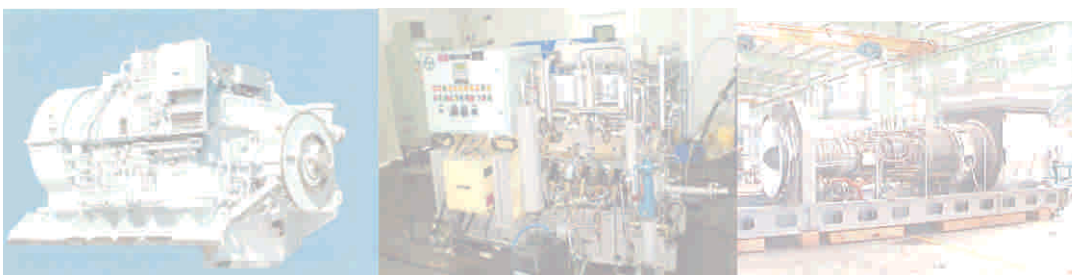
DIRECTORATE GENERAL OF QUALITY ASSURANCE

GUIDELINES FOR QUALITY ASSURANCE OF ENGINEERING & HULL EQUIPMENT FOR INDIAN NAVAL WARSHIPS



Directorate of Quality Assurance (Warship Project)
DGQA, H Block, DHQ Post
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FOREWORD

1. The Directorate of Quality Assurance (Warship Project) [DQA(WP)] is one of the 13 Directorates functioning under the Director General of Quality Assurance (DGQA) in the Department of Defence Production, Ministry of Defence, Government of India. The Quality Assurance responsibility of 'Mission Critical Equipment' of Indian Naval Warships such as Main Propulsion, Power Generation & Distribution, Shafting Line, Steering Gear & Stabilizer, Controls & Instruments, Water Generation, Compressors, Pumps, HV Air Conditioning & Refrigeration, STPs, Aviation equipment, Winch, Underwater Valves etc. has been vested with DQA(WP) by the Indian Navy. This onerous task is carried out by DQA(WP) through its 16 field establishments across the country, which provide Quality Assurance cover for all types of Marine Engineering & Hull Machinery (including associated electrical/ electronic equipment/ control systems) and spares being procured against Purchase Orders placed by Defence Shipyards, Naval Procurement Agencies, Coast Guard and DRDO, both for warships under construction and in commission.

2. This document is aimed at providing Guidelines for Inspection by Field Units of DQA(WP), as well as, for the Industry supplying equipment to the Navy and encompasses a formalised set of processes designed to ensure that all equipment being procured for use on Indian Naval warships meet the performance requirements under the environmental and operating conditions experienced onboard a warship. The process has been evolved based on internationally followed norms, experience gained by the Indian Navy over six decades of operation and the infrastructure available within the country. It is envisaged that adherence to the guidelines will enable the Industry to manufacture equipment that conform to the requirements of warship applications which are inherently more exacting than those found in commercial or land based applications.

3. With the technological advancements making inroads rapidly, it would be the endeavor of HQ DQA(WP) to keep abreast of future developments in Quality Assurance methodology and practices which may bring about changes to the concepts and procedures envisaged and revise these guidelines from time to time.

New Delhi

Mar 13

(Dinkar Sharma)
Rear Admiral
Addl Director General Quality Assurance
(Warship Project)

CONTENTS

List of Annexures

ABBREVIATIONS

QAP	Quality Assurance Plan
IAY	Inspecting Authority – DQA(WP)
IAG	Inspecting Agency
OPA	Order Placing Agency
PEA	Project Executing Agency
PDs	Professional Directorates (namely DME/DEE/DNA)
IHQ	Integrated Headquarters of Min of Defence
SOTR	Statement of Technical Requirements
PO	Purchase Order
TNC	Technical Negotiations Committee
GC	Guarantee Certificate
MTC	Manufacturer’s Test Certificate
UT	Ultrasonic Test
RT	Radiography Test
AWS	American Welding Society
CWI	Certified Welding Inspector
C & M	Chemical & Mechanical Tests

RECORD OF AMENDMENTS

SL.NO	DATE	TYPE OF AMENDMENT	AUTHORITY

CHAPTER 1

GUIDELINES FOR QUALITY ASSURANCE - AN OVERVIEW

General

1. The Guidelines for Inspection by Field Units of DQA(WP) encompass a formalised set of processes designed to ensure that all equipment being procured for use on Indian Naval warships meet the performance requirements under the environmental and operating conditions experienced onboard a warship. The process has been evolved based on internationally followed norms, experience gained by the Indian Navy over six decades of operation and the infrastructure available within the country.

2. The list of marine engineering equipment for warships, covered under the ambit of these guidelines is given at **Appendix A.** It is envisaged that adherence to the guidelines will enable the industry to manufacture equipment that conform to the requirements of warship applications which are inherently more exacting than those found in commercial or land based applications.

3. The guidelines are not an alternative to the Quality Management System of the firm. It is taken as a premise that all products manufactured by a firm meet the international standards of quality for non military applications. The guidelines specify additional QA requirements that are essential to meet the quality standards and performance criteria required for making the equipment **'Warship Compliant'**. Therefore, these guidelines essentially add a dimension to the existing QA process and cannot be considered as a quality standard in isolation.

4. The document is applicable across the industry for the entire spectrum of equipment intended for Indian Naval warships catering inter alia for new inductions. The document also has a provision for accommodating and factoring the maturity of technology and confidence gained with firms pertaining to its products.

Terminology of Inspection Heirarchy and Equipment Classification

5. **Inspecting Authority & Inspecting Agency.** Before proceeding further, it is important to understand the hierarchy of Inspection Organisation which can be categorised into two levels as explained below:-

(a) **Inspecting Authority (IAY).** The **Directorate of Quality Assurance (Warship Project) - [DQA (WP)]** is designated as the **Inspecting Authority** for all Engineering and Hull equipment including associated Controls, motors, control panels and instrumentation, contracted by the Indian Navy. The powers, charter and responsibilities have been mandated in DGQA Standing Orders. The organisation chart of HQ DQA(WP) is at **Appendix B1.**

(b) **<u>Inspecting Agencies (IAG).</u>** DQA (WP) has 16 field units covering industrial zones across India. Each field unit is designated as **Inspecting Agency (IAG).** A list of field units under DQA (WP) is placed at **Appendix B2.**

6. **<u>Classification of Equipment / Components.</u>** The next terminology that needs to be understood is the various classes of equipment. Based on the criticality, the items can be categorised into **five** classes as mentioned below:-

(a) **<u>Class QA – 1 Equipment</u>.** Equipment subjected to completely invasive inspection. No major deviations or concessions are permitted.

(b) **<u>Class QA – 2 Equipment</u>.** These equipment are basically of Class QA – 1 but for which deviations / concessions are permitted.

(c) **<u>Class QA – 3 Equipment</u>.** These are the equipment for which the QA cover is reduced. However there are no major deviations / concessions.

(d) **<u>Class QA – 4 Equipment.</u>** The QA cover in this case is generally restricted to physical verification and performance checks. Quality of internal components is accepted on Guarantee Certificate rendered by the firm.

(e) **<u>Class QA – 5 Equipment.</u>** The QA cover for this class is only for physical verification. The complete equipment is accepted on Guarantee / Warranty Certificate or import documents produced by the firm.

7. As can be seen from the definitions above, the stringency conditions and intensity of inspections vary from class to class.

<u>Main Stages of Quality Assurance Process</u>

8. The mandatory Quality Assurance (QA) requirements for all warship equipment shall include but not be limited to the following processes:-

(a) Manufacturing Plan and Processes.

(b) Drawings and Quality Assurance Plan.

(c) Raw Material Inspection.

(d) In Process Inspection.

(e) Final / Assembly Inspection.

(f) Tests & Trials under specified conditions.

(g) Inspection of Painting, Packing, Preservation & Shipment.

(h) Inspection of Documentation for Operation, Maintenance & Repair.

(j) Issue of Inspection Note (Form 4 / DGS&D – 84 Formats).

9. Each of these stages has been elaborated upon in the subsequent chapters. However, the essence of each has been briefly explained in the paragraphs that follow.

Manufacturing Processes – Understanding and Finalising

10. The Manufacturing Plan is the seed from which the Quality Assurance Plan germinates. Hence, it is vital for all concerned that every aspect of Manufacturing Plan is comprehended unambiguously. This is the first and most critical stage in the process. The formulation of QA Plan is a complex activity that requires detailed analysis both on part of the Firm and QA personnel to arrive at a plan which is optimal and can be implemented**. Therefore, it is vital that the Manufacturing Plan is discussed bilaterally between the firm and IAG.**

Drawings and Quality Assurance Plan

11. The next logical step is the preparation of drawings and draft QAP by the firm which is subsequently approved by the designated Naval Authorities. The following should be taken into account at this stage:-

(a) Requirements stated in SOTR.

(b) Relevant Specifications and Standards.

(c) Type of Equipment or Component.

Raw Material Inspection

12. Once the drawings and QAP are approved, the firm is given the clearance to commence production. Consequently, the first step of manufacture is procurement and acceptance of Raw Material. This would entail inter alia conducting requisite tests for determining the chemical composition and mechanical properties. Factors that influence the extent and quantum of raw material inspection are as follows:-

(a) Specifications and Standards.

(b) Intended application.

(c) Type and Source of raw material.

(d) Approved Drawings.

In – Process Inspection

13. Once the raw materials have been cleared for use, the manufacturing can commence. In–process inspection is carried out with the aim of ensuring that the final product meets the required standards of quality. The governing considerations are:-

(a) Specifications and Standards.

(b) Criticality of the components in the operation of equipment.

(c) Peculiarities of manufacturing problems.

(d) Approved Drawings.

Final / Assembly Inspection

14. Once the item or equipment is ready, it is subjected to final inspection. The extent and quantum is decided based on: -

(a) Applicable Specifications and Standards.

(b) Requirements stated in SOTR.

(c) Validating integrity of assembly.

(d) Requirements of recording:-

(i) Assembly parameters such as surface finish, clearances and torque values.

(ii) Assembly / disassembly procedures.

(e) Approved Drawings.

Testing and Trials

15. Tests and Trials of the final assembled equipment shall be undertaken based on Acceptance Test Procedure (ATP). ATP essentially includes performance trials offered by the firm prior dispatch which are termed as Factory Acceptance Trials (FATs). FATs may be supplemented by trials onboard after the equipment has been installed or on any other test bed as specified in the terms of the Contract and in ATP. The ATP is to be prepared based on: -

(a) Specifications and Standards.

(b) Performance parameters stated in SOTR.

(c) Any other requirements emerging subsequent to placement of order.

(d) Validation of parameters meeting specified functional performance.

(e) Validation of parameters meeting specified environmental specifications.

(f) Type Tests if applicable.

Painting, Preservation, Packing and Shipment

16. After the equipment or product has been cleared for dispatch, it has to be suitably painted, adequately preserved and appropriately packed. Factors that influence painting, preservation, packing and shipment are as follows:-

(a) Requirements stated in SOTR.

(b) Requirements of Specifications and Standards.

(c) Storage period before commission.

(d) Approved Drawings.

Documentation

17. The preparation of documentation should be a concurrent activity after the drawings have been finalized. The documentation should be comprehensive and comprehensible. It should be replete with Technical Description, Operating Instructions, Album of Illustrations, Maintenance Procedures, Trouble shooting and list of spares, both depot as well as on–board. These aspects need to be unambiguously included in the Tender Enquiries and Purchase Orders.

Inspection Note (DGS & D – 84) / (Form 4)

18. This is the last and final stage of the QA process. The Inspection Note (I–Note) is issued for items contracted by Naval procurement agencies. The format of I–Note is specified in form DGS & D – 84. For equipment ordered by shipyards, Form 4 is issued. Form 4 is also issued by inspecting agencies for a sub–order. Sample formats of various forms are placed at **Appendix C**.

CHAPTER 2

CLASSIFICATION OF NAVAL EQUIPMENT

Introduction

1. Equipment inspected by field units of DQA(WP) are classified into five categories depending on the criticality of equipment which in turn dictates the quantum of QA coverage to be provided by DQA (WP) and its field units. The various classes and associated QA activities are discussed in this chapter.

2. **Class - 1 QA Equipment**. Equipment of extreme criticality which when unavailable or non – operational can result in compromise of mission or can result in situation which is dangerous to ship and personnel fall in this category. The scope of QA cover for these equipment should include, but not be restricted to:-

(a) Raw Material tests – 100% Witness.

(b) In Process inspection – Pressure testing in all cases as applicable and 100% witnessing is to be undertaken for following cases:-

(i) Castings – Radiography Level I.

(ii) Welds – Radiography Level I. The Weld Joint Efficiency should not be less than 0.9.

(iii) Forgings – Without any flaw or defect.

(c) Environmental specifications.

3. **Class - 2 QA Equipment**. These are basically Class-1 QA equipment, wherein concessions and deviations can be issued at various stages of the QA process.

4. **Class - 3 QA Equipment**. These are equipment for which the **QA cover is either on the lower scale or certain provisions of the QA process have not been applied**. **It is important to note that there are no major concessions or deviations**. The reduction in QA cover does not necessarily mean that the equipment is non critical. It can even be applied to mission critical equipment of imported nature. Typical examples of reduction in QA cover are:-

(a) Sample raw material inspection.

(b) Components being accepted on Firm's guarantee.

(c) Environment specifications are not as stringent as Class–1 QA equipment but can be restricted to the extremities of operating conditions.

5. **<u>Class - 4 QA Equipment</u>**. These are equipment where the QA cover has been substantially reduced. QA activities pertaining to manufacturing stages can be waived off. Guarantee provided by the firm is acceptable in lieu.

6. **<u>Class - 5 QA Equipment</u>**. These are equipment which can be **accepted based solely on physical identification.** Functional checks need not be carried out. These equipment can be accepted against firm's guarantee / warranty certificate or against import documents.

CHAPTER 3

QUALITY ASSURANCE OF WARSHIP EQUIPMENT

Quality Assurance Process and Quality Assurance Plan

1. Quality Assurance of equipment intended for use on warships is achieved by adopting an approach that has two distinct yet interwoven paths:-

(a) **Quality Assurance Process** that defines the requirements of quality as well as performance.

(b) **Quality Assurance Plan** that specifies the means of achieving these requirements.

2. The **Quality Assurance Process** comprises nine stages starting from Manufacturing Plan to issue of Inspection Note. Synthesis of all these stages specifies the requirements of quality and standards.

3. Once the Quality Assurance Process is finalized, the **Quality Assurance Plan** is prepared that specifies the quantum of checks and methods of verification.

Quality Assurance Process

4. Five basic factors influence QA process. These are:-

(a) Expectations of the Customer.

(b) Type of equipment.

(c) Parameters critical to quality.

(d) Safeguards against failure.

(e) Process variation safeguards.

Expectations of the Customer

5. The term ‘customer’ refers to the ‘user’ onboard the warship. The **Expectations of Customer** are based on the conditions and exploitation pattern onboard a warship. These are reflected in the material, manufacturing process and performance parameters specified. The expectations can be categorized as:-

(a) **Ruggedness and Robustness**. Equipment should be adequately rugged as well as robust to withstand the exploitation under harsh conditions across the entire range of operation.

(b) **Reliability**. Equipment should be able to operate reliably under all envisaged conditions of exploitation.

(c) **MTBO & MTBF**. The Mean Time Between Overhauls (MTBO) and Mean Time Between Failures (MTBF) should be high.

Type of Equipment

6. The types of equipment onboard a warship will fall into one of the following three categories:-

(a) **Mission Critical Equipment**. Equipment which directly or indirectly affect the mission of the ship are termed as Mission Critical Equipment. Main propulsion machinery, HVAC, STP, stabiliser and steering gear are some examples of Mission Critical Equipment.

(b) **Safety Equipment**. All such equipment, the performance of which, directly or indirectly influences the ship's safety are called Safety Equipment. Some examples of safety equipment are underwater valves, firemain pumps, salvage pumps, fire–fighting equipment and Damage Control appliances.

(c) **Non – Critical Equipment**. Equipment which do not directly jeopardize either the ship's mission or its safety can be termed as non – critical.

Parameters Critical to Quality

7. Once the expectations of the Customer and type of equipment are known, the next logical step is to derive all critical parameters at each stage of manufacture that affect the final quality of the equipment. In case of warship equipment, the critical parameters extend to the entire Life Cycle of the equipment which includes stages beyond manufacture such as documentation, maintenance and repair. The common parameters applicable across all types of equipment are:-

(a) Type of materials, specifications and grade.

(b) Manufacturing methods.

(c) Constraints in manufacture – Limits, Fits, Tolerances etc..

(d) Maintenance Intervals and Repair Methodologies including Testing, Tuning and STW procedures.

Safeguards Against Failure

8. It is imperative to eliminate possibilities of failure. This can be done at the design and drawing stage by considering following factors:-

(a) Stage of failure – Manufacturing or Exploitation.

(b) Type of failures and their past history.

(c) Probability of occurrence of the failure, its severity and probability of detection.

(d) Replacement /repair criterion.

Process Variation Safeguards

9. The harsh operating conditions onboard a warship mandate that the manufacturing processes need to be subjected to more stringent control than that in case of COTS items. The safeguards can be achieved by adequate control on raw material and the manufacturing processes involved as also the trials of the finished product.

Factors Influencing the Quality Assurance Plan (QAP)

10. The implementation of QA process is achieved by Quality Assurance Plan (QAP). The QAP is prepared based on following considerations:-

(a) Quantum of QA check required.

(b) Method of Verification necessary.

11. **Quantum of QA Check**. The quantum of QA check to be carried out at various stages is specified as follows:-

(a) Sample size based on relevant standards such as IS 2500 (Part I & II).

(b) 100% inspection which means that the entire batch is subjected to specified checks.

12. **Method of Verification**. The standard methods are: -

(a) Witness.

(b) Review of Records from NABL accredited laboratories/ Inspection sheets.

