standard are very similar to those of BS 5750 : Part 2 : 1979, but a small number of additional quality system elements have been included, and other elements enhanced. This was mainly because the UK had proposed them in the light of the UK user experience with BS 5750 : Part 2 : 1979. Consequently it was agreed that this revision of BS 5750 : Part 2 should be identical with ISO 9002 in the interests of international harmonization and international trade. BS 5750 : Part 2 : 1979 also called up requirements in BS 5781 : Part 1, however all of these requirements are considered to be incorporated into ISO 9002. Guidance on implementation is given in BS 5750 : Part 5.*
In 1987 the European Committee for Standardization (CEN) accepted ISO 9002-1987 as European Standard EN 29002-1987.

Terminology and conventions. The text of the international standard has been approved as suitable for publication as a British Standard without deviation. Some terminology and certain conventions are not identical with those used in British Standards; attention is drawn especially to the following.

Wherever the words 'International Standard' appear, referring to this standard, they should be read as 'Part of BS 5750'.

Cross-references

International standard	Corresponding British Standard
ISO 8402-1986	BS 4778 Quality vocabulary Part 1 : 1987 International terms (Identical)
ISO 9000-1987	BS 5750 Quality systems Part 0 Principal concepts and applications Section 0.1 : 1987 Guide to selection and use (Identical)
ISO 9001-1987	Part 1 : 1987 Specification for design/development, production, installation and servicing (Identical)
ISO 9003-1987	Part 3 : 1987 Specification for final inspection and test (Identical)
†ISO 9004-1987	Part 0 Principal concepts and applications Section 0.2 : 1987 Guide to quality management and quality system elements (Identical)

Compliance with a British Standard does not of itself confer immunity from legal obligations.

*BS 5750 'Quality systems' Part 5 : 1981 'Guide to the use of BS 5750 : Part 2 Specification for manufacture and installation' is currently being revised to reflect the changes brought about by adoption of the ISO 9000 series. There is no ISO equivalent to this guide either existing or envisaged.

†This standard is not referred to in ISO 9002-1987, but is included here for completeness.

EUROPEAN STANDARD
NORME EUROPÉENNE
EUROPÄISCHE NORM

EN 29002

December 1987

UDC 658.562:658.51
Key words: quality, quality assurance, quality assurance programme, production, installation, specifications, models.

English version

Quality systems–Model for quality assurance in production and installation

Systèmes qualité – modèle pour l'assurance de la qualité en production et installation

Qualitätssicherungssysteme; Qualitätssicherungs-Nachweisstufe für Produktion und Montage

CEN

European Committee for Standardization
Comité Européen de Normalisation
Europäisches Komitee für Normung

Central Secretariat: rue Bréderode 2, B-1000 Brussels

Brief history

The Technical Board decided to submit the International Standard ISO 9002-1987 Quality systems – Model for quality assurance in production and installation to the Formal Vote.

In accordance with the CEN/CENELEC Common Rules, all CEN members are bound to implement this European Standard:

Austria, Belgium, Denmark, Finland, France, Germany, Greece, Ireland, Italy, Netherlands, Norway, Portugal, Spain, Sweden, Switzerland, United Kingdom.

Statement

The text of the International Standard ISO 9002, 1st edition, 15 March 1987 was approved by CEN as a European Standard without any modification.

All references within this document to ISO 9000, ISO 9001, ISO 9002, ISO 9003 and ISO 9004 should be read as EN 29000, EN 29001, EN 29002, EN 29003 and EN 29004 respectively.

British Standard

Quality systems

Part 2. Specification for production and installation

0 Introduction

This International Standard is one of a series of three International Standards dealing with quality systems that can be used for external quality assurance purposes. The alternative quality assurance models, set out in the three International Standards listed below, represent three distinct forms of "functional or organizational capability" suitable for two-party contractual purposes :

— ISO 9001, *Quality systems — Model for quality assurance in design/development, production, installation and servicing.*

For use when conformance to specified requirements is to be assured by the supplier during several stages which may include design/development, production, installation and servicing.