(c) Manufacture’s Test Certificates.

Formulating the QA Plan

13. Various factors influencing both the QA processes and plans have been discussed in the preceding paragraphs with an aim to help in formulating a QAP, based on these factors. The draft QAP submitted by the firm needs to be vetted by the Inspection Agency prior to final approval by the Inspection Authority. Draft QAP is expected to be in conformance with the latest manufacturing processes and QA procedures.

CHAPTER 4

MANUFACTURING PROCESSES – A CONSPECTUS

1. The choice of manufacturing process is dependent on various factors such as type of equipment, raw materials used, manufacturing process, the expected service conditions, reliability expected, etc.. Understanding the Manufacturing Plan and stages is crucial for formulating the Quality Assurance Plan.

2. **Raw Materials**. The raw material is specified in the SOTR, as well as, in the Purchase Order and reflected in the approved drawings. These when selected, often dictate the manufacturing process and the extent of control that needs to be exercised during the process.

3. **Process Selection**. The selection of the manufacturing process is vital for ensuring that the equipment meets the operating and reliability criteria on board the warship. Some of the options are briefly elicited below. **Primarily, the decision for selecting the manufacturing process lies with the firm.** However, inputs can be taken from the Indian Navy at developmental stage of the item (only for order placed by DMDE) and subsequently as feedback for improvements.

4. **Castings.** There are various types of castings and the selection has to be done considering the type of job involved:-

(a) **Gravity Casting.** This is used for general purpose and is the most common type of casting.

(b) **Centrifugal Casting.** This is adopted in case of axi-symmetrical parts such as bushes and cylinders.

(c) **Pressure Die – Casting.** It is used when surface finish is critical and dimensional consistency vital.

(d) **Investment Casting.** This is used for complicated shapes and high accuracy.

5. **Joining Process.** This is a generic term used for a process that fuses two similar or dissimilar materials. Joining process commonly used are:-

(a) **Welding.** It is a process in which two materials, usually metals, are permanently joined together through localised coalescence, resulting from a suitable combination of temperature, process and metallurgical conditions. This is achieved by gas welding, arc welding, resistance welding, and inert gas welding.

(b) **Brazing.** In this process, the base metal is heated to below its recrystallisation temperature. This generally used when working with copper and copper alloys.

(c) **Soldering.** This is generally used in electrical and electronic applications wherein only the filler material is melted and deposited on the base metal.

6. **Metal Forming Processes.** The objective of metal forming process is to alter the shape of metal to meet the required form, size and strength. The various types of Metal Forming Processes are rolling, drawing, embossing, extruding and bending. These can be broadly classified as:-

(a) **Cold Working.** Plastic deformation of metals below the re–crystallization temperature is known as cold working.

(b) **Hot Working.** It involves plastic deformation of metals above the re-crystallization temperatures.

7. **Metal Cutting Process.** It is the process in which unwanted metal is removed from work piece in the form of chips so as to obtain the final product of desired size, shape and finish. This includes shaping, turning, boring, drilling, reaming, milling, abrasive machining process, broaching, sawing, filing and punching process.

8. **Jigs and Fixtures.** Proper jigs and fixtures are designed to minimise faults and increase productivity whilst achieving the required shape and dimensions.

9. **Surface Finish.** Surface finish requirements are indicated in drawings. Surface finish of various jobs is maintained by machining, honing, broaching and lapping.

10. **Paint Application.** All painting is done by either dipping, spraying or electro–coating. It is used primarily to ensure adhesion, provide an even surface by filling in minor porosity and protect the equipment from corrosion.

CHAPTER 5

DRAWINGS AND QAP

Drawings

1. **Need for Details**. The drawings of equipment installed onboard warships are to include inter alia, manufacturing particulars, material specifications, surface finish and tolerances. Incorporating these details does not in any way dilute the OEM status.

2. **Stages**. Drawings are to be submitted in the following sequence :-

(a) **Preliminary GA/ SA/ Component Drawings.** These should include:-

(i) Schematic drawing of the equipment.

(ii) General Arrangement (GA) drawing indicating overall dimensions.

(iii) Component drawings with material specifications, manufacturing process, surface finish, fits, tolerances and other relevant details.

(b) **As Built Drawings.** These will be the final drawings of equipment containing design and performance data, modifications or changes incorporated during the **preliminary approval stage** and all other requisite information. These should faithfully reflect the final product on paper and vice versa.

3. **Mandatory Contents**. These are listed below:-

(a) **Title Block.** This should include Customer Name, Purchase Order number, title of drawing, revision number, tolerances, other reference drawings, date of drawing, drafting/ checking/ approving particulars and any other details sought by the customer.

(b) The **General Arrangement Drawings** should depict:-

(i) General description of the equipment and components giving technical features.

(ii) Foot print details.

(iii) Maintenance envelope.

(c) Bill of material with material specifications, weight and quantities.

(d) Performance details and special features of the equipment.

(e) The Centre of Gravity with X, Y & Z co-ordinates.

(f) Circuit diagrams for all electrical, mechanical, control and instrumentation as applicable.

(g) Operation details such as direction of rotation and direction of flow should be clearly marked.

(h) Details of interconnections, end–connections, counter couplings and sockets as applicable for both mechanical as well as electrical components.

(j) Shock specifications.

(k) Lifting arrangements as required.

(l) Instrumentation and control details if applicable.

(m) Special coating procedures and precautions if any.

4. **Additional Information.** Apart from these details, any other details, necessary for the specific case in point, are to be incorporated.

5. **Sizes & Scales.**

(a) **Size**. The drawings should be prepared in paper sizes ranging from A1 to A4. In extreme cases A0 can be used but under no condition should the size be below A4.

(b) **Scale**. The scale used should be clearly mentioned in the drawings.

6. **Views**. All three views shall be displayed in third angle projection.

7. The procedure for Vetting and Approval of Drawings should be in accordance with policies and orders in vouge.

Documents for Approval of Drawings

8. The following documents are required for approval of drawings:-

(a) Purchase Order.

(b) SOTR as approved and agreed upon during TNC/ PNC meetings.

(c) Final Minutes of TNC/ PNC meeting.

(d) Complete set of drawings.

9. **Authority for Approval of Drawings**. The drawings are to be forwarded to the Inspection Agency who will forward the same to appropriate authority for approval in conformance with the policy directives in force. The drawings are to be approved by the Professional Dte/ Production Dte/ Inspecting Authority from the SOTR/ Binding Data/ QA angles respectively.

Quality Assurance Plan (QAP)

10. QAP should incorporate all aspects related to the qualification, condition assignment and acceptance needs. The Quality Assurance Plan can be broadly divided into following parts:-

(a) Raw Material Inspection.

(b) In-process Inspection.

(c) Inspection of Assembled Components.

(d) Tests and Trials.

(e) Documentation.

(f) Painting, Preservation and Packing.

11. Essentially, inspection of every equipment or spare will entail the first three stages. Where specified, the balance three stages will be applicable.

12. **Format.** The format of QAP is placed at **Appendix D**. The quantum of inspection and type of checks for various stages of inspection are to be finalized based on the requirements of the case and orders in force.

Documents for Approval of QAP

13. The following documents are required for approval of QAP:-

(a) Copy of Purchase Order.

(b) SOTR as approved and agreed upon during TNC/ PNC meetings.

(c) **Final Minutes of TNC/ PNC meetings.**

(d) Complete set of approved drawings.

(e) Draft QAP.

(f) Acceptance Test Plan (ATP).

14. While the information contained in Purchase Order and Drawings may suffice, inputs from minutes of TNC/ PNC meetings and SOTRs also contribute significantly in finalising the QAP.

<u>Procedure for Approval of QAP</u>

15. **<u>Responsibility of Firm</u>**. The contracted firm is to submit the complete set of Approved Drawings to concerned QAOs along with draft QAP and SOTRs as a set. Where applicable, draft ATP is also to be submitted.

16. **<u>Responsibility of QAO/ IAG</u>**. The concerned QAO is to scrutinise the draft QAP with reference to the Approved Drawings and SOTRs. The actions to be taken are as follows:-

(a) **<u>QAP Conforming to SOTR and QA Rules/ Norms</u>**. The draft QAP is to be dispatched to the **Inspecting Authority** with comments/ recommendations without delay.

(b) **<u>QAP Deviating from SOTR and QA Rules/ Norms.</u>** There can be two situations:-

(i) **<u>Primordial Deviations.</u>** Observations which can be resolved at the level of QAO should be done expeditiously through bilateral meetings and working level discussions. Visits if required should be made to site, test labs or any other organisations for obtaining clarifications or solutions. Master QAP is the reference for resolving such issues.

(ii) **<u>Complex Issues.</u>** Deviations that require intervention of IAY/ Professional Directorates at IHQ (MoD)/ Navy are to be forwarded to **Inspecting Authority** giving full details of the case for decision. Recommendations of the QAO are invariably to be included, when forwarding the case to HQ DQA(WP)

17. **<u>Responsibility of DQA(WP)</u>**. The authority for approval of the QAP rests with DQA(WP) being the Inspection Authority. Upon receipt of QAP from the Inspection Agency, the same is to be scrutinized against the updated Master QAP held and either of the following decisions is to be communicated to the Inspection Agency :-

(a) **<u>Approval</u>.** If QAP is in consonance with Approved Drawings/ SOTR/ QA Rules/ Norms without any deviations, the same should be approved expeditiously to facilitate commencement of manufacturing process.

(b) **<u>Provisional Approval.</u>** QAPs deviating from Approved Drawings SOTR/ QA Rules are to be scrutinized and provisional approval for initiation of certain QA process can be granted by DQA(WP) to enable progressing with initial stages of the order such as raw material procurement and in some cases the basic manufacturing, **provided** that the deviations observed **do not affect these stages**. The relevant clarifications/ issues are to be simultaneously processed with the Professional Directorates at IHQ MoD (Navy) for final recommendation, keeping the Order Placement Authority or the Project Executing Agency informed.

(c) **Approved as Amended.** If the QAP is deemed unacceptable in part or completely, the same is to be amended suitably. Prior promulgating, discussions may be held with the firm and any other agency involved so that it is acceptable to all concerned.

Exemptions for Submission of Drawings and QAP

18. Submission of approved Drawings and QAP is exempted in the following circumstances:-

(a) Repeat Orders for equipment without change of specifications. In this case firm is to submit a certificate to this effect with a reference to the complete set of Drawings and QAP already approved by respective competent authority. The inspection can thereafter progress against the earlier original approved drawings and QAPs made available by the firm (copies of the drawings and QAPs are **not repeat not** to be accepted).

(b) Spares for Equipment, that are ordered separately are also exempted submission of approved Drawings and QAP provided the firm is able to produce evidence/ traceability of the spares to the original equipment for which they have been ordered.

(c) Imported stores.

Exceptions to Submission of Drawings & QAP

19. **Circumstances**. Though it is mandatory to submit complete set of Drawings & QAP, they can be submitted in part quantities to facilitate initiation of QA process in case of the following circumstances:-

(a) Large equipment being developed for first time.

(b) Unresolved issues at the time of finalization of contract which affect the finalization of QAP. Typical examples of such issues are:-

(i) Unresolved dimensions due to restrictions of installation/ maintenance envelope.

(ii) Doubts over availability of raw material to specifications sought.

(iii) Doubts over ability to conduct tests/ trials or availability of facilities for same as sought in the specification.

20. **Mandatory Requirements**.

(a) Part submission of Drawings and QAPs will be restricted to the following:-

(i) Drawings – Maximum of three parts.

(ii) QAP – Maximum of two parts.

(b) The drawings when processed in parts are to be submitted in the following manner:-

(i) **Part 1**. Individual parts/components for which manufacture can be initiated without any effect on overall equipment dimensions/ performance.

(ii) **Part 2**. Main/ sub assemblies which have no effect on overall equipment dimensions/ performance. The assemblies /parts chosen should be complete in themselves in all manner with no effect of the unresolved assemblies/ part on their manufacture. All drawings should carry a linking reference to the components/ parts.

(iii) **Part 3 (Final set)**. All components/ parts left out from earlier two parts. Declaration/ evidence to submission of drawings of all components/ parts is to be submitted by the firm along with final set.

(c) The two parts of QAP are to be submitted in the following manner:-

(i) **Part 1**. Raw material and In-process Inspection of all components/ parts for which drawings can be frozen to facilitate commencement of manufacture initiated without affecting the final assembly / performance.

(ii) **Part 2.** Final/ Assembly Inspection, Tests, Trials, Documentation, Preservation & Packing.

Approval of Drawings and QAPs Submitted under Exception

21. Drawings and QAPs submitted in parts invoking the ‘Exception’ criteria will be subject to **provisional approval only**. Final approval shall be given only after submission of complete set of drawings & QAP.

22. **For QAO/IAG**. Final Inspection, Tests & Trials shall be witnessed by QAO/IAG only after the final stamp of approval on a consolidated set of Drawings and QAPs is endorsed by IAY. Final Inspection Note (Form 4) in such cases is to be issued post satisfactory inspection in all respects.

CHAPTER 6

RAW MATERIAL INSPECTION

Purpose

1. All raw materials that are used in manufacture of equipment or spares should be tested to ascertain that the chemical and mechanical properties conform to those specified in the standards mentioned in the SOTRs, the Purchase Order and the Approved Drawings.

Extent and Quantum of Tests

2. The range and scale of Chemical as well as Mechanical tests is decided on the following factors:-

(a) Requirements of specifications/ standards.

(b) Intended application.

(c) Type of raw material.

(d) Source of procurement.

Requirements of Standards / Specifications

3. **Standards.** All raw materials used onboard warships shall conform to established standards. The most commonly used material standards onboard Indian Naval ships are IS, ASTM, DIN, GOST, BS and NES. This list is indicative and not exhaustive. The standards to be followed are reflected in SOTRs as well as the Purchase Order and shall be the primary guiding factor for deciding the scope of inspection.

4. **Contents.** All the material standards, apart from specifying the Chemical and Mechanical properties for various grades, also specify the tests to be carried out on the raw material. The procedures for conducting these tests are also mentioned and elaborated. These tests have to be conducted at NABL accredited laboratories. The values given in the standard have to be strictly adhered to.

5. **Use of Equivalent Standards**. In case the firm requests for use of material conforming to any other equivalent standard eg. IS in lieu of ASTM, then the same should be approved by Professional Directorates at IHQ MoD (Navy)/ local Headquarters through respective order placing authority.

6. **Source of Procurement.** All the raw material is to be sourced in a manner that traceability can be established.

Inspection Criteria

7. **Parameters.** Inspection of Raw Material is a multi–dimensional activity which depends on a set of factors which may be mutually exclusive or may be inter–related. Some of these considerations are examined below and amplified in succeeding paragraphs:-

(a) The application and redundancy.

(b) Form and selection of Raw Material.

(c) Type of the item or component for which the raw material is being inspected.

(d) Source of raw material.

Application

8. Although standards do exist to decide the sampling size, the application of equipment for which the raw material is being inspected can be an additional factor deciding the quantum. The categories mentioned below can be treated as guidelines and not statutory. If considered necessary, the entire lot can be inspected irrespective of the application, particularly if non conformity has been observed in the selected samples.

Sl. No.	TYPE		QUANTUM	VERIFICATION
	CATEGORY	DESCRIPTION		
(a)	Mission Critical	Equipment whose failure can impair the mission, cause flooding, affect water and gas tight integrity or can compromise the safety of the ship and personnel	100%	As per applicable rules
(b)		Components or parts whose failure does not compromise ship safety and mission.	As per IS 2500 (Part I & II)	

(c)	Non–critical		As per IS 2500 (Part I & II)	As per applicable rules or Firm's Guarantee/ Warranty certificates

Type of Raw Material

9. **Unique Grades.** In some cases, to meet the technological requirements, the materials specified in the SOTR or the Purchase Order may be **Non–Commercial.** These materials are specifically manufactured to Standards/ Process Specified in the SOTR. Considering the novelty of the item, as well as the process, it is required that the inspection involved is intensive. In such cases following broad rules will apply:-

(a) **Quantum.** There should be no sampling. The entire quantity ordered (100 %) is to be checked.

(b) **Verification.** As the use of such grade is nascent, it is important to **witness** the activities rather than **review** the results as follows:-

(i) **Castings.** The pouring should be witnessed to ascertain use of **virgin metal** so that the cast product is in accordance with the grade specified. Stamping and marking of heat number for ensuring traceability is essential. The Chemical, Mechanical and Metallurgical properties should be checked at NABL accredited laboratories. Any additional checks required should also be carried out. The test coupon drawn should be an integral part of casting. General guidelines for manufacture, inspection and quality assurance of castings are given at **Appendix E**.

(ii) **Forgings.** The forging should be witnessed to guarantee that the process chosen is apt, stock selected proper, heating appropriate and forging direction correct. These checks shall contribute towards ensuring that flow lines and grain flow are commensurate with the load or stress conditions of intended application. The conformance to standards and specifications, Chemical, Mechanical and Metallurgical properties should be checked at NABL accredited metallurgical test laboratory. The heat number should be marked for subsequent traceability. General guidelines for manufacture, inspection and quality assurance of forgings are given at **Appendix F**.

(iii) **Bars/ Strips/ Sheets/ Plates/ Pipes/ Tubes.** The samples should be sealed in the presence of Inspection Agency for despatch to NABL accredited metallurgical test laboratory for Chemical, Mechanical and Metallurgical properties tests. If considered necessary and if possible, the tests also should be witnessed.

10. **Common Commercial Grades.** These grades follow internationally accepted standards. It may be appreciated that the market as well as the industry have gained enough experience and hence the confidence in producing raw material to these specifications. In such cases the inspection can be as follows:-

(a) **Quantum.** As per IS 2500 (Part I & II) or 100% depending on criticality or defects observed in samples.

(b) **Verification.**

(i) Witnessing Castings and Forgings may be decided depending on criticality and considering the experience gained.

(ii) Review of Material Test Certificate (MTC) for tests at NABL Accredited Laboratories.

(iii) The tests carried out at the firm's premises also can be reviewed. However if considered essential, these should be witnessed.

Castings

11. **Classification of Castings**. Castings are classified into categories ranging from **Class I to III, with Class I being of highest order.** These have been adopted by various standards**.** The classes are briefly described below:-

(a) **Class I.** A casting whose failure would lead to uncontrollable flooding or the total immobilization of the vessel, or serious hazard to personnel.

(b) **Class II**. A casting whose failure would lead to severe but controllable flooding, the serious disruption of weapon systems, main propulsion machinery, or its associated auxiliaries including generators.

(c) **Class III.** All other castings.

12. It is obvious that the inspection requirements for Class I will be most stringent of the three and that for Class III shall be the least.

Non Destructive Tests

13. **Types.** Non–destructive testing (NDT) is a wide group of analysis techniques used in science and industry to evaluate the properties of a material, component or system without causing damage. Since NDT does not permanently alter the article being inspected, it is a highly – valuable technique that can save both money and time in product evaluation, troubleshooting, and research. While the field of NDT is vast and has myriad varieties, the common NDT methods are **Ultrasonic Testing, Magnetic Particle Inspection (MPI), Liquid Dye Penetrant Test, Positive**

Material Identification (PMI), Radiography, Remote Visual Inspection (RVI), Eddy Current Testing and Low Coherence Interferometry. For further reference and details recommended website to be explored is http://en.wikipedia.org/wiki/Nondestructive_testing - cite_note-Cartz-0

14. The conditions or situations that warrant NDT are decided by factors such as type of raw material, application and production technology adopted.

15. **Forms of Raw Material**. It is recommended that raw materials be inspected by suitable NDT methods to ensure that there are no defects. **These checks are in addition to Chemical, Mechanical and Metallurgical tests.** NDT methods are to be used for:-

(a) Castings.

(b) Forgings.

(c) Plates / Bars.

(d) Pipes.

(e) Compressed Air/ Fluid storage Bottles and other pressure vessels.

(f) Sheets.

16. **Application**. The types of equipment/ components/ parts to be subjected to NDT are:-

(a) Main load and stress bearing structural members of mission critical equipment. Crankshafts, gear blanks, propulsion shaft, rudder bushes, stern tube bushes and foundation frames fall in this category.

(b) Underwater equipment/ components/ parts such as pump casings, Kingston valve body.

(c) Equipment used in fire fighting and necessary for ensuring safety of the ship.

(d) Any other item if considered necessary.

17. **Classification for Ultrasonic Testing (UT) / Radiography Testing (RT). The grades for deciding the quality have been elaborated in concerned standards which are different for ferrous and non–ferrous items. The size and severity of defects acceptable for each level are specified therein.** For example, ASME specifies following:-

(a) **Level I.** No/ very minor defects.

(b) **<u>Level II</u>.** Minor defects.

(c) **<u>Level III</u>.** Moderate number of defects.

(d) **<u>Level IV</u>.** Large number of defects.

(e) **<u>Level V</u>**. Unacceptably high number of defects.

18. **<u>Inspection and Acceptance Criteria of UT / RT Results.</u>** The decision to witness the NDT will be based on criticality of item as well as discussions between Inspection Agency and the firm. The acceptance criteria will be based on the standards applicable. It is important that radiographs are compared with reference plates prior to certifying acceptance.

<u>Commercially Off the Shelf (COTS) Items and Bought Out Items</u>

19. **<u>Branded and Commercially Off the Shelf (COTS) Items</u>**. Branded products and COTS items should be accepted as per procurement procedures in force. However, confirmation that the item is COTS should be obtained from Professional Directorates. A list of some approved Brand names is placed at **Appendix G**. The list, though not comprehensive, is intended to be a general purpose guide for reference.

20. **<u>List.</u>** The list of Bought Out items should be submitted by the firm along with the drawings. Once ratified, these items should be reflected in the Bill of Material.

21. **<u>Items Not Acceptable as Bought – Out Items (BOIs).</u>** The following items **do not** classify as Bought Out Items:-

(a) Ready made castings/ forgings purchased from any source. The reputation or standing in the industry of the source **should not be considered for any concessions.**

(b) Major equipment/ self contained self assemblies such as Journal Bearings, Motors, Gear boxes and Superchargers.

22. **<u>Inspection of Bought Out Items (BOIs).</u>** The extent of inspection will be based on the severity and the relevant standards. Accordingly, following guidelines are to be followed:-

(a) **<u>Quantum.</u>** If the item is critical, there need not be any sampling and the entire lot (100%) should be inspected. Alternately size of sample can be based on IS 2500 (Part I & II). It can be more than the quantities mentioned in this standard but not less.

(b) **<u>Verification.</u>** Based on the situation and criticality, it can be either witnessed or review of Certificate of purchase from authorized vendor for the item can be carried out.

CHAPTER 7

IN–PROCESS INSPECTION

Purpose

1. All components and parts that undergo manufacturing process or a set of processes are to be subjected to **In–Process Inspection** for ascertaining conformance to standards at every stage of manufacture as specified in the **Approved QAP**. Thus, the objective of In–Process inspection is to verify and document that all applicable specifications and requirements pertaining to the product are stable and continue to meet specification a as well as requirement.

Need

2. The role of equipment fitted onboard warships necessitates that the design caters for longevity and shock besides being able to withstand ambient conditions of roll, pitch, high temperature and humidity. Propulsion Shafts, Gear Boxes and Boilers are some examples of equipment which are not changed during the life of the ship.

3. It may be noted that in most cases, an equipment or machinery will be the same across the same class of ships or even beyond. Even on the same platform, the equipment will have multiple entities. Turbines, air conditioning plants, pumps, motors and blowers are few such examples. Such proliferation is desirable in order to exploit economies of scale and attaining commonality for ease of maintenance. Hence, interchangeabiltiy of components is inescapable so that it can be used in any of the machinery of which it is a part, irrespective of batch or serial number. This demands a high level of dimensional accuracy and proportionate degree of quality checks.

4. This stage inspection also provides scope for recording the procedure for assembly and dismantling. Any modifications carried out to improve upon the design or to overcome problems envisaged during assembly are documented and ratified.

5. For these reasons, In–Process Inspection is important. The by–product of this stage is to arrest any flaw or mistake so that necessary corrective action is taken at an early stage which saves time, besides mitigating cost implications.

Extent and Quantum of Tests

6. The extent and quantum of In–Process inspection is decided on the following factors:-

(a) Requirements of Specifications / Standards.

(b) Criticality of components in operation of equipment.

(c) Raw materials warranting special conditions and considerations for processing.

(d) Source of manufacture.

<u>Requirements of Specifications/ Standards</u>

7. The extent of inspection and the batch size will be decided based on the established manufacturing standards specified in the SOTR or Purchase Order or followed by the industry. However, if SOTR specifies a more stringent requirement, the same should be met. **Quantum of Check and Type of Verification** would be strictly as per the specification in the Standard. **No deviations from the specifications or standards shall be permitted.**

8. **<u>Use of Equivalent Standards.</u>** Transition from the promulgated standard to its equivalents has to be approved by the professional directorates at IHQ MoD(N) or Command Headquarters depending upon the case.

<u>Criticality</u>

9. The application or use and implication of its failure are an important consideration for deciding the scope of inspection. As a guide, the following is recommended:-

(a) **<u>Mission Critical.</u>** For equipment or components having direct impact on the mission, safety and survivability, the scope should be:-

(i) **<u>Quantum.</u>** There should be no sampling. The entire lot is to be inspected.

(ii) **<u>Verification</u>**. It is preferable that the process should be inspected. This is to be decided while preparing the QAP and promulgated.

(b) **<u>Other Components</u>**. For items whose failure does not compromise the safety of ship and personnel, the involvement can be as follows:-

(i) **<u>Quantum.</u>** The batch size can be calculated in accordance with **IS 2500 (Part I & II)** or equivalent standards. However, if necessary, the entire lot can be inspected.

(ii) **<u>Verification</u>**. If warranted, the process should be witnessed. Such requirements should be clearly reflected in the QAP. Alternatively, certificates submitted by the firm can be reviewed.

Special Processes for Raw Material

10. Certain raw materials need additional precautions, special environment and separate considerations because of intrinsic properties and inherent reactivity. Some examples are:-

(a) Inert atmosphere for Titanium welding.

(b) Fixtures to arrest shrinkage while welding steels like HY80 and U3.

(c) Controlled temperature during NAB welding.

11. Considering the fact these situations are not common, it is recommended that the inspection should be for the entire lot and the process should be witnessed. In addition, qualification standard of workers may be also specified. However, after repeated orders, case for resorting to sampling and review may be considered.

Source of Manufacture

12. Very few firms have a captive facility for undertaking production of every component being used in the equipment ordered. To overcome this limitation, firms resort to out sourcing certain items from sub–vendors. In order to ensure the same quality standards are maintained homogenously, following is to be adhered to:-

(a) The firm contracted by the Procurement Authority should submit a list of probable sub–vendors along with the manufacturing process.

(b) The Inspecting Agency should assess the list for capability and check if there have been any adverse reports for naval orders executed in the past.

(c) If any sub–vendor is found not acceptable due to past record or based on assessment carried out, the same should be communicated to the firm keeping the Inspecting/ Procurement Authorities informed.

(d) **In such cases the onus of finding another sub–vendor is on the main contractor only.**

13. The inspection criteria will remain the same as in other cases mentioned in aforesaid paragraphs.

Example of In–Process Inspection

14. **Welding.** Welding is an important in-process stage that needs to be inspected diligently and conscientiously adhering to promulgated procedures and standards in force. General guidelines for inspection and quality assurance of welds are given at **Appendix H**.

15. The following guidelines are to be followed for inspection of welds:-

(a) The dimensions of the weld are to be as per established standards, which is to be indicated in the Approved Drawings and QAP.

(b) The firm is to submit **Weld Procedure Specification** (WPS) and **Process Qualification Record** (PQR) to the Inspection Agencies for approval as per the applicable standards.

(c) The Inspection agencies should ask for the PQR certificate prior commencement of welding.

(d) Whenever, welding is to be carried out for critical equipment, the firm shall tack weld the structure/ component and call the Inspecting Agency for inspection. The Inspecting Agency is to ascertain that the preparation has been done in accordance with the specifications and only then approve complete welding.

16. **Dimensional Checks.** While the overall dimensions are measured and recorded, the emphasis during In–Process Inspection would be on Fits, Clearances and Tolerances. The following in-depth details are to be documented to ensure that the information serves as a reference for repairs, dismantling and re–assembly:-

(a) **Fits.** ANSI has categorised fits into eight classes. These have to be reflected in the drawings. The component or item should conform to the specified dimensions given in the approved drawings.

(b) **Tolerance.** It is termed as a permissible deviation from the specified value. The range of this tolerance is specified in the approved drawings. These are either bilateral or unilateral. The checks are required to ensure that the dimensions are within the given limits so that the designated class of fits is achieved.

(c) **Clearances.** Value of clearances for various assemblies.

(d) **Movements.** The limits of travel or degree of movement wherever applicable.

CHAPTER 8

FINAL INSPECTION

Purpose

1. For any part, component or equipment, this is the third stage of QAP, with **Raw Material Inspection** and **In–Process Inspection** brought out in Chapters 6 and 7 respectively being the former two.

2. Raw Material Inspection and In–Process Inspection are necessary to primarily ensure use of correct material, adherence to appropriate processes, identify defects if any in early stages and take corrective action to rectify the same. During these stages, dimensional details of every component including fits and clearances are recorded. In case of sub–assemblies, the functional checks are also carried out and checked for compliance with stated requirements.

3. The Final Inspection is aimed at assessing completeness of the assembly (or aggregate), the condition of the final product and dimensional conformance. **Thus the purpose of final inspection is vastly different from that of component level inspections**.

Extent and Quantum of Tests

4. The scope of Final Inspection depends on:-

(a) Requirements of Specifications and Standards.

(b) Constructional features of assembly.

Requirements of Specifications and Standards

5. The extent of checks is governed by the Standards and Specifications given in the **Terms of Contract.** The torque values to be used for tightening during assembly should be in accordance with the applicable standards.

6. In addition to industrial standards, it is required to refer specifications published by Professional Directorates at IHQ MoD(Navy). These specifications amplify the applicable standards in force.

Constructional Features of Assembly

7. The integrity of the final assembly needs to be validated and is a vital part of final inspection and should be done by the Inspecting Agency. It should be confirmed

that modifications approved by authorities based on results of type test including EMI/ EMC or other tests have been incorporated. Besides dimensional measurements, where applicable, following aspects also need to be assessed for acceptance:

(a) All exposed parts of the equipment that can prove hazardous to operating personnel are properly covered.

(b) All sensitive and breakable components are adequately protected.

(c) Vulnerability of equipment or component to corrosion, humidity, heat or fire.

(d) Ease of watch–keeping.

(e) Protection against toxicity of effluents and exhaust.

(f) The equipment is amenable to easy maintenance or repair. If not, this has to be brought to the notice of Professional Directorates through the Inspection Authority.

8. As a rule, **Final Inspection** has to be **witnessed** by the **Inspecting Agency.** In extreme cases, **Inspecting Authority** may also be present. In case of components, the final inspection of a bulk order can be carried out based on sampling lots dictated by IS 2500.

Records

9. Some of the details that are required to be recorded during Final Inspection are:-

(a) Torques used for tightening various assemblies and sub–assemblies.

(b) Special tools, jigs and fixtures used during assembly and required for dismantling.

(c) Alignment values.

(d) Values of Static and Dynamic Imbalance.

CHAPTER 9

TESTS AND TRIALS

General

1. **Purpose.** While the equipment has undergone inspection and scrutiny at every stage of manufacture, it is the **Tests and Trials** that provide the proof as well as the confidence that the equipment will function in conformance to the parameters and under the conditions specified in the contract. Hence, tests and trials are conducted to validate the operation of the equipment under rated conditions. A list of commonly conducted performance/ validation tests is given at **Appendix J**.

2. **Terminology.** In parlance of Quality Assurance, the two terms though cognate, have distinguishing nuances as follows:-

(a) **Tests.** Essentially, these are akin to '**Go– No Go' gauges** to either pass or reject the material or component. Tests are intended to check the **properties. Type tests which are conducted for prototypes do entail performance trials but basically to either clear the prototype for bulk production or return it for re–designing and modifications.**

(b) **Trials.** These are conducted to ascertain the functional and operational aspects of the machinery or component. Thus, trials are meant to evaluate the **performance.**

3. **Realm and Scope.** These are explained below:-

(a) **Realm.** All equipment and components are to be subjected to tests and trials. The extent to which the testing is carried out depends on the scope.

(b) **Scope.** The scope varies depending on the equipment or the component. Further, **Tests and Trials** for **prototypes** are more expansive than those for bulk production.

Acceptance Test Procedure (ATP)

4. While there are standards in force for various machinery and components, the actual mechanism of testing and conducting the trials is elaborated in minutest detail in a document known as **Acceptance Test Procedure (ATP).** The ATP should encompass the requirements given in the relevant standards as well take into consideration the various guidelines and policies in force. Normally, ATP is not applicable for spares. However, sub–assemblies such as fuel pumps and superchargers would warrant an ATP to be formulated.

Witnessing

5. As a standard practice, all trials are to be witnessed. Though even tests are to be witnessed, the condition is not mandatory for those conducted at NABL accredited and government laboratories.

Type Tests

6. **Aim.** Type Tests are a group of tests which are conducted to validate the designed characteristics of the equipment/ component.

7. **Applicability.** Type tests are carried out when:-

(a) **New Induction.** The equipment is being developed for the first time.

(b) **Firm.** The firm or the manufacturer is producing the equipment for the first time.

(c) **Design.** The design of existing equipment has been changed or modified.

8. **Scope.** There are various forms of Type Tests. The selection of Type Tests is governed by pertinent standards and promulgated policies. The common Type Tests applicable to warship equipment are given in **Appendix K**. Some of these tests are discussed below:-

(a) **Shock Test.** This test is to certify that the equipment can withstand the forces likely to be experienced in case of explosions and impact. The shock values that the equipment is to withstand depend on the weight and its location within the ship. These values are indicated for all the three axis in every SOTR and the Purchase Order. Shock Testing machines are available in select places within the country, each having its own limit on the weight of the test piece. Equipment being tested on these machines are to be mounted in the same way as the likely installation onboard. Special jigs and fixtures may be required for arranging this mounting. The impacts are to be given along all the three axis. **For equipment beyond the capacity of the machines, the shock calculations have to be submitted by the firm along with results of Finite Element Analysis.**

(b) **Vibration Test.** The vibrations experienced by the equipment during transportation and in use are complex resulting from cumulative effect of the excitation force, mounting, impedance and inherent characteristics of the equipment itself. These vibrations are generally not amenable to simulation. Hence the equipment is subjected to induced vibrations of specified frequency and amplitude while running to check that the equipment does not malfunction.

(c) **Tilt Tests.** The ship as a platform undergoes rolling and pitching during which all equipment is tilted either longitudinally or athwart ships. It is vital that the equipment continues to perform under these conditions. The angle and direction of tilt along with the duration is specified in the Purchase Order.

(d) **Endurance Tests.** The endurance life is mentioned in Purchase Order. This can be confirmed by running the equipment under rated conditions for the indicated period based on the relevant standards or for the duration given in the Purchase Order.

(e) **Fatigue Test.** In case the equipment is subjected to cyclic loading, the fatigue life is important. The equipment like bellows are subjected to specified cycles of operation to confirm that the equipment does not fail under fatigue.

(f) **Creep Test.** Where the temperatures encountered are to be high, the equipment is subjected to **Creep Test** to ensure that the loading under conditions of high temperature for prolonged duration does not affect the performance.

(g) **Tests to Establish Characteristics.** Type tests are also carried out to generate the **performance curves** for a family of equipment. This is done as part of type tests. Some parameters like **$NPSH_R$** of pumps can be determined experimentally only. This too forms part of type tests.