— ISO 9002, *Quality systems — Model for quality assurance in production and installation.*

For use when conformance to specified requirements is to be assured by the supplier during production and installation.

— ISO 9003, *Quality systems — Model for quality assurance in final inspection and test.*

For use when conformance to specified requirements is to be assured by the supplier solely at final inspection and test.

It is emphasized that the quality system requirements specified in this International Standard, ISO 9001 and ISO 9003 are complementary (not alternative) to the technical (product/service) specified requirements.

It is intended that these International Standards will normally be adopted in their present form, but on occasions they may need to be tailored for specific contractual situations. ISO 9000 provided guidance on such tailoring as well as selection of the appropriate quality assurance model, *viz* ISO 9001, ISO 9002 or ISO 9003.

1 Scope and field of application

1.1 Scope

This International Standard specifies quality system requirements for use where a contract between two parties requires demonstration of a supplier's capability to control the processes that determine the acceptability of product supplied.

The requirements specified in this International Standard are aimed primarily at preventing and at detecting any nonconformity during production and installation and implementing the means to prevent its recurrence.

1.2 Field of application

This International Standard is applicable in contractual situations when

a) the specified requirements for product are stated in terms of an established design or specification;

b) confidence in product conformance can be attained by adequate demonstration of a certain supplier's capabilities in production and installation.

2 References

ISO 8402, *Quality — Vocabulary.*

ISO 9000, *Quality management and quality assurance standards — Guidelines for selection and use.*

3 Definitions

For the purposes of this International Standard, the definitions given in ISO 8402 apply.

NOTE — For the purposes of this International Standard, the term "product" is also used to denote "service", as appropriate.

4 Quality system requirements

4.1 Management responsibility

4.1.1 Quality policy

The supplier's management shall define and document its policy and objectives for, and commitment to, quality. The supplier shall ensure that this policy is understood, implemented and maintained at all levels in the organization.

4.1.2 Organization

4.1.2.1 Responsibility and authority

The responsibility, authority and the interrelation of all personnel who manage, perform and verify work affecting quality shall be defined; particularly for personnel who need the organizational freedom and authority to

a) initiate action to prevent the occurrence of product nonconformity;

b) identify and record any product quality problems;

c) initiate, recommend or provide solutions through designated channels;

d) verify the implementation of solutions;

e) control further processing, delivery or installation of nonconforming product until the deficiency or unsatisfactory condition has been corrected.

4.1.2.2 Verification resources and personnel

The supplier shall identify in-house verification requirements, provide adequate resources and assign trained personnel for verification activities (see 4.17).

Verification activities shall include inspection, test and monitoring of the production and installation processes and/or product; audits of the quality system, process and/or product shall be carried out by personnel independent of those having direct responsibility for the work being performed.

4.1.2.3 Management representative

The supplier shall appoint a management representative who, irrespective of other responsibilities, shall have defined authority and responsibility for ensuring that the requirements of this International Standard are implemented and maintained.

4.1.3 Management review

The quality system adopted to satisfy the requirements of this International Standard shall be reviewed at appropriate intervals by the supplier's management to ensure its continuing suitability and effectiveness. Records of such reviews shall be maintained (see 4.15).

NOTE — Management reviews normally include assessment of the results of internal quality audits, but are carried out by, or on behalf of, the supplier's management, *viz* management personnel having direct responsibility for the system. (See 4.16.)

4.2 Quality system

The supplier shall establish and maintain a documented quality system as a means of ensuring that product conforms to specified requirements. This shall include

a) the preparation of documented quality system procedures and instructions in accordance with the requirements of this International Standard;

b) the effective implementation of the documented quality system procedures and instructions.