(h) **Environment Tests.** These tests are conducted in an environment created in the laboratory to give confidence that the equipment will survive the conditions in the field. These tests are specified in JSS 55555 and other standards. Some of these are:-

(i) **High Temperature.** The temperature and the duration of the test are specified in the Purchase Order.

(ii) **Damp Heat.** Along with temperature and duration, the relative humidity is also specified for the test.

(iii) **Ingress Protection (IP).** It is carried out to ensure that the equipment is impermeable to water and dust under specified conditions given in the Purchase Order. The IP protection level is denoted by a two digit number wherein the first digit ranging from 1 to 6 is for dust and the second ranging from 1 to 8 is for water. Higher the number better is the protection.

(iv) **Mould Growth Test.** This test is carried out to confirm that the equipment is not susceptible to mould growth during storage and operation.

(v) **EMI / EMC.** The equipment should not emit radiation that affects other equipment. This is termed as **Electromagnetic**

Interference (EMI). At the same time the equipment should not be affected by the radiations being emanated by other equipment. This is termed as **Electromagnetic Compatibility (EMC). The plan for EMI/ EMC test is to be approved by the concerned authority. These tests are conducted in accordance with MIL–STD 461 E.**

(j) **Noise Measurement.** Ideally, the noise levels being generated by the equipment are to be measured in accordance with ISO 3644 at a distance of **1m** from the equipment. To eliminate the background or ambient noise, it is preferable that these tests are carried out in **Anechoic Chambers.** Such tests can be considered as type tests because anechoic chambers are not available everywhere.

Trials

9. Trials are conducted to evaluate the performance under rated conditions to confirm that all parameters are within limits. Broadly, trials can be divided into three categories:-

(a) **Factory Acceptance Trials (FATs).** These are conducted prior despatch within the precincts of the firm or at any other designated test bed.

(b) **Harbour Acceptance Trials (HATs).** After the equipment is installed, trials which are conducted along side are called Harbour Acceptance Trials.

(c) **Sea Acceptance Trials (SATs).** Equipment such as shafting and main propulsion machinery can only be proved for the complete range of operations only at sea. These are subjected to Sea Acceptance Trials.

10. **Factory Acceptance Trials (FATs).** These trials are conducted for assessing the performance of the equipment. The plan for conducting these trials is to be prepared which after ratification should be promulgated as **Acceptance Test Procedure (ATP).** The ATP should be replete with:-

(a) **Test Set–up.** The specifics of test bed, the mounting arrangement and lay – out of equipment including that of instrumentation and control is to be described in detail along with supporting drawings.

(b) **Ambient Conditions.** If applicable, the ambient conditions under which the trials are to be conducted should be specified. Though these generally pertain to atmospheric conditions such as temperature and humidity, at times the ambient noise may also need to be mentioned.

(c) **Parameters.** All parameters to be recorded and the frequency of recording should be mentioned in the ATP. This includes the inlet conditions to equipment such as air conditioning plants and heat exchangers or the power supply to motors. The parameter chart should also give the limiting conditions given in Purchase Order.

(d) **Air Borne Noise (ABN) and Structure Borne Noise (SBN).** The noise levels generated by the equipment are termed as ABN and are to be measured during operation. The methodology of measurement is given in ISO 3744. Promulgated standards are also available for factoring the background noise. Similarly, the vibrations generated termed as SBN have to be measured to be treated as **Base Line Signature.** The measurements are generally to be done in 1/3 octave. For both ABN as well SBN, the regime of operation as well as the method of recording the signatures should be described in the ATP.

(e) **Regime and Duration.** The regimes at which the equipment should be operated and the duration for each regime should be unambiguously mentioned in the ATP.

11. **Harbour Acceptance Trials Schedule (HATS).** In some cases, the equipment will have to undergo trials after installation on board. Some of these trials can be conducted alongside when the ship is in harbour. Such trials are called **Harbour Acceptance Trials Schedule (HATS).** An ATP is to be prepared for HATS which would cover peculiarities of ship conditions as well.

12. **Sea Acceptance Trials Schedule (SATS).** Essentially, the Sea Acceptance Trials Schedule (SATS) are conducted to exploit the equipment for the full range of operation. For this the regimes and duration are to be clearly brought out in the ATP as also the requirements of measuring noise and vibrations.

CHAPTER 10

PAINTING, COATING, PRESERVATION, PACKING & SHIPMENT

Need

1. Equipment and spares for marine applications, in most cases, need to be stored for prolonged durations prior to installation or use. During the time spent in transit, on shelf or in storage, it is necessary to protect the equipment and items against corrosion, environment and damage.

Types

2. The protection for marine equipment and spares can be divided into three categories:-

(a) **Painting.** External protection is provided by adopting an appropriate paint scheme and application of suitable paints. This is generally applicable to complete equipment or sub–assembly such as turbo chargers. Spares and components are normally not painted.

(b) **Electroplating.** Components not amenable to painting may be electroplated with zinc, chromium or any other corrosion resistant material, if acceptable.

(c) **Preservation.** Preservation is done to inhibit corrosion of internal and external surfaces by eliminating contact with oxygen and/ or moisture. Oils and grease are some of the compounds used for this purpose.

(d) **Packing.** Equipment and spares are to be suitably packed both for transportation as well as storage. The packing should be so designed that it facilitates lifting, protects the contents from weather and offers sufficient padding to absorb shocks and vibrations during transportation. If required, the consignment should be supported correctly to eliminate structural deformation and to ensure that no stresses are induced. In specific cases, provision should be made to control the atmospheric conditions within the container.

Painting

3. **Special Properties.** Due to peculiarities of environment, the paints used for marine applications need to have attributes that are different from paints used elsewhere. The paints should have a high flash point and should be non–toxic. Moreover, the paints should be heat resistant, fire retardant, should not produce poisonous gases even at high temperatures. The life of applied coat should be such that it should not need renewal during the operational cycle of the ship or equipment

which translates to about five years for capital equipment and about 18 months for smaller machinery.

4. **Painting Process – Liquid Paint.** In generic terms, there are three steps as follows:-

(a) **Surface Preparation.** It is the first step of painting process. It is necessary to achieve uniformity of coating thickness, proper adhesion of paint and durability. The methodology used will depend on the type of paint and the surface to be painted. If applicable, relevant standards on the subject are to be followed.

(b) **Application of Primer.** Primer is a paint product that improves the adhesiveness of the paint being used. For this purpose, primer is designed to adhere to surfaces and to form a binding layer that is better prepared to receive the paint. Because primers do not need to be engineered to have durable, finished surfaces, they can instead be engineered to have improved filling and binding properties with the material underneath.

(c) **Application of Paint.** After the above steps have been completed, actual paint is applied. The colour will depend on the specifications given in the contract. Number of coats, the dry film thickness and the procedure of application will depend on the paint selected and the requirements of the contract.

5. **Painting Process – Powder Coating.** Powder coating is a type of coating that is applied as a free – flowing, dry powder. The main difference between a conventional liquid paint and a powder coating is that the powder coating does not require a solvent to keep the binder and filler parts in liquid suspension form. The coating is typically applied by an electrostatic process and is then cured under heat to allow it to polymerise, flow and form a "skin". The powder may be a **thermoplastic** or a (http://en.wikipedia.org/wiki/Thermoset**) thermoset** polymer. It creates a hard finish that is tougher than conventional paint. The process involves:-

(a) **Surface Preparation.** Chemical pre–treatments involve the use of phosphates or chromates in submersion or spray application. These often occur in multiple stages and consist of degreasing, etching, de–smutting, various rinses and the final phosphating or chrome plating. of the substrate. The pre–treatment process both cleans and improves bonding of the powder to the metal. In some cases, abrasive techniques such as sand–blasting or shot blasting are also used.

(b) **Powder Coating.** After the component or the part is prepared, powder is applied using an electrostatic gun.

(c) **Curing.** When a thermoset powder is exposed to elevated temperature, it begins to melt, flows out, and then chemically reacts to form a higher molecular weight polymer in a network-like structure. This process, called cross–linking, requires a certain temperature for a certain length of time in order to reach full cure and establish the full film properties for which the material was designed. Normally the powders cure at 200°C (390°F) for 10 minutes. The curing schedule could vary according to the manufacturer's specifications. Curing process can be done in convection or infra–red ovens.

Electrochemical Processes

6. **Application.** For components which cannot be painted the external surfaces can be covered by resorting to **Electroplating** or **Anodizing** for providing the necessary protection.

7. **Electroplating.** Electroplating is a plating process in which metal ions in a solution are moved by an electric field to coat an electrode. The process uses electrical current to reduce cations of a desired material from a solution and coat a conductive object with a thin layer of the material, such as a metal. Electroplating is primarily used for depositing a layer of material to bestow a desired property like abrasion and wear resistance, corrosion protection, and lubricity to a surface that otherwise lacks that property.

8. **Anodizing.** This is an electrolytic passivation process wherein it produces a coating made from the oxide of the base metal. It is used to increase the thickness of the natural oxide layer on the surface of metal parts. The process is called "anodizing" because the part to be treated forms the anode electrode of an electrical circuit. Anodizing increases corrosion resistance and wear resistance. **In some cases this surfaces are anodized prior painting for better adhesion.**

Preservation

9. **Preservation.** Equipment and spares manufactured for naval applications may have to be stored for long periods before these are installed or commissioned. Hence it is crucial to devise a preservation procedure that would protect the equipment or component from atmospheric conditions of temperatures and humidity. Preservation can be internal as in case of Gas Turbines and Diesel Engines as well as external. The type of preservation to be carried out depends on the machinery, spare and item. The plan has to be discussed during the Technical Negotiations and elaborated in the contract.

10. **Internal Preservation.** This is done to protect the inner surfaces of the equipment or component from corrosion and/ or wear. Typically, it is carried out by flushing the system with appropriate medium to remove the impurities and then filling it with preservative oils.

11. **External Preservation.** This is done by introducing an insulating medium or film between the surface and the environment. This can be done by applying grease, oil or paint.

12. **Procedure for Preservation and De-preservation.** The procedure to be adopted for preserving and subsequently de–preserving the equipment should be elaborated in the documentation. Often equipment such as diesel engines have failed because the de–preservation procedures had not been followed.

Packing, Shipment and Storage

13. **Packing.** The preservation that has been carried out can be retained by proper packing. The packing of the machinery or component or item should be capable of withstand any means of transportation.

14. **Eliminating Moisture.** The various techniques available are:-

(a) **Silica Gel.** By placing packets of silica gel or any other moisture absorbing compound will protect the item against humidity.

(b) **Vapour Corrosion Inhibitor (VCI) Paper.** Small components can be wrapped in VCI papers to eschew contact with moisture.

(c) **Heaters.** Electrical heaters are provided in some cases for eliminating moisture during storage and transportation.

(d) **Vacuum Packing.** This is for very sensitive equipment or equipment having complicated contour where normal methods of packing are not satisfactory. A vacuum gauge is to be placed on the packing box at a convenient location with adequate protection and frequency of check clearly painted.

(e) **Nitrogen Filling.** Being dry, nitrogen when filled will drive the moisture out. This method is adopted for equipment such as heat exchangers and compressors.

15. **Avoiding Ingress.** It is vital that no foreign particle enters the equipment during transportation and storage. This can be achieved by sealing all orifices and openings. Threaded openings can be capped while flanged openings can be covered with gasket and blanks.

16. **Protective Covers.** Threaded portions or other sensitive parts can be covered with a shield to avoid physical damage as well as atmospheric corrosion.

17. **Other Features.** It is not sufficient to protect the items but also handle the consignment with due care. Hence, additional attributes are:-

(a) **Lifting Arrangements.** Where applicable, lifting hooks should be provided and indicated.

(b) **Special Markings.** The position in which the equipment is to be kept should be indicated with arrows. Further, precautions for handling sensitive equipment should be depicted on the packing.

(c) **Identification Tags.** All components are to have a label giving the part number.

18. **Packing List.** A copy of scope of supply and packing note is to be laminated and put into a box (preferably 6” x 4”) outside the packing in addition to a similar copy inside the packing.

19. **Shipment**. This is very vital aspect and has to be done with due care. While the firm generally may be careful about the shipment from their factory, it should be appreciated that there may be further shipments from the consignee. This necessitates that adequate provisions and instructions are in place for shipment by any agency.

20. **Storage.** While majority of the equipment or spares may not require any special arrangements, it may not be the case with all. Items such as crankshafts and main propulsion shafts would require supports at correct intervals to avoid distortion and building up of stresses. Likewise, the rubber components and control equipment would require controlled conditions of temperature and humidity. Hence, the storage requirement should be indicated by the manufacturer.

Specifications

21. **Standards.** While there are a plethora of standards on the subject, the contract should specify the ones to be followed in consonance with the current policies in force.

CHAPTER 11

DOCUMENTATION

General

1. **Need.** Every equipment fitted onboard warships needs to be understood consummately by the user for correct running, proper upkeep and appropriate maintenance. Since the crew is ever changing, it is necessary to retain on board all information related to the equipment. This can only be done through **documentation.**

2. **Purpose.** It may be appreciated that documentation is the connection between the man and machine. Hence requirement of comprehensive documentation cannot be over emphasized.

3. **Scope.** Exploitation of equipment in any warship is multi–faceted. It includes operating under exacting environmental conditions, often sustaining rated performance for prolonged duration and carrying out first line of maintenance. This implies that the documentation should have exhaustive and detailed information on all these aspects.

4. **Features.** Essentially, any set of technical documentation of warship equipment should have at least the following manuals or sections:-

(a) Technical Description.

(b) Album of Drawings.

(c) Operating Instructions.

(d) Maintenance Instructions and Schedule.

(e) Repair Technical Documentation.

(f) Catalogue of Spare Parts, Tools, Test Equipment and Accessories.

(g) Passports, Log Books and Service Logs.

5. **Specifications and Policies.** The guidelines for preparation of documentation should be in accordance **standards and orders in force.** However, in case other standards are being followed, the same should be mentioned in the contract. It is preferable that for engineering equipment, the documentation should be in accordance with DME 452.

6. **Format.** In order to achieve uniformity in documentation across all platforms and for all equipment, it is recommended that a standard format be

adopted. This needs to be promulgated as a policy by an appropriate authority for implementation by all Order Placement Authorities. The format should detail the design of Cover, First Page, Provision for recording Amendments and List of Associated Documents.

Technical Description

7. **Spectrum.** This manual should contain complete technical data, parameters, characteristics and performance curves. If required, sketches or schematic drawings are to be included for better clarity.

8. **Introduction.** Usually, the first chapter should be giving an introduction about the equipment, its purpose and standard configuration. The working principle should be explained in this chapter as it forms the basis for rest of the document.

9. **Technical Specifications**. The complete technical specifications, including the list of materials with specifications and their standards are to be indicated. If essential, the manufacturing standards are also to be mentioned.

10. **Constructional Details.** It is recommended that a **Top–Down** approach is adopted in giving the description of the equipment. A narrative should be given about the entire equipment listing out the main assemblies and components. Thereafter, each item in the list is to be described bringing out the sub–assemblies and parts followed by the description of these till the smallest component. This document should also include instrumentation and controls. Wherever possible, cross–referencing should be done with Album of Drawings so that the text and drawings are co–related.

11. **Installation, Setting to Work, Testing and Tuning**. This chapter should contain all instructions for installation for first time, setting to work, testing and tuning for both new equipment as well as after repairs I overhauls. It should also detail the procedure for removal for major overhauls and subsequent installation/ setting to work.

12. **Packing, Transportation and Instructions for Preservation/ De-preservation**. This chapter should contain instructions for stages before first Installation, during storage and after the equipment is brought into use for the first time.

13. **Album of Drawings**. The hard copy of General Arrangement, Sectional Arrangement, Layout, Control circuits and component drawings should be supplied in a folder duly bound. The GA, SA and component diagrams for all assemblies and its sub–assemblies could be **laminated** to ensure longevity.

<u>Operating Instructions</u>

14. **<u>Introduction.</u>** This chapter serves to explain the layout of the document.

15. **<u>Commissioning of Equipment – Initial and Post Repairs</u>**. This chapter should give the procedure to be followed for commissioning of the equipment for first use and also after a major repair and overhaul.

16. **<u>Starting and Stopping Procedure.</u>** This chapter should detail the steps involved in **Starting and Stopping** the equipment. As this will be the guiding and governing document for personnel onboard, no detail should be missed. It should also include:-

(a) Starting and stopping under normal conditions of operation.

(b) Starting and stopping under emergency conditions.

(c) Use of normal and alternate supplies if applicable.

(d) Status of annunciators and indicators during starting and stopping.

(e) Any auxiliaries to be operating prior starting or after shut down.

17. **<u>Operation.</u>** The purpose of this chapter is to enumerate detailed procedures for trouble free operation and exploitation of the equipment. The instructions should be clear and unambiguous and the language should be pegged at a level which can be understood by a literate operator. As far as possible, the **instructions should be assertive statements and not discretionary**.

18. **<u>Limits of Exploitation and Operation During Service</u>**. This chapter should bring out in detail the following:-

(a) The regimes of operation.

(b) The parameters to be recorded.

(c) Frequency of recording or the intervals at which the parameters are to be recorded.

(d) The range and limits of these parameters at various regimes.

(e) Various safety, control features, trips and threshold values. The re–setting procedures should be elaborated in detail.

19. **<u>Interlocks and Safety Trips.</u>** This chapter should elaborate the various safety interlocks that are provided for safe starting as well as stopping of the equipment and inhibiting operation in prohibited regimes. The precautions to be taken and the safety trips are to be described in detail.

20. **Operation of the Equipment Under Special Conditions**. This chapter may not be applicable for all equipment. However, if pertinent, it should elucidate the various situations other than normal operating conditions, under which the equipment can be operated and the procedure for doing so.

21. **Monitoring of Performance and Recording of Parameters**. This chapter should give the various parameters to be logged and monitored for trouble free operation of the equipment. A format of the log sheet should also be given. Any other information which is necessary for safe, reliable and sustained operation of the equipment should also be included.

22. **Trouble Shooting**. Restoration of equipment after breakdown or failure is as crucial as correct exploitation of machinery. Hence every conceivable failure should be listed and explained along with symptoms, checks and repair action. Preferably a **Fault Diagnosis Chart** should be given for easy assimilation and implementation.

Maintenance Schedule and Maintenance Instructions

23. **Purpose.** The purpose of this chapter is to enumerate a systematic procedure for Planned Preventive Maintenance (PPM) of the equipment to ensure trouble-free operation for sustained periods. However, the time and periodicity of the maintenance should be in consonance with the overall PPM philosophy followed by the Navy.

24. **Maintenance Instructions**. This section should contain the following chapters:-

(a) **Preventive Maintenance Plan**. This can be formulated either based on **Running Hours** or on **Calendar** (i.e daily routines, weekly routines, monthly routines, quarterly routine, six monthly routines, yearly routines and so on). While some activities are strictly based on running hours, others can be scheduled based on calendar. Hence a judicious combination can be used for practical implementation.

(b) **Preventive Maintenance Procedure.** The following procedural aspects should be covered in this section:-

(i) Routine checks and maintenance on board.

(ii) Overhaul schedule and detailed procedure for assembly and dismantling.

(iii) Requirement of spares and special tools.

(iv) Cleaning devices and solvents.

(v) Allowable wear of parts and components.

(vi) Torque tightening values.

(vii) Alignment values if necessary.

(viii) Performance criteria for acceptance after repairs or overhaul.

(ix) Any other information or instruction relevant.

(c) **Corrective Maintenance**. This chapter should give **instructions for maintenance to correct an observed abnormality or degradation of performance**. It is, therefore, not periodic. The contents should essentially cover the following :-

(i) Steps to identify the problem.

(ii) Procedure for carrying out maintenance defect rectification.

(iii) Probable cause.

(iv) Requirement of spares and special tools.

(v) Type of facility or infrastructure required to carry out the repairs.

(vi) Safety Precautions.

(vii) Types of tests along with methodology.

(viii) Tuning procedures.

(d) **Maintenance During Long Layoff**. This chapter should enumerate instructions for preservation and de–preservation when the equipment is not likely to be used for extensive periods.

(e) **Setting to Work, Testing and Tuning.** This is also an important chapter to be given in adequate detail.

25. **Maintenance Schedule.** The maintenance plan ranging from daily routines to overhaul involving capital repairs is to be drawn up. Some of the features are elaborated below :-

(a) **Table of Routines.** It is recommended that the schedule be presented in a tabular form wherein the **Activity, Maintenance Levels, Frequency and Requirement of Special Tools or Accessories are juxtaposed for easy comprehension.** A possible format is given below:-

Maintenance Activity	Maintenance Levels				Frequency	Special Tools
	1	2	3	4		

(b) **Maintenance Levels.** These are denoted by numbers ranging from 1 to 4 depending on the complexity of work. The levels are applicable for routines as well as repairs.

(i) **Levels 1 and 2** activities are those that can be done onboard ship without dismantling the equipment or with minimal dismantling. Mostly, these routines are carried out in–situ. Each maintenance activity is to be amplified and presented in a tabulated manner as recommended below:-

Details of Maintenance Work	Frequency	Remarks	Cross Reference with Main Table

(ii) **Level 3** activities are those which can be undertaken in–situ but, shore support is necessary. It generally involves extensive dismantling.

(iii) **Level 4** are those activities which require the equipment to be taken to a base repair workshop for overhaul or repairs.

26. **Service Log and Certificate.** It must be understood that while **Log Books continue to be held on the ship, the Service Logs and certificates go along with the equipment. Hence, the former are ship–centric while Service Logs and Certificates (Passports) are equipment–centric. Service Logs and Certificates are to be** given as **separate documents.** The aim of this document is to have a complete history of the equipment since its commissioning, through overhauls and repairs to final decommissioning. The following sections must form a part of this document (as applicable to the equipment):-

(a) Brief Introduction and Purpose of the Equipment.

(b) Make, Model, Serial Number, Year of Manufacture of complete equipment and its subassemblies.

(c) Complete Name and Address along with contact details of the Manufacturer of the equipment. In case certain subassemblies components are outsourced from sub vendors, above details are also to be mentioned for the sub vendors.

(d) Service and Stowage Life Guarantee.

(e) Instructions on Preservation and Storage.

(f) Compendium of Lubricants and their international equivalents.

(g) Certificate of Packing and Acceptance.

(h) Certificate of Tests and Trials done during Factory Acceptance.

(j) Report of Noise and Vibration Trials (for recording baseline signature and after major overhaul/ refit).

(k) Instructions for transportation of equipment.

(l) Record of monthly and cumulative running hours.

(m) Record of Repair and Maintenance giving details of activity carried out and spares used.

(n) Record of Changes, Upgradations and Modifications carried out.

(p) Record of Post– repair Inspection and Sea Worthiness Certificate.

(q) Record of Critical Parameters during Operation and trials conducted after maintenance or repairs.

(r) Record of Defects and Remedial Action Taken.

(s) Special Observations on Performance during Operation.

Repair Technical Documents

27. **Purpose.** Typically, these documents are meant for capital repairs of the equipment that are carried out in any of the designated workshops, naval or otherwise. The equipment in most conditions is removed from the ship. The contents should encompass the following:-

(a) **Dismantling and Assembly Procedure.** The procedure for shipping and unshipping as well as assembly and dismantling should be explained in detail.

(b) Requirement of special tools, slings, lifting appliances and other accessories.

(c) Wear Limits, alignment and tightening Torque Values.

(d) Noise and Vibration Limits.

(e) Shop Floor Performance trial procedure.

(f) Special Jigs and Fixtures for repairs and overhaul.

(g) Test bed and infrastructure required for trials, testing and tuning.

(h) Any other Information necessary for major repairs/ overhauls.

28. **Inspection and Test Records**. All Records of Inspections and Trials carried out during manufacture of the equipment are to be submitted as a bound document and should include the following:-

(a) Guarantee/ Warranty Certificate duly signed by appropriate authority.

(b) General data of equipment and specifications.

(c) Acceptance Test Procedure (ATP).

(d) Record and Results of acceptance trials.

(e) Report of Noise and Vibration Trials as applicable.

(f) All records of Material Test Certificates, Lab Reports, In–Process Inspection, Acceptance Certificate, Inspection Note.

(g) Record of deviations and concessions.

(h) Certificate of Painting, Preservation and Packing.

(j) Materials of Major components.

(k) Details of instrumentation with specifications.

(l) Details of welds and weld procedures.

(m) Loading Data and its distribution.

(n) Packing list of equipment and documentation supplied.

Spare Parts, Tools, Test Equipment and Accessories

29. **Contents.** This will be a separate document. The document should consist of the following main sections:-

(a) Section 1 - Part Identification List.

(b) Section 2 - List of spares along with quantities.

(c) Section 3 - List of Accessories.

(d) Section 4 - List of Special Tools, Test Equipment, Jigs and Gauges.

30. **Part Identification List.** This section should contain a 3D exploded view of the equipment with a number for each part placed on the left side of the book. On the right side the detailed parts list is to be given along with the description and part number.

31. **Ranging and Scaling of Spares.** This section should indicate the spares along with quantities required to be stocked for the equipment. These are to be categorized into three types as explained below:-

(a) **Onboard (SPTA)**. These are spares to be stored essentially onboard ship for maintenance and repairs. The factors deciding the list would depend on the size of equipment and type of repairs or overhaul.

(b) **Base (B).** These spares are stored at the base depots for second line maintenance. Consequently, these will be bigger and heavier than those forming part of onboard spares and would be required for repairs or routine replacements.

(c) **Depot (D)**. These are spares which required for major repairs and overhauls. These may include complete assemblies, sub–assemblies or in some cases complete equipment.

32. **List of Accessories**. This section is to contain the list of accessories required for installation, maintenance and operation of the equipment.

33. **List of Special tools, Test Equipment and Gauges**. This section gives the list of tools, test equipment, gauges and other implements **specific to the equipment** which are required for tuning, setting to work, alignment, repair and maintenance of the equipment.

Electronic Manual

34. **IETM Class III.** In accordance with orders in force issued to keep pace with current trends, the documentation for Engineering Equipment should be in IETM Class III format.

CHAPTER 12

INSPECTION NOTE

Significance

1. The programme of Quality Assurance culminates in issuing a document that clears the item or equipment for acceptance and dispatch. The generic term for this document is **Inspection Note (I-Note).**

2. Two formats have been promulgated for Inspection Note as mentioned below:-

(a) **DGS & D (S) – 84 Form.** Inspection Note is issued in this format for orders placed by any agency or organisation **except shipyards** and for **sub–orders.** This form is entirely filled by the Inspecting Agency. Sample format is placed at **Appendix C1**.

(b) **Form 4.** Form 4 is issued when an item is inspected for which the order was placed by a shipyard or in case the item is a part of a sub–order. In this case, the firm fills up the form and submits the same to **Inspecting Agency** for approval and issue. Sample format is placed at **Appendix C2**.

3. The issue of Inspection Note (Form 4 / DGS & D (S) – 84 Form) by Inspection Agency primarily certifies that:-

(a) The component or equipment has been inspected in accordance with approved QAP and drawings

(b) The requirements stated in the Purchase Order have been met with approved concessions or deviations if any.

4. **The Inspection Note reflects the acceptability of the ordered goods at the point of despatch.** In case the equipment or part is damaged during transit, the applicable clauses of insurance, guarantee and warranty will be invoked.

Issue of Inspection Note

5. **The Inspection Note is a document having financial implications.** Hence all regulations and orders in force should be strictly adhered to. The salient features are:-

(a) The Inspection Note is to be issued only after all inspections have been completed, including that of preservation and packing.

(b) The number of Inspection Notes in each order should match with the **Part Supply Part Payment (PSPP) clauses** mentioned in the Purchase Order.

(c) During issue of I-Note for part quantities, the rules for painting, preservation, packing & shipment will be applicable at par with the complete equipment and there shall be no concessions.

(d) The Inspection Note is to be issued **only if** the delivery period is valid.

(e) **The Inspection Note can be signed by authorised officers only.**

6. **No Certified True Copy** of the Inspection note is to be issued as a routine. If specifically sought by the firm or Order Placement Authority, a certificate from Purchasing Agency stating "**No payment has been made against the lost Inspection Note and no payment will be made against the original document if retrieved",** has to be obtained prior to issue of a duplicate Inspection Note. The extant rules are to be rigidly adhered to.

7. In case of any eventuality, if the Inspection Note needs to be withdrawn for amendment or cancellation, the same should be done under intimation to Inspecting Authority and Order Placement Authority.

Responsibility of Firm

8. The firm has to submit the following documents to enable the Inspection Agency to process the Inspection Note:-

(a) Copy of all the inspection certificates and test reports pertaining to the equipment or components for which the Inspection Note is being sought.

(b) Certificate of preservation, warranty and guarantee as applicable.

(c) Copy of relevant extract of Purchase order indicating the items of delivery, any amendments to Purchase Order and Delivery Period extension if granted.

(d) Packing List, Delivery Challan and Transit Insurance documents.

(e) In case of shipyard orders or sub–orders, the firm is required to submit inspection and test certificates (Form 4) duly filled. The reports of FATs and other trials are also to be attached.

(f) The firm is required to complete all documentation including Technical Description, Operation Instructions, Part Identification List and any other documentation in accordance with the terms of Purchase Order. The documentation has to be approved by the Professional Directorates at IHQ MoD (Navy).

9. The firm is to enclose special instructions for preservation, handling and such other relevant instructions for safety of the equipment along with the Inspection Note.

Responsibility of Inspecting Agency

10. The issue of **Inspection Note** marks the conclusion of QA process. Therefore it is essential to ensure that all the records necessary for traceability of QA activities are compiled for future reference. Towards this, following documents are to be compiled into a single dossier:-

(a) Copy of Purchase order with all amendments.

(b) Copy of "As–Fitted Drawings" and Approved Drawings in the format specified.

(c) Copy of approved QAP and ATP along with all amendments.

(d) Copy of all concessions, deviations and any other correspondence relevant to the QA process.

(e) Copy of all inspection certificates for every stage of the QA process.

(f) Copy of all I–Notes.

(g) Copy of Tests and Trial reports including type tests.

(h) Copy of special instructions for preservation and handling.

(j) Copy of Guarantee/ Warranty certificates.

Distribution

11. **Number of Copies.** The Inspection Note irrespective of the format, are to be issued in **septuplicate.** Each of the seven copies is to be numbered and accounted for.

12. **Addressees.** The distribution of seven copies has been specified in the DGQA Standing Orders and the same is reproduced below:-

(a) **Copy Nos. 1, 2 and 5** are to be forwarded to Order Placement Authority.

(b) **Copy No. 3** is for the firm or supplier.

(c) **Copy No. 4** is to be given to the firm for attaching along with the consignment.

(d) **Copy No. 6** is sent to the consignee directly by the Quality Assurance Agency.

(e) **Copy No. 7** is to be retained by QA agency as office copy.

CHAPTER 13

CONCESSIONS AND DEVIATIONS

General Principles

1. **Need.** In order to retain the practicality of contract, it is necessary to incorporate the requisite flexibility in the system of Quality Assurance so that the equipment or component is manufactured on time despite the constraints, **whilst maintaining the quality standards and performance criteria.**

2. **Caveat.** Essentially, the Purchase Order and the SOTRs have to be complied with in totality. However, changes to these documents, if inevitable, may be carried out only if approved by the Order Placing Authority or the Professional Directorates.

3. Quality Assurance and acceptance of equipment/ stores is to be done solely on the basis of terms specified in the Contract and particulars governing the supply. While the primary responsibility of compliance with approved SOTRs and issued Purchase Order rests with the manufacturer, the adherence is to be ensured by the Inspection Agencies. In case dispensation is inevitable, then it has to be ratified adopting a promulgated procedure.

Definitions

4. **Deviation.** When the firm seeks approval in advance to use material different from that specified or to manufacture components that differ from the specifications, then the permission if given, is termed as **Deviation.** Deviation is issued prior to commencement of manufacture and is limited to a definite quantity or period.

5. **Concession.** It is defined as permission granted by the Inspection Authority to the firm when:-

   (a) To accept the errors arising during manufacture.

   (b) Supply a component or an item which is at variance from contractual requirements.

Consideration Factors and Classification

6. **Factors.** It is reiterated that the specifications given in the Contract are to be faithfully reproduced by the manufacturer or the supplier. However, due to extenuating circumstances, if the specifications are deemed unachievable, the firms ought to seek deviations which have to be approved by the Professional Directorates

and subsequently incorporated as amendments in the Purchase Order by the Order Placement Authorities. The factors to be considered before according approval for either **deviations** or **concessions** are:-

(a) Serviceability.

(b) Interchangeability.

(c) Reliability.

(d) Durability.

(e) Safety of equipment/ personnel.

7. **<u>Classification of Deviations and Concessions.</u>** Based on the severity of implications, **Deviations** and **Concessions** can be divided into five categories. These are tabulated below:-

Class	Nature of Deviations/ Concessions
A	Major deviations in design and materials affecting serviceability/ functions, interchangeability and durability
B	Major deviations in design and materials affecting durability but not affecting functions including safety of equipment and personnel or interchangeability
C	Deviations in design and materials causing minor changes in durability but not affecting functions including safety of equipment and personnel or interchangeability
D	Minor deviations in design and materials but not affecting durability, functions including safety of equipment and personnel or interchangeability
E	Minor deviations in manufacturing details not affecting design or materials, functions including safety of equipment and personnel or interchangeability

<u>Procedure</u>

8. **<u>Grant of Deviations/ Concessions</u>**. Circumstances may arise when a manufacturer of equipment requests permission to depart from a particular standard guiding production prior to the commencement of manufacturing or to grant a concession and accept errors made during manufacture. In all such cases, a **'Deviation Permit'** is to be issued for an intentional departure from item's specification in order to facilitate production. Similarly a **'Concession Permit'** is to be issued for acceptance of errors in manufacturing, which does not necessitate its rejection or when there is dissimilitude in the item being supplied and the specifications of Purchase Order.

9. **<u>Deviation Permit.</u>** A **Deviation Permit** constitutes permission in advance to use material or to manufacture components, which differ from design or specification and is limited in its application to cover a definite quantity or period.

10. **<u>Concession Permit.</u>** A **Concession Permit** constitutes permission to accept a limited quantity of materials/ components/ stores which have already been manufactured but do not conform strictly to the specifications**. However, any work done in anticipation of the decision on a request for a concession would be the Supplier's liability.**

11. **<u>Authority for Approval of Deviations and Concessions.</u>** The deviations at Class A, B, C and D above will be referred to HQ DQA(WP) for detailed examination and acceptance. However, the acceptance of the said concessions would only be examined after approval of the concerned professional Directorate. After scrutiny, in case it emerges that the acceptance of the concession would not in any way compromise the main parameters and performance of the equipment, the said concession would be deemed as acceptable with an appropriate proviso depending on the nature of the concession. The approving authority for Class E cases is the concerned Inspecting Agency.