NOTE — In meeting specified requirements, timely consideration needs to be given to the following activities :

a) the preparation of quality plans and a quality manual in accordance with the specified requirements;

b) the identification and acquisition of any controls, processes, inspection equipment, fixtures, total production resources and skills that may be needed to achieve the required quality;

c) the updating, as necessary, of quality control, inspection and testing techniques, including the development of new instrumentation;

d) the identification of any measurement requirement involving capability that exceeds the known state of the art in sufficient time for the needed capability to be developed;

e) the clarification of standards of acceptability for all features and requirements, including those which contain a subjective element;

f) the compatibility of the production process, installation, inspection and test procedures and the applicable documentation;

g) the identification and preparation of quality records (see 4.15).

4.3 Contract review

The supplier shall establish and maintain procedures for contract review and for the coordination of these activities.

Each contract shall be reviewed by the supplier to ensure that

a) the requirements are adequately defined and documented;

b) any requirements differing from those in the tender are resolved;

c) the supplier has the capability to meet contractual requirements;

Records of such contract reviews shall be maintained (see 4.15).

NOTE — The contract review activities, interfaces and communication within the supplier's organization should be coordinated with the purchaser's organization, as appropriate.

4.4 Document control

4.4.1 Document approval and issue

The supplier shall establish and maintain procedures to control all documents and data that relate to the requirements of this International Standard. These documents shall be reviewed and approved for adequacy by authorized personnel prior to issue. This control shall ensure that

a) the pertinent issues of appropriate documents are available at all locations where operations essential to the effective functioning of the quality system are performed;

b) obsolete documents are promptly removed from all points of issue or use.

4.4.2 Document changes/modifications

Changes to documents shall be reviewed and approved by the same functions/organizations that performed the original review and approval unless specifically designated otherwise. The designated organizations shall have access to pertinent background information upon which to base their review and approval.

Where practicable, the nature of the change shall be identified in the document or the appropriate attachments.

A master list or equivalent document control procedure shall be established to identify the current revision of documents in order to preclude the use of non-applicable documents.

Documents shall be re-issued after a practical number of changes have been made.

4.5 Purchasing

4.5.1 General

The supplier shall ensure that purchased product conforms to specified requirements.

4.5.2 Assessment of sub-contractors

The supplier shall select sub-contractors on the basis of their ability to meet sub-contract requirements, including quality requirements. The supplier shall establish and maintain records of acceptable sub-contractors (see 4.15).

The selection of sub-contractors, and the type and extent of control exercised by the supplier shall be dependent upon the type of product and, where appropriate, on records of sub-contractors' previously demonstrated capability and performance.

The supplier shall ensure that quality system controls are effective.

4.5.3 Purchasing data

Purchasing documents shall contain data clearly describing the product ordered, including, where applicable,

a) the type, class, style, grade or other precise identification;

b) the title or other positive identification, and applicable issue of specifications, drawings, process requirements, inspection instructions and other relevant technical data, including requirements for approval or qualification of product, procedures, process equipment and personnel;

c) the title, number and issue of the quality system International Standard to be applied to the product.

The supplier shall review and approve purchasing documents for adequacy of specified requirements prior to release.

4.5.4 Verification of purchased products

Where specified in the contact, the purchaser or his representative shall be afforded the right to verify at source or upon receipt that purchased product conforms to specified requirements. Verification by the purchaser shall not absolve the supplier of his responsibility to provide acceptable product nor shall it preclude subsequent rejection.

When the purchaser or his representative elects to carry out verification at the sub-contractor's plant, such verification shall not be used by the supplier as evidence of effective control of quality by the sub-contractor.

4.6 Purchaser supplied product

The supplier shall establish and maintain procedures for verification, storage and maintenance of purchaser supplied product provided for incorporation into the supplies. Any such product that is lost, damaged or is otherwise unsuitable for use shall be recorded and reported to the purchaser (see 4.15).

NOTE — Verification by the supplier does not absolve the purchaser of the responsibility to provide acceptable product.

4.7 Product identification and traceability

Where appropriate, the supplier shall establish and maintain procedures for identifying the product from applicable drawings, specifications or other documents, during all stages of production, delivery and installation.

Where, and to the extent that, traceability is a specified requirement, individual product or batches shall have a unique identification. This identification shall be recorded (see 4.15).

4.8 Process control

4.8.1 General

The supplier shall identify and plan the production and, where applicable, installation processes which directly affect quality and shall ensure that these processes are carried out under controlled conditions. Controlled conditions shall include the following :

a) documented work instructions defining the manner of production and installation, where the absence of such instructions would adversely affect quality, use of suitable production and installation equipment, suitable working environment, compliance with reference standards/codes and quality plans;

b) monitoring and control of suitable process and product characteristics during production and installation;

c) the approval of processes and equipment, as appropriate;

d) criteria for workmanship which shall be stipulated, to the greatest practicable extent, in written standards or by means of representative samples.

4.8.2 Special processes

These are processes, the results of which cannot be fully verified by subsequent inspection and testing of the product and where, for example, processing deficiencies may become apparent only after the product is in use. Accordingly, continuous monitoring and/or compliance with documented procedures is required to ensure that the specified requirements are met. These processes shall be qualified and shall also comply with the requirements of 4.8.1.

Records shall be maintained for qualified processes, equipment and personnel, as appropriate.

4.9 Inspection and testing

4.9.1 Receiving inspection and testing

4.9.1.1 The supplier shall ensure that incoming product is not used or processed (except in the circumstances described in 4.9.1.2) until it has been inspected or otherwise verified as conforming to specified requirements. Verification shall be in accordance with the quality plan or documented procedures.

4.9.1.2 Where incoming product is released for urgent production purposes, it shall be positively identified and recorded (see 4.15) in order to permit immediate recall and replacement in the event of nonconformance to specified requirements.

NOTE — In determining the amount and nature of receiving inspection, consideration should be given to the control exercised at source and documented evidence of quality conformance provided.

4.9.2 In-process inspection and testing

The supplier shall

a) inspect, test and identify product as required by the quality plan or documented procedures;

b) establish product conformance to specified requirements by use of process monitoring and control methods;

c) hold product until the required inspections and tests have been completed or necessary reports have been received and verified except when product is released under positive recall procedures (see 4.9.1). Release under positive recall procedures shall not preclude the activities outlined in 4.9.2a).

d) identify nonconforming product.

4.9.3 Final inspection and testing

The quality plan or documented procedures for final inspection and testing shall require that all specified inspection and tests, including those specified either on receipt of product or in-process, have been carried out and that the data meets specified requirements.

The supplier shall carry out all final inspection and testing in accordance with the quality plan or documented procedures to complete the evidence of conformance of the finished product to the specified requirements.

No product shall be despatched until all the activities specified in the quality plan or documented procedures have been satisfactorily completed and the associated data and documentation is available and authorized.

4.9.4 Inspection and test records

The supplier shall establish and maintain records which give evidence that the product has passed inspection and/or test with defined acceptance criteria (see 4.15).

4.10 Inspection, measuring and test equipment

The supplier shall control, calibrate and maintain inspection, measuring and test equipment, whether owned by the supplier, on loan, or provided by the purchaser, to demonstrate the conformance of product to the specified requirements. Equipment shall be used in a manner which ensures that measurement uncertainty is known and is consistent with the required measurement capability.