12. **<u>Application for Deviations/ Concessions.</u>** **Manufacturers or Suppliers** are to submit an application by filling **Form 8 (Format placed at Appendix C)** for seeking **Deviations/ Concessions** as the case may be. The main vendor is to submit the application in **quintuplicate** while in case of sub–vendor, the application has to be in **sextuplicate**. The concerned **Inspecting Agency** is to scrutinize the application, check for veracity and applicability **for Classes A, B, C, and D;** forward the case to **HQ DQA (WP)** along with remarks and recommendations. For **Class E,** approval if considered warranted, is to be accorded by the **Inspecting Agency and details reported to Inspecting Authority.**

13. Procedurally, the request for Deviations/ Concessions has to be made in Form 8 and approval is to be granted in form of relevant Permit. **It should be noted that this is the only procedure for seeking and according approvals for Deviations or Concessions. Any other form of correspondence, though official is not valid for this purpose.**

14. **<u>Due Diligence.</u>** Each case, irrespective of class and level, is to be analyzed in totality. Inputs should be sought from the **User** or the **Purchaser** as well as the **Professional Directorates. Any additional tests required to be carried out should be undertaken prior sentencing the case.**

15. **<u>Validity.</u>** The permit granted is valid for only one occasion and only for the indicated component. Even if the case is repeated in the next order, a **fresh** application is to be submitted and processed. **No Deviation or Concession can be treated as a precedent.**

16. **<u>Nomenclature.</u>** Since the permit is for solitary usage, it is obvious that every deviation or concession has a unique identity. In order to facilitate traceability, a common nomenclature as given below is to be adopted:-

Unit / Serial No. / Year / Deviation or Concession / Classification / Ordering Authority / Purchase Order Reference / Firm's name

17. **Record of Deviations and Concessions.** A register is to be maintained by the concerned Inspecting Agency of all Deviations and Concessions recommended and given. Similarly, a master record is to be maintained by the Inspection Authority for all deviations and concessions granted based on the recommendations of field units.

18. **Notification.** The approved **Deviations and Concessions** are to be notified by the Inspection Authority to all concerned in accordance with format given in **Appendix F**. The concerned Inspecting Agency is to record the details in the Inspection note.

19. **Number of Copies and Disposal.** If the Deviation or Concession is being sought by the main contractor, Form 8 is to be filled in quintuplicate. An additional copy is required if the applicant is a sub–contractor. The distribution is tabulated below:-

COPY No.	ORGANISATION
1	Headquarters, DQA (WP)
2	Design Authority / Professional Directorate
3	Order Placement Authority
4	Inspecting Agency
5	Main contractor / Firm
6	Sub–contractor

20. **Rejection.** In case the application is not approved by the Permit Granting authority, a communication to this effect is to be made to the concerned Inspecting Agency for onward transmission to the firm.

Appendix A
(Refers to Para 2 of Chapter 1)

LIST OF EQUIPMENT COVERED UNDER GUIDELINES

Mission Critical Main Equipment

1. **Main Propulsion Equipment**. Main & Auxiliary Boilers & associated Boiler Fittings, Steam Turbines, Gas Turbines & Diesel Engines & Main Reduction Gear.

2. **PGD Equipment**. Turbo Alternator, Diesel Alternators, Gas Turbine Alternators. Emergency Diesel Gensets > 50 kw.

3. **Shafting Line Equipment.** Propellers (Fixed Pitch & CPP), Main Shaft, Intermediate Shaft, 'A' Bracket / 'P' Bracket, CPP OD Box & Hub Assembly, Plummer Block / Bearing, Bulkhead Gland, Stern Tube & A Bracket Bushes / Bearings, Cutlass Rubber Segments for 'A' Bracket Bearings, Sound absorption couplings, shaft lock / brake, Thrust / Torsion Meters.

4. **Steering Gear & Stabilizer Equipment.** Hydraulic Rams / Actuators, Hydraulic Power Pack, Servo-controlled Valves / Manoeuvering Valves, Stabilizer Fin & Fin Stock, Rudder & Rudder Stock with Support Bearings & Associated Controls.

5. **Control & Instrumentation**. All Control System components & Instrumentation for Propulsion, PGD & Steering that are specially designed & developed (excluding COTS components).

Mission Critical Auxiliary Equipment

6. **Water Generation Equipment**. Distilling Plants / Fresh Water Generators / Reverse Osmosis Plants.

7. **Compressors**. L.P, HP, Servo, Salvage & Diving Air Compressors.

8. **Pumps**. Turbo Driven pumps & Motor Driven pumps for critical / special applications only & AVCAT pumps, Hull & Fire Pumps, Fire & Bilge Pumps.

9. **A/C & Refrigeration Equipment.** Compressors, Condensers, Evaporators, Heat Exchangers, ATUs & Associated Control Equipment.

10. **Helo Equipment**. Helo Traversing & Handling system, Helo Landing Grid, Helo Hanger & general purpose Rolling shutters. Helo Fuelling / De-fuelling System.

11. **Winch**. Winch for Helicopter Handling / Towing / Minesweeping Boat Davit, Ammunition Loading and any special purpose.

<u>Mission Critical Common Equipment</u>

12. **Motors**. Only those motors for special applications and not yet type tested.

13. **Starters**. Starters & Control Panels for only DQA(WP) inspected. equipment.

14. **Valves**. All Underwater valves & ship system valves > 100 mm NB.

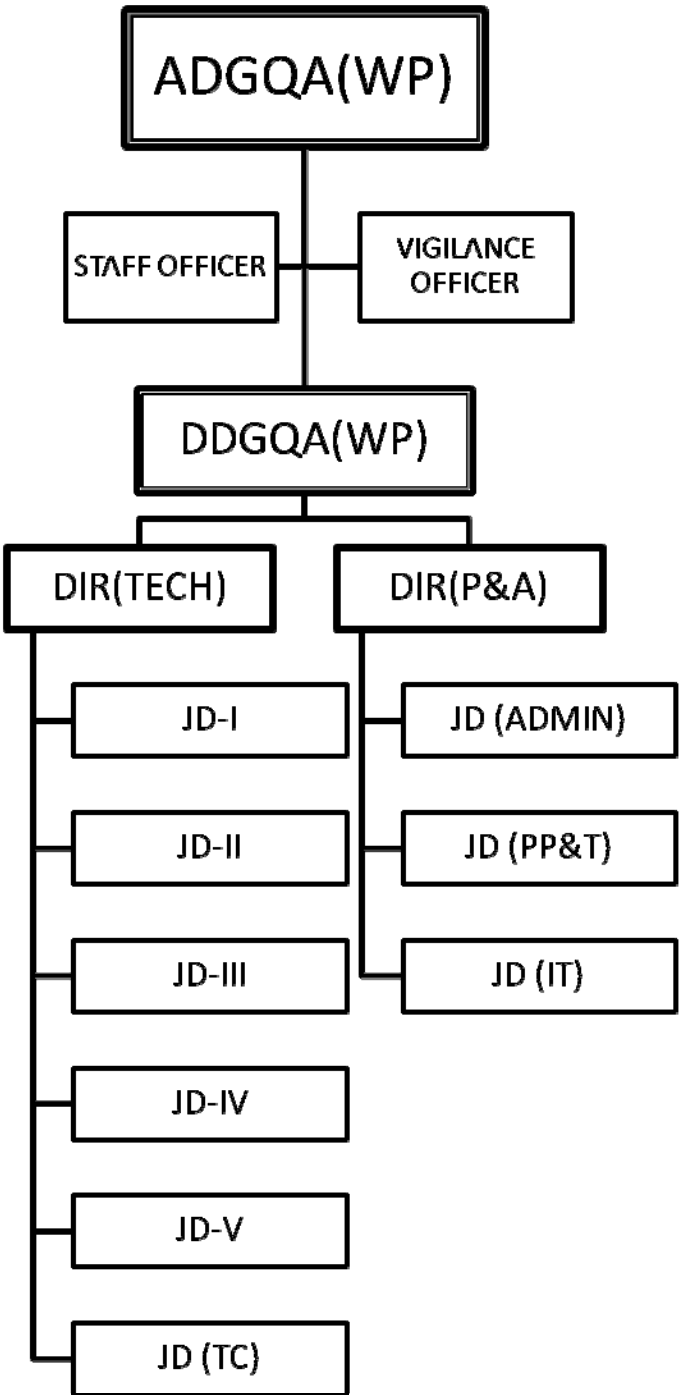
15. **Shock Mounts**. All categories of shock mounts.

16. **Doors & Hatches**. Gas / Water Tight / Fire Proof Doors & Hatches.

17. **Miscellaneous Eqpt**. Steam Sirens, Air Whistle & Electric Hooter.

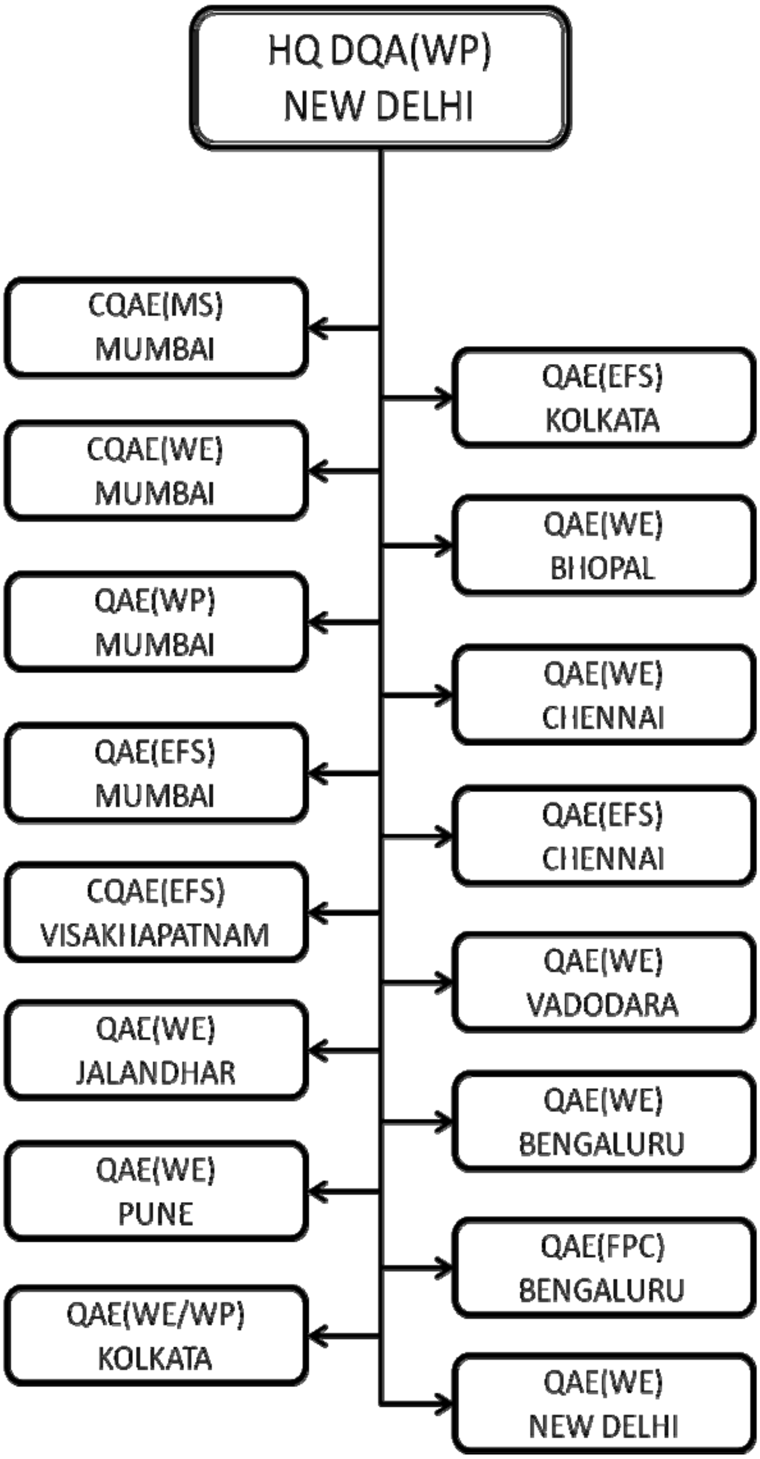
Appendix B1
(refers to Para 5(a) of Chapter 1)

HQ DQA(WP) ORGANISATION



Appendix B2
(Refers to Para 5(b) of Chapter 1)

ORGANISATION OF FIELD UNITS UNDER DQA(WP)



Appendix C
(Refers to Para 18 of Chapter 1)

FORMAT OF STANDARD FORMS

FORM 1

ORDER PROGRESS REVIEW FORM

Order No **Date of Order** **Delivery Date**

1. Date of submission of drawings
2. Date by which approval is required
3. Date by which inspection & Test Schedule will be submitted
4. Date by which approval required for (3)
5. Expected date of ordering of raw materials/castings/forgings
6. Expected date of delivery of other bought out items
7. Expected date of delivery of other bought out items
8. Forwarding of components environmental tests (if applicable)
9. Machining to commence by
10. Machining to complete by
11. Assembly to commence by
12. Assembly to complete by
13. Forwarding of prototype sub-assembly/assembly/equipment for type tests
14. Final shop test or final inspection to commence by
15. Final shop test or final inspection to complete by
16. Delivery by

Date : Signature of responsible Officer of firm

Place :

Note 1: The QAO, on receipt of PO, should forward this form to the firm for completing details. For each separate order (item if considered necessary) in quadruplicate.

Note 2: In case first of the type is required to be tested to determine whether or not the product meets environmental and performance requirements and design criteria delineated in applicable specifications the form duly completed should immediately be forwarded to IAY in respect of the prototype separately.

FORM 4

INSPECTION AND TEST CERTIFICATE

Firm's Ref______________________________ Date_______

1. Inspection Authority _________________________________

2. Date of Inspection __________________________________

3. Firm's Name ___________________________________

4. Ordering Authority ___________________________________

5. Order No and Date ___________________________________

6. Full description, quantity and registration Nos. of any of items of which this Certificate refers. (If this consignment represents only part supply, this column should be endorsed `PART SUPPLY '

7. Drawing & specification Numbers _______________________

8. Dispatch details ____

9. Firm's Certificate

I/We hereby certify that:

(a) The articles described hereon have been inspected and tested at our works in accordance with the relevant specifications and drawings, with which they comply except as detailed at (c) below.

(b) Any other requirements of the relevant order including those referring to identification and packing of the articles have been met or will be met.

(c) This certificate does not relieve us from any guarantee regarding performance on board stipulated in the order.

(d) There has been no departure from these drawings and specifications except as authorized by the Agent Inspecting Authority. The authorized departure are stated in Para 10 below.

(e) Records of the relevant inspection and test certificates and reports have been retained by us with copies provided to the Inspector. The records retained by us will not be destroyed without his written authority.

10. Concessions granted as per para 9(d) above.

Concession Number	Ref. of affected Items	Brief details of Concession	Authority for Concession

Signature on behalf of the firm ________________________________

Signature ________________________________

Position held ________________________________

Date ________________________________

11. Remarks of CQAE(WE)/QAE(WE):

12. Class Accorded : The Equipment has been accorded CLASS _____.

13. Inspector's Certificate No ______________________________

Certified that inspection and tests have been carried out to my satisfaction.

Signature	______________________	Signature	___________________
Name	_____________________	Name	_____________________
Representing	__________________	Representing	________________
Date	___________________	Date	__________________

*(To be signed by Engineering and Electrical Inspector separately as required).

FORM 7

TELE:

TELEGRAM: *(2)

GOVERNMENT OF INDIA
MINISTRY OF DEFENCE (DGQA)
DEPTT OF DEF. PRODUCTION
Office of *(1)
(WARSHIP EQUIPMENT)
*(2)

No. 1991

To

Ref: LETTER OF INTENT NO.__________DT.___FROM *(3)
*(3) MDL/GRSEL/GSL ORDER NO.______________DT._____
SUB-ORDER NO._____________DATED_____FROM *(3)
INDENT NO.________________DATED_____FROM *(3)
FOR____

Dear Sirs,

I am to refer to the above mentioned order and to state that I am the representative of the Inspection Authority nominated for inspection of the above referred order vide -*(4)- para 2(b) of STANDARD TERMS AND CONDITIONS OF SUPPLY of the Shipyard applicable for the order/para of the order/clause of the indent, and following personnel of my Establishment will be carrying out the inspection:

a.
b.
c.
d.

2. I am further to state that this order is subject to 'CONDITIONS OF INSPECTION AND TESTS' - (CITS) issued by the Ministry of Defence, copies of which will be supplied on request, if not already held with you.

3. I am further to request you to comply with the following requirements for the timely and satisfactory execution of the subject order:

(a) Confirmation of the acceptance of the subject order/sub order/indent to the Ordering Authority if not already done, under intimation to me by _____*(5)_____.

(b) Forward 5 copies of your Schedule of Inspection &

Tests required vide para 8 of 'CITS' by ______*(6)______.

(c) Forward programme for preparation of drawings/ ordering of bought out items covering raw materials components and proprietory items etc. and probable delivery date, on Order Progress Review Form 1 in quadruplicate by ______*(7)______.

(i) Programme for first of type production

(ii) Programme for type testing of components if applicable.

(d) Forward 5 copies of production schedule indicating cardinal dates for various stages such as procurement of raw materials, bought-out components, casting of components, manufacturing schedule of components, sub-assembly/assembly of items and their final testing etc. by ______*(9)______.

(e) Forward 5 copies of your detailed drawings for the items on order by ______*(10)______.

(f) Forward list of sub-contractors on whom sub-orders will be placed by ______*(11)______.

(g) Forward monthly report on the progress of the order on Form 2/Form 3 as applicable in quadruplicate to reach this -*(12)- office/Quality Assurance Officer (WP)-*(13)- by end of 3rd week of each calendar month. This is necessary to ascertain that satisfactory progress is being maintained in accordance with Production Schedule already supplied. To monitor progress actually a representative of this office/QAE(WP) will be visiting the firm periodically.

4. ______*(14)______ I am listing here special requirements in addition to the general requirements applicable to orders indicated in para 3 above:

a)
b)
c)

5. Finally I am to request you to acknowledge receipt of this letter.

Yours faithfully,

Encl.: Order Progress Review Forms 1, 2/3 as applicable. *(16)

FORM 8

Supplier's Ref No:………………………………………………..
Sub-Contractor's Ref No:………………………………………….
(If applicable)

APPLICATION TO PROCUREMENT AUTHORITY FOR DEVIATION / CONCESSION PERMIT

Notes:

(a) The granting of this deviation is strictly limited to this specific application and is not to be regarded as a precedent. IT IS NOT AN AMENDMENT TO THE CONTRACT AND IS WITHOUT PREJUDICE TO ANY OF THE MINISTRY RIGHTS THEREUNDER.