The supplier shall

a) identify the measurements to be made, the accuracy required and select the appropriate inspection, measuring and test equipment;

b) identify, calibrate and adjust all inspection, measuring and test equipment and devices that can affect product quality at prescribed intervals, or prior to use, against certified equipment having a known valid relationship to nationally recognized standards — where no such standards exist, the basis used for calibration shall be documented;

c) establish, document and maintain calibration procedures, including details of equipment type, identification number, location, frequency of checks, check method, acceptance criteria and the action to be taken when results are unsatisfactory;

d) ensure that the inspection, measuring and test equipment is capable of the accuracy and precision necessary;

e) identify inspection, measuring and test equipment with a suitable indicator or approved identification record to show the calibration status;

f) maintain calibration records for inspection, measuring and test equipment (see 4.15);

g) assess and document the validity of previous inspection and test results when inspection, measuring and test equipment is found to be out of calibration;

h) ensure that the environmental conditions are suitable for the calibrations, inspections, measurements and tests being carried out;

i) ensure that the handling, preservation and storage of inspection, measuring and test equipment is such that the accuracy and fitness for use is maintained;

j) safeguard inspection, measuring and test facilities, including both test hardware and test software, from adjustments which would invalidate the calibration setting.

Where test hardware (e.g. jigs, fixtures, templates, patterns) or test software is used as suitable forms of inspection, they shall be checked to prove that they are capable of verifying the acceptability of product prior to release for use during production and installation and shall be rechecked at prescribed intervals. The supplier shall establish the extent and frequency of such checks and shall maintain records as evidence of control (see 4.15). Measurement design data shall be made available, when required by the purchaser or his representative, for verification that it is functionally adequate.

4.11 Inspection and test status

The inspection and test status of product shall be identified by using markings, authorized stamps, tags, labels, routing cards, inspection records, test software, physical location or other suitable means, which indicate the conformance or nonconformance of product with regard to inspection and tests performed. The identification of inspection and test status shall be maintained, as necessary, throughout production and installation of the product to ensure that only product that has passed the required inspection and test is despatched, used or installed.

Records shall identify the inspection authority responsible for the release of conforming product (see 4.15).

4.12 Control of nonconforming product

The supplier shall establish and maintain procedures to ensure that product that does not conform to specified requirements is prevented from inadvertent use or installation. Control shall provide for identification, documentation, evaluation, segregation (when practical), disposition of nonconforming product and for notification to the functions concerned.

4.12.1 Nonconformity review and disposition

The responsibility for review and authority for the disposition of nonconforming product shall be defined.

Nonconforming product shall be reviewed in accordance with documented procedures. It may be

a) reworked to meet the specified requirements, or

b) accepted with or without repair by concession, or

c) re-graded for alternative applications, or

d) rejected or scrapped.

When required by the contract, the proposed use or repair of product [see 4.12.1b)] which does not conform to specified requirements shall be reported for concession to the purchaser or his representative. The description of nonconformity that has been accepted, and of repairs, shall be recorded to denote the actual condition (see 4.15).

Repaired and reworked product shall be re-inspected in accordance with documented procedures.

4.13 Corrective action

The supplier shall establish, document and maintain procedures for

a) investigating the cause of nonconforming product and the corrective action needed to prevent recurrence;

b) analysing all processes, work operations, concessions, quality records, service reports and customer complaints to detect and eliminate potential causes of nonconforming product;

c) initiating preventative actions to deal with problems to a level corresponding to the risks encountered;

d) applying controls to ensure that corrective actions are taken and that they are effective;

e) implementing and recording changes in procedures resulting from corrective action.

4.14 Handling, storage, packaging and delivery

4.14.1 General

The supplier shall establish, document and maintain procedures for handling, storage, packaging and delivery of product.

4.14.2 Handling

The supplier shall provide methods of handling that prevent damage or deterioration.

4.14.3 Storage

The supplier shall provide secure storage areas or stock rooms to prevent damage or deterioration of product, pending use or delivery. Appropriate methods for authorizing receipt and the despatch to and from such areas shall be stipulated. In order to detect deterioration, the condition of product in stock shall be assessed at appropriate intervals.

4.14.4 Packaging

The supplier shall control packing, preservation and marking processes (including materials used) to the extent necessary to ensure conformance to specified requirements and shall identify, preserve and segregate all product from the time of receipt until the supplier's responsibility ceases.

4.14.5 Delivery

The supplier shall arrange for the protection of the quality of product after final inspection and test. Where contractually specified, this protection shall be extended to include delivery to destination.