(b) **Main Contractor (Supplier)** is only authorized to **sign** and **submit** the application even if prepared by a sub-contractor for his sub order.

(c) If any variation in cost due to the concession / deviation is to be charged or credited to the state full allowance is to be made for the disposal of any scrap or redundant material arising. The estimate of charge / credit is given without prejudice to the final settlement.

(d) Only one item is to be shown on each form.

PART I (To be completed by the **Main Contactor**)

---

1. Main Contractor (Name and Address)

2. Main Contract No.

3. Sub-contractor (Name & Address):

4. Sub-Contract No.

5. Description of Material Component or Store

6. Specification/Drawing No.
   Stores reference etc.

7. (a) Quantity / period
   (b) Batch / Lot No.

8. Description of Deviation/Concession.
   (Including proposals for recovery)

These must accompany sketches/ Drawings)/relevant mechanical or Performance Tests, Radiographs, U/S Tests, N&V test results if applicable

(Continue overleaf if necessary)

9. Reference numbers of deviations / concessions previously granted for any other Indenting Authority
(a) of a similar nature
(b) for the quantity/period of item 7 above.

10. REASONS FOR DEVIATION/ CONCESSION	11. EFFECT ON COST (See Note 3)	12. If deviation is granted, are any of the following adversely affected?
	Cost will be increased	
To reduce production costs	Cost will be decreased	(State `YES', `NO' or `N. K.' (Not Known). If answer is `YES' particulars are to be attached.
Error in manufacture data	Cost will be unchanged	
Material specified not available	Deviation costs:	
Manufacturer's error	Will be charged to the Govt.	Functioning
To accommodate local manufacturing methods	Will not be charged to the Govt.	Serviceability / Maintainability
Any other reasons:	Will be credited to the Govt.	Interchangeability
	Will not be credited to the Govt.	Reliability (Strength)
(Item affected to be ticked)	Estimated amount of Charge Rs. OR	Durability (Life of item)
	Estimated amount of Credit Rs.	Safety of Equipment & Personnel

13. Effect on agreed delivery date.

(a) If deviation granted:

(b) If not granted:

14. Design vetting where the Supplier is also the design authority:

AGREED: - ** Condition attached.

Signature (Design Department) Date

---

15. Submitted by:

Signature On behalf of

Date Position held
(Seal of the Main Contractor)

PART-II
(INSPECTING AGENCY)

16. Reference Number/ Control Number: ______________________________

17. Nature of Deviation: _____________________________________

18. Class of Deviation: ___________________

19. Confirm if any affect on safety, service life, functioning, interchangeability or durability.

20. Give reference no. of previously granted deviation of similar nature.

21. Recommendations.

Signature (QAO)

---

22. **Reference to Design Authority/IHQ MoD(N) for approval**.

Date Signature and Stamp of Signing Authority

---

23. **Acceptance by Inspection Authority/DQA(WP)**.

Date Signature and Stamp of Signing Authority

____

Note

Distribution : Five copies of Form are to be prepared. However, in case of Contractor, six copies of Form are to be prepared and submitted to CQAE/QAE for processing.

Main Contractor	-	One copy
Sub-Contractor	-	One copy
CQAO/QAO	-	One copy
HQ DQA(WP)	-	One copy
Design Authority	-	One copy
Order Placing Authority	-	One copy

Appendix D
(Refers to Para 12 of Chapter 5)

FORMAT OF QAP

Sl. No.	Component name & part no. in Ref Drg	Qty	Characteristic/ Type of Check	Quantum of Check	Reference Document	Accep-tance Method	Record Format	Verific-ation
1	2	3	4	5	6	7	8	9
	RAW MATERIAL STAGE (ALL COMPONENTS)		CHEMICAL & MECHANICAL	1/HEAT, 1/LOT,100%, (10-25%), RANDOM	SOTR, Ref. Stds		IR, TC, RD MTC, FGC,	CHP, W, RW
	IN PROCESS / FABRICATION STAGE (ALL COMPONENTS)		V/D, MP, CO, BA. DP, RT, UT	100%, 10-25% RANDOM	SOTR, Ref. Stds			
	ASSEMBLY STAGE		V/D, T, ADF	100%	SOTR, Ref Stds			
	TEST & TRIALS STAGES		HT, LPT, NPSH ETC.	100%	ATP			
	DOCUMENTATION			One Set	SOTR, Ref Stds			
	PAINTING, PRESERVATION, PACKING & SHIPMENT			100%	SOTR, Ref Stds			

RT	Radiography Test	HT	Hydro Test
UT	Ultrasonic Test	LPT	Liquid Penetration Test
DP	Dye Penetrant Test	NPSH	Net Positive Suction Head Test (for pumps)
MP	Magnetic Particle Test	TC	Test Certificate
V/D	Visual/ Dimensional	MTC	Manufacture's Test Certificate
T	Tolerance	FGC	Firm's Guarantee Certificate
BA	Balancing	IR	Inspection Record (Evidence of Inspection by QAO)
CO	Concentricity	RD	Record (Evidence of Firm's Internal QA Record)
CHP	Customer Hold Point	W	Witness by Customer (Same as CHP)
RW	Review of Firm's Internal QA Documents	ADF	Assembly Demerit Factor
SOTR	Statement of Technical Requirements	Ref Stds	Reference Standards – ASTM, ASME, GOST, DIN, BS, NES, IS

Appendix E
(Refers to Para 9 b(i) of Chapter 6)

GUIDELINES FOR QUALITY ASSURANCE OF CASTINGS

General

1. All classes of castings shall be subjected to visual & dimensional inspection including wall thickness measurement. Test of external surfaces is mandatory whereas internal surfaces are to be examined as per requirements stated in SOTR. In any case, the decision of the IAY/ IAG shall be binding and final on the type and extent of tests.

2. The **visual inspection shall be augmented with** Liquid Penetrant Test (LPT)/ Magnetic Particle Induction (MPI) Test/ Ultrasonic test (UT) or Radiography Test (RT) test as appropriate to the material or as specified in the SOTR .

3. The complete casting shall be examined 100% for sub surface defects with special emphasis on critical/ specified test regions, the Contractor should submit a detailed written procedure of the stipulated tests to the QAO/IAG and shall satisfy the QAO/IAG on the competency of the technique and operators before commencement of the tests.

4. In case of RT, the test regions can be examined by Single or Double Wall technique (SWT or DWT) . **For critical/ specified test regions, only SWT is to be used as a matter of policy unless there is adequate evidence to prove that it is impractical**. In all other cases, DWT can be used. It should be noted that defects observed by DWT should be further examined by SWT for the designated area to establish the extent of severity of the defect.

5. In case of UT, for critical applications, the results shall be reconciled by RT of the selected areas to a minimum coverage of 10% of the total area being examined.

6. **Exceptions**. Requirement of 100% NDT test of castings is waived off for the non critical categories (if specified in the SOTR). The NDT in the following cases may be undertaken on sample basis:-

(a) Low stress Class II castings.

(b) Sample positions on large Class II/ III castings.

(c) Batch supply of Class III castings.

Assessment of Severity of Defects & Acceptance Standards

7. The severity of defect other than cracks, hot tears etc. is to be assessed in

terms of reductions of wall thickness and area as observed visually or by NDT methods. The following guidelines are to be followed for assessment of severity of defects.

8. **Assessment by Radiography**. Reduction in wall thickness in the way of sub surface defects is to be assessed by visual comparison with appropriate density check films showing the approximate %ge change for the particular RT technique, material & thickness range. The density check films should belong to the same standard i.e. a film generated by ASTM standard cannot be used for comparison of a film generated by BS standard.

9. **Assessment by Ultrasonic Method**. The assessment by UT shall be by a mutually agreed procedure between Contractor and IAY/ IAG.

10. **Acceptance Standards – Dimensional**.

(a) A tolerance of 10% of the designed wall thickness or 6 mm whichever is less may be accepted on all casting dimensions.

(b) Where the wall thickness fails to meet the designed wall thickness, a reduction may be accepted upto 10% of designed wall thickness or 6 mm whichever is less. The reduced wall thickness shall be free from sub surface defects in critical/ specified test regions. The total area of reduced thickness including that which may arise through blending out of surface defects shall not exceed 10% of critical test regions and designated test regions containing the defects.

11. **Acceptance Standards – Surface Defects**

(a) On visual examination in the finished condition, all surfaces shall be clean and free from cracks, tears, laps, burrs, scams, cold shuts, shrinks, folds, laminations, slivers, scale rust, sand, flux and dross.

(b) Round forms of surface defects including visible porosity are **unacceptable in critical/ specified test regions** but, may be accepted in non specified areas at the discretion of the IAY/ IAG. Whilst checking the surface defects, account should also be taken of the subsequent finishing procedures to be applied for the surfaces. Blending out of unacceptable surface defects is permitted in accordance with clauses given under the heading – ‘Rectification of Defects’ in subsequent paragraphs.

(c) After examination of all defects which are apparent by visual examination, critical/ specified test regions are to be examined by MPI or LPT tests. For the test, the surfaces are to be free of all cracks and crack like defects and similar indications.

(d) Defects like porosity etc. shall be accepted provided that the immediate areas of the casting are acceptable when examined for sub surface defects or after repairs to the sub surface defects.

12. **Acceptance Standards – Sub Surface Defects.**

(a) Cracks, hot tears, and cold shuts are not acceptable except where the defect can be shown, to the satisfaction of the QAO/ IAG, to be wholly within the middle third of the thickness of the casting and its maximum dimension does not exceed:-

(i) One half of the designed wall thickness of the casting in length; and

(ii) 10% of the designed wall thickness of the casting in depth.

(b) Filamentary shrinkage, sponginess and porosity shall only be accepted where local reduction in wall thickness resulting from these defects does not exceed 5% of designed wall thickness in critical test regions and 10% in specified test regions, subject to the total defective area not exceeding 10% of each critical test regions or 20% of the specified test region containing the defect.

(c) In thick walled castings i.e. 50 mm and above, where reduction in wall thickness exceeds the limits in clause 12(b) above, but nowhere exceeds 20% of the defective areas, the same may be accepted provided that the maximum dimension does not exceed the thickness of the casting at that point and it can be shown that the defect lies wholly within the middle third of the thickness.

(d) Shrinkage cavities, gas holes, airlocks and rounded inclusions shall be accepted provided that the local reduction in wall thickness resulting from these defects together with other sub surface defects does not exceed 10% of the designed wall thickness in Critical test regions and 20% in Specified test regions.

13. **Acceptance Standards for Sample Inspection – Sub Surface Defects**. Where sample inspection is being carried out in accordance with SOTR /QAP provisions, the cumulative local reduction in wall thickness resulting from sub surface defects at any position shall not exceed 20% of the designed wall thickness. The total defective area shall not exceed 20% of the total area of the casting.

14. **Proximity of Individual Sub Surface Defects**.

(a) The defective areas as defined at paragraphs 12 & 13 above, are to be separated by at least:-

(i) 2.25 x thickness of the material in the way of defect; or

(ii) 1.25 x length of the large adjacent defect.

(b) However, if the distance between the ends of two defects/ defective areas is less than either of the above two values, they shall be considered as a single defect having an overall length equal to the distance measured between the two extremities of the two defects/ defective areas.

Rectification of Defects

15. **General**. Rectification of defects on casting is by welding. The section gives the various methods and the acceptable standards for repair by welding. However, it should be noted that the guidelines below are not all encompassing and are to be read in conjunction with relevant applicable standards.

16. **Rectification of Dimensions**. Correction of casting dimensions, machining errors and repair of surface defects may be made by weld deposition using approved procedures for the material concerned and shall be within the following limits:-

(a) 5 mm maximum build up for wall thickness <= 25 mm.

(b) 20% of wall thickness (max) build up for wall thickness > 25 mm but not exceeding 10 mm.

(c) Areas of build up on Class I and II castings to be restricted to 10% of the inner/ outer surface area of the casting, not including flange thickness and webs, subject to any limitations indicated at paragraph 20 below.

(d) Areas of build up on Class III castings are to be restricted to 20% of the inner/ outer surface area of the casting, not including flange thicknesses and webs.

(e) All the above mentioned thicknesses are applicable to finished condition. Weld build-up exceeding the dimensions shall either entail rejection or be referred to IAY for acceptance.

17. **Rectification of Surface Defects**.

(a) Unacceptable surface defects may be blended out by an approved process provided the resulting depression does not reduce the designed wall thickness by more than 6 mm or 10% which ever is less. The depression shall be flared out with a minimum radius equal to *3 x Max depth* and the remaining wall thickness in the way of the depression shall be free from sub surface defects in Critical/ Specified test regions.

(b) The total area subjected to blending, including the area affected by the flaring shall not exceed 10% of the critical test region and 20% of the specified test region in which the defect is observed.

(c) Surface defects which cannot be blended out within the limits indicated at paragraphs 17 (a) & (b) may be repaired by welding by an approved procedure for the material concerned within the overall limitation mentioned at paragraph 16.

18. **Rectification of Sub Surface Defects.** Unacceptable sub surface defects may be repaired by welding using an approved procedure for the material concerned and shall be within the following limits:-

(a) Total weld repairs in Class I and II castings shall not exceed 10% of the inner or outer surface area of the casting, not including flange thickness and webs subject to limitations indicated at paragraph below.

(b) Total weld repair in Class III castings shall not exceed 20% of the inner or outer surface area of the casting not including flange thicknesses & webs.

Limits on Individual Sub Surface Defects

19. Any individual repair in Critical test region shall not exceed 5% of the test area containing the defect. In Specified test regions any individual repair shall not exceed 10% of the test area containing the defect.

Limits on Combined Weld Repairs

20. The total combined area of weld repairs from all causes i.e. dimensional correction, surface & sub surface defects shall not exceed 10% of the Critical test region and 20% of the Specified test regions. Non designated areas of Class III castings are to be examined in accordance with provisions stipulated at paragraph 6 above.

21. The extent of weld repair undertaken should be only that necessary to bring the casting within the appropriate standards indicated at paragraphs 10 to 13 above. The defects repaired are to be decided in consultation with the IAY.

Non Destructive Examination of Repairs

22. All castings which have been repaired shall be inspected as detailed in the succeeding paragraphs. Non destructive examination method requirements shall be in accordance with procedures/ requirements indicated at Appendix K.

23. **Visual Inspection**. Each casting shall be inspected after repair for conformance to dimensions, surface condition and identification of markings.

24. **Magnetic Particle (MPI) & Liquid Penetrant Test (LPT) Inspection**. The MPI/ LPT inspections are to be carried out on all weld build up areas after grinding or machining the weld surface flush with the casting surface. The area inspected should extend upto 50 mm from the weld boundaries in all directions.

25. **RT & UT Inspection**.

(a) All weld repairs shall be ultrasonically examined or radio-graphed except for surface repairs (effected accordance with guidelines indicated at paragraph 16 above) on Class III castings and non designated areas of Class I & II castings.

(b) UT can be used in lieu of RT, for examination of weld repair, subject that the firm is to forward the UT methodology for approval to IAY.

Acceptance Standards for Cold Repairs

26. The acceptance standard for both ferrous & non ferrous castings in both Critical & Specified test regions shall be as follows:-

(a) **Cracks & Lack of Fusion**. These are not accountable.

(b) **Linear Inclusions**. The max length of any single linear inclusion shall not exceed 0.5 x designed wall thickness in the way of inclusion. Such inclusions should be separated in accordance with guidelines given at paragraph 14 above. The total length of inclusions shall not exceed 20% of max dimensions of the area affected by the repair.

(c) **Porosity & Rounded Inclusion**. Porosity & Rounded inclusion revealed by RT shall be assessed by assuming the repair area to be a series of strips of width approximately equal to mean depth of repair. The strips should be aligned to the direction which gives the worst total defect indication. For circular indications revealed by LPT on non ferrous welds.

Appendix F
(Refers to Para 9 b(ii) of Chapter 6)

GUIDELINES FOR QUALITY ASSURANCE OF FORGINGS

Performance Specification

1. The materials, chemical composition, carbon equivalent values, product analysis variations, manufacture, heat treatment, testing and quality assurance of forgings for use in IN Ships and Submarines shall be in accordance with these guidelines.

Materials

2. **Requirements**. The material shall strictly conform to the requirements of the grades specified in the SOTR/ PO to meet the specific environment for which it is intended.

3. **Ladle Analysis**. The material, on ladle analysis, shall conform to the limitations of chemical composition given in the relevant standard.

4. **Carbon Equivalent Values (Steel Forgings).** The Carbon Equivalent Values (CEV) shall not exceed the values given in the relevant standards.

5. **Product Analysis Variations**. A check analysis is required, using broken test pieces or adjacent material. The percentages of the elements shall not exceed the variations specified in the relevant standards. Where no check analysis variation is specified, the limits for check analysis and ladle analysis are the same.

Manufacture

6. **Methodology**. The basic ingot is to be manufactured by internationally recognized methods of manufacture or as specified in the relevant applicable standard or as specified in the SOTR/PO.

For example : Low alloy or carbon-manganese steels are to be produced by the basic electric or basic oxygen furnace route, to be vacuum degassed/ refined and fully killed using the Aluminium fine-grained practice.

7. **Discard**. Sufficient discard shall be removed from the top and bottom of ingots to ensure freedom from piping and harmful segregation in the finished forging. The bottom discard shall not be less than 3% of the body of the ingot above the well.

8. **Dimensions**. Forgings shall be brought as near to final dimensions as feasible by hot working. Grain flow in the forging shall be in accordance with the requirements of the SOTR/ PO/ Standard or, if not specified, shall be consistent with established good forging practices.