4.15 Quality records

The supplier shall establish and maintain procedures for identification, collection, indexing, filing, storage, maintenance and disposition of quality records.

Quality records shall be maintained to demonstrate achievement of the required quality and the effective operation of the quality system. Pertinent sub-contractor quality records shall be an element of these data.

All quality records shall be legible and identifiable to the product involved. Quality records shall be stored and maintained in such a way that they are readily retrievable in facilities that provide a suitable environment to minimize deterioration or damage and to prevent loss. Retention times of quality records shall be established in writing. Where agreed contractually, quality records shall be made available for evaluation by the purchaser or his representative for an agreed period.

4.16 Internal quality audits

The supplier shall carry out internal quality audits to verify whether quality activities comply with planned arrangements and to determine the effectiveness of the quality system.

Audits shall be scheduled on the basis of the status and importance of the activity.

The audits and follow-up actions shall be carried out in accordance with documented procedures.

The results of the audits shall be documented and brought to the attention of the personnel having responsibility in the area audited. The management personnel responsible for the area shall take timely corrective action on the deficiencies found by the audit (see 4.1.3).

4.17 Training

The supplier shall establish and maintain procedures for identifying the training needs and provide for the training of all personnel activities affecting quality during production and installation. Personnel performing specific assigned tasks shall be qualified on the basis of appropriate education, training and/or experience, as required. Appropriate records of training shall be maintained (see 4.15).

4.18 Statistical techniques

Where appropriate, the supplier shall establish procedures for identifying adequate statistical techniques required for verifying the acceptability of process capability and product characteristics.

This British Standard, having been prepared under the direction of the Quality, Management and Statistics Standards Committee, was published under the authority of the Board of BSI and comes into effect on 29 May 1987.

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Committees responsible for this British Standard

The preparation of this British Standard was entrusted by the Quality, Management and Statistics Standards Committee (QMS/-) to Technical Committee QMS/2, upon which the following bodies were represented:

BEAMA Ltd.
British Engine Group of SMMT
British Quality Association
British Railways Board
British Telecommunications plc
Ceramic Industry Certification Scheme Ltd.
Chemical Industries Association
Computing Services Association
Consumer Standards Advisory Committee of BSI
Consumers' Association
Defence Manufacturers' Association
Department of Trade and Industry, National Weights and Measures Laboratory
Department of Trade and Industry, Standards and Quality Policy Unit, Quality and Education Division
Design Council
Electricity Supply Industry in England and Wales
Electronic Engineering Association
Energy Industries Council
GAMBICA (BEAMA Ltd.)
Home Office
Institute of Quality Assurance
Institution of Electrical Engineers
Institution of Mechanical Engineers
Institution of Production Engineers
Medical Sterile Products Association
Ministry of Defence
Society of British Aerospace Companies Limited
Telecommunication Engineering and Manufacturing Association (TEMA)

The following bodies were also represented in the drafting of the standard, through subcommittees and panels:

Association of Consulting Engineers
Association of Consulting Scientists
British Coal
British Gas plc
British Maritime Technology
British Non-Ferrous Metals Federation
British Nuclear Forum
British Shipbuilders
British Steel Industry
British Welded Steel Tube Association
Business Equipment and Information Technology Association
Cable and Wireless plc
Cement and Concrete Association
Department of Trade and Industry, National Physical Laboratory
Electronic Components Industry Federation
Engineering Equipment and Materials Users Association
Guildford County College of Technology
Hydrocarbon Solvents Association
Institute of Cost and Management Accountants
Institute of Purchasing and Supply
London Regional Transport
National Association of Plumbing, Heating and Mechanical Services Contractors
Post Office
Process Plant Association
Rotating Electrical Machines Association (BEAMA Ltd)
Society of Motor Manufacturers and Traders Limited
Transmission and Distribution Association (BEAMA Ltd)

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9203—5—5k—B QMS/2

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