9. **Hot-working Temperatures**. The initial & subsequent hot working on ingot feedstock is to be done as per the specifications given in the relevant applicable standard/ SOTR. The selected forging temperature range shall be such that no detrimental effects are imparted to the forgings. Final dimensions shall only be achieved by the minimum of machining and/or grinding.

10. **Forging Ratio**. The ratio of the mean cross sectional area of the ingot to that of the main body of the forging shall be as specified in the relevant applicable standard or SOTR or as per internationally accepted practices. For example in case of steel forgings, the ratio should not be not less than 2:1. Where an upsetting operation is used, this criteria relates to the cross sectional area of the upset bloom and not the ingot. In such as case, this ratio shall not be greater than 10:1 on the thinnest section as forged.

Heat Treatment.

11. Heat treatment of the forgings at all stages of manufacture shall be conducted in a manner that shall preclude the formation of detrimental metallurgical structure or physical defects. Heat treatment shall be performed in suitably designed furnaces with an adequate level of temperature monitoring. Monitoring equipment shall produce a hard copy permanent record of temperature and time.

12. Finish forged products shall be 'normalized and tempered' or 'quenched and tempered' unless specified otherwise. To achieve the specified properties, the normalizing and tempering temperatures shall be within the ranges specified in the SOTR / applicable relevant standard.

Testing

13. **Non–Destructive Testing, Acceptance Standards and Recording of Defects**.

(a) After final heat treatment and machining each forging shall be visually examined for surface defects and shall be subjected to MPI and/ or Radiogrpahy and/or Ultrasonic examinations. Dye Penetrant Testing may be used as an alternative to MPI test. All Non-Destructive Testing (NDT) methods shall be in accordance with the requirements of relevant applicable standards, guidelines for which are given at Annexure 2 to 4.

(b) The size and location of all defect indications shall be recorded and marked on the item as the examination progresses. Records shall be sufficiently detailed to permit application of the quality acceptance standard required by the customer as defined in the contract documents.

(c) With the agreement of the customer and provided the final component dimensions can still be achieved, surface defects may be removed by grinding.

14. **<u>Sampling for Mechanical Testing</u>**.

(a) All samples for mechanical testing shall be taken from the forging prolongations as shown in Figure 1, Figure 2 and Figure 3 after all heat treatment has been completed. Provision shall be made for retests as considered necessary.

(b) Test pieces shall be taken as follows:-

(i) For forgings weighing 200 kg or more, specimens shall be taken from every forging prolongation in accordance with Figure 1, Figure 2 or Figure 3 as appropriate.

(ii) For forgings weighing less than 200 kg, individual forgings specimens shall be taken from every forging in accordance with Figure 1, Figure 2 or Figure 3 as appropriate. For batches of forgings, specimens shall be taken from 25% of the forgings in accordance with Figure 1, Figure 2 or Figure 3 as appropriate. Duplicate specimens from the bottom end are not required regardless of length to width ratio. A batch is defined as a group of forgings produced from one heat or melt and heat treated in the same heat treatment charge.

(iii) For multiple forgings, the composite forging weight governs whether the procedure at Clause 6.3.2(b)(1) or Clause 6.3.2(b)(2) above applies.

(iv) For bars in the finally heat treated condition, specimens shall be cut from the heat treated bars and shall not be further heat treated or mechanically worked after their removal. One longitudinal tensile and three transverse Charpy ‘V’ notch impact tests shall be made on any batch of bars of similar size from the same cast and heat treated together.

(c) Certain components of complex shape, e.g. closed die forgings, where all the parameters are not fully defined, shall be subject to approval by the equipment sponsor at the design stage. Approval submissions for such items shall include the following:-

(i) Sufficient sketches to define shape, size and grain flow.

(ii) Details of the production route.

(iii) Proposals for the locations and number of test pieces.

Figure 1 – Location of Specimens for Rectangular & Cross Sections

When L = 2 x w or greater, tests shall be repeated on this end also

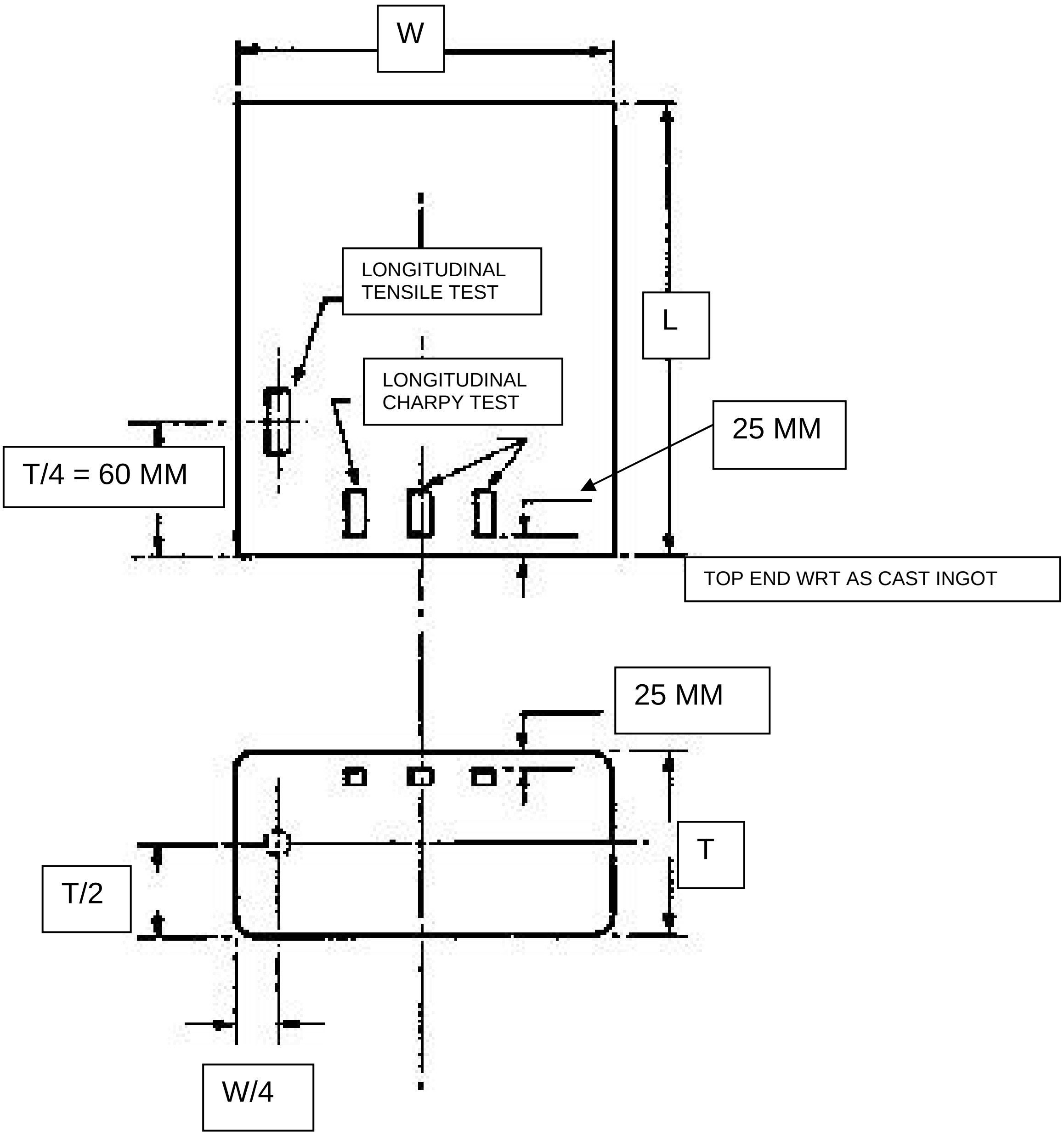


Figure 2 – Location of Test Specimens for Solid Circular Cross Section

When L = 2 x d or greater, tests shall be repeated on this end also

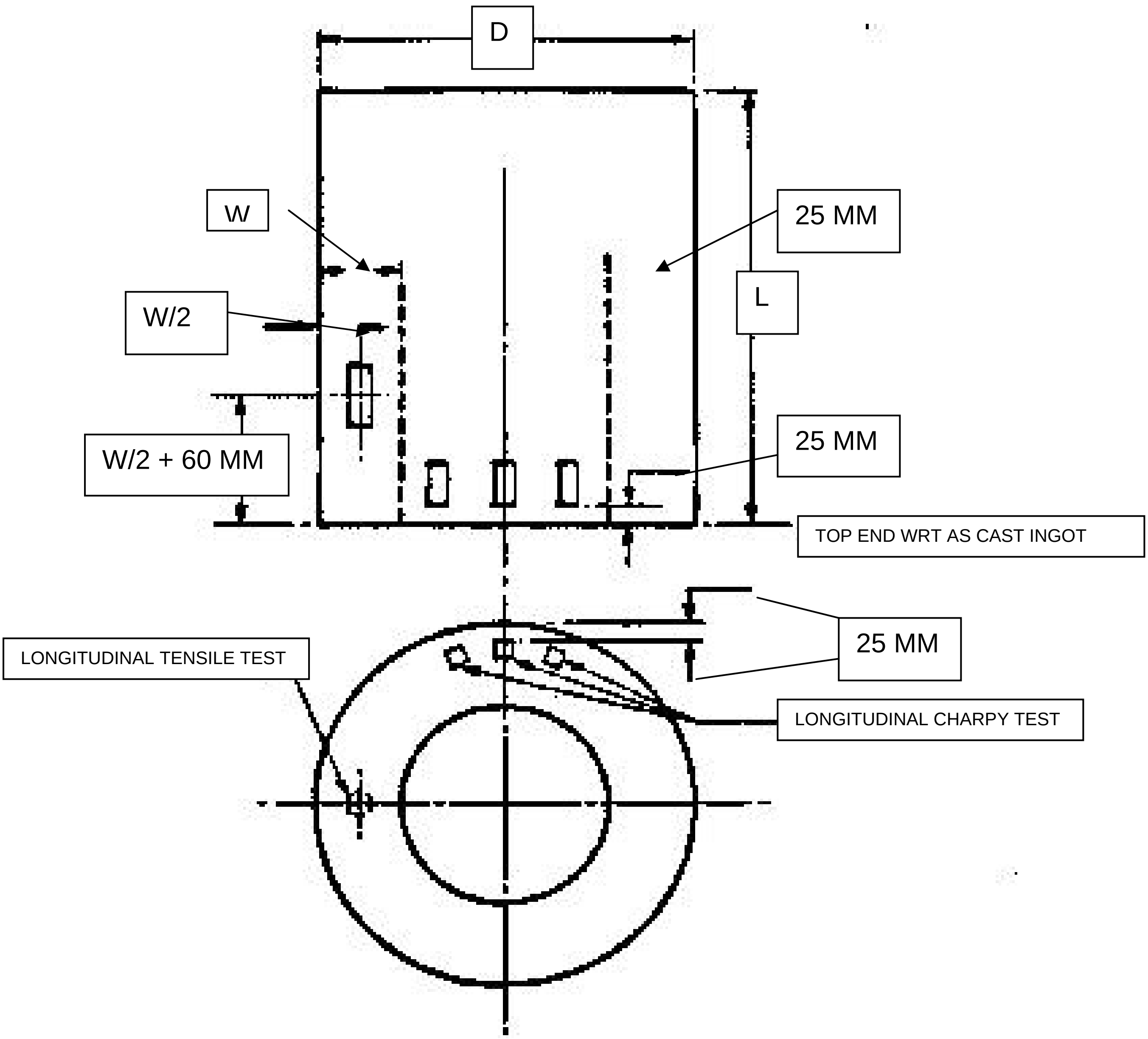
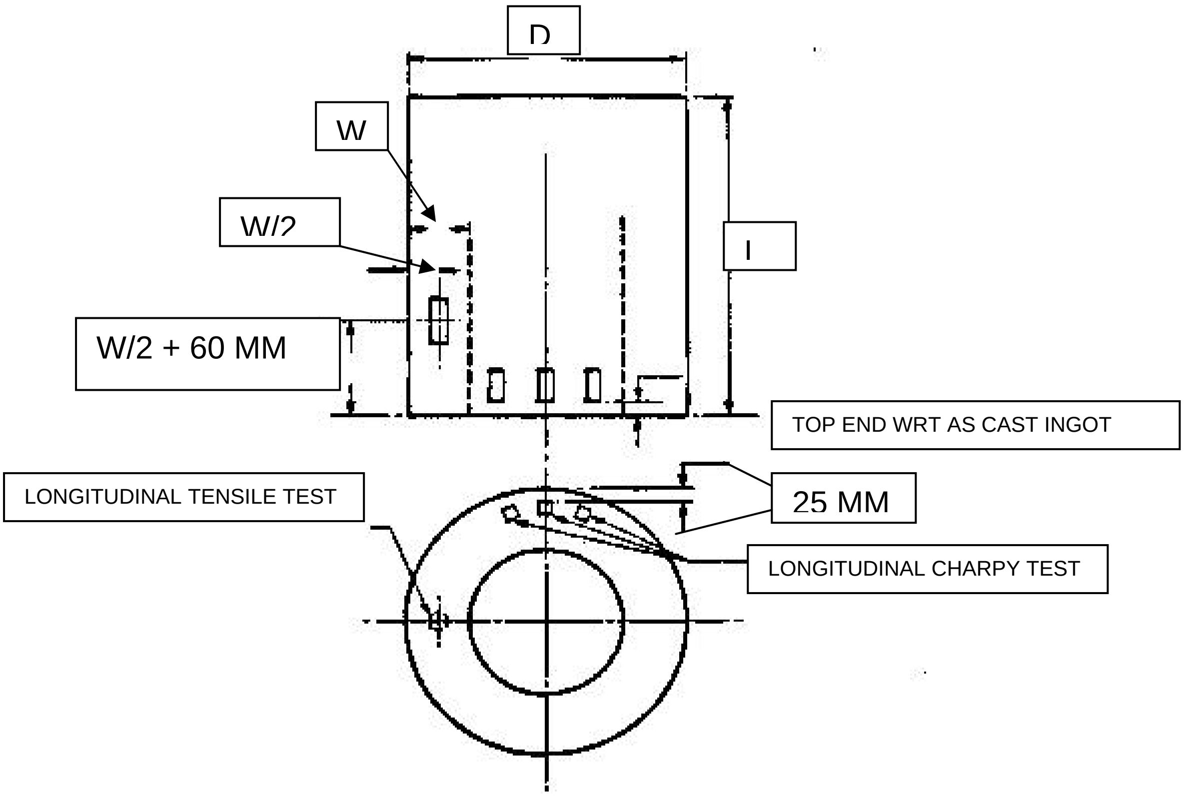


Figure 3– Location of Test Specimens for Bored Circular Cross Section

When L = 2 x d or greater, tests shall be repeated on this end also



Mechanical Test and Properties

15. Tensile tests shall be conducted in accordance with the requirements of BS EN 10002-1 / eqv. ASTM or IS standards. The dimensions of the test pieces shall be in accordance with the requirements of BS EN 10002-1 Annex C / eqv. ASTM or IS standards.

16. When required for the grades specified or required by the contract documents, tensile testing at elevated temperature shall be in accordance with the requirements of BS EN 10002-5 / eqv. ASTM or IS standards.

17. Charpy V–notch impact tests shall be in accordance with the requirements of BS EN 10045-1 / eqv. ASTM or IS standards. Full size specimens shall be used where practicable. Energy requirements for sub-size specimens shall be as per relevant applicable standard.

18. The Yield Strength or 0.2% Proof Stress, Tensile Strength, %ge Elongation, Impact Test Temperature and Impact Energy requirements for the forgings shall be in accordance with the requirements stated in the relevant applicable standards or as indicated in the SOTR.

19. When hardness testing is required by the applicable standard or the contract documents, this shall be either Rockwell, Vickers or Brinell hardness values specified in the relevant applicable standards or as specified in the SOTR. Acceptance criteria for the hardness test results shall also be as stated in the applicable standard or the contract documents.

20. Portable hardness testing methods may be employed for large forgings when agreed in the contract document.

21. When specified in the contract documents, the mechanical properties for large section forgings shall be determined in the 'through thickness direction' with an agreed specimen location and test frequency.

22. The mechanical properties of the forgings shall be in accordance with the requirements stated in the applicable standard or the contract documents. It should be noted that the mechanical properties quoted are consistent with the Maximum Ruling Sections quoted. However, the following shall apply:-

(a) For components with ruling sections below the maximum quoted it may be possible to heat treat to the Tensile Strength and Yield/0.2% Proof Stress figures in excess of those quoted. Provided the higher properties are consistent with those quoted in the material specification for the ruling section prevailing, then the higher release properties may be as defined in the contract document.

(b) For components with ruling section above the maximum quoted, the minimum release properties shall be agreed between the Forge Master and the Purchaser and stated in the contract document.

(c) If there is provision within the material specification regarding 0.2% Proof Stress compliance at elevated temperature, then the test temperature(s) for same is to be stated in the SOTR and the requirements of the material specification are to be met.

23. **Retests**.

(a) Should any test pieces fail to meet the mechanical property requirements, two further test pieces may be selected from the same sample for retest. If these are acceptable, then the item shall be deemed to meet the specification.

(b) The manufacturer has the right, provided appropriate test material is available, to re-heat/ re-treat the forgings, in which case the tests and examination shall be repeated in full as if it were a new item.

(c) The item shall be rejected if the requirements are not achieved after two re-heat/ re-treat cycles.

Quality Assurance

24. **General**. The manufacturer shall maintain QA systems and procedures in accordance with internationally recognized procedures & practices which, shall ensure full material traceability.

25. **Quality Assurance Documentation**. Documents and certificates detailing material source, chemical analyses, heat treatment records, results of mechanical tests and Non Destructive Tests shall be supplied in accordance with the requirements of relevant standards. All documents/ certificates shall be uniquely referenced to the items to which they refer.

26. **Identification.** All items shall be clearly marked by an approved method in accordance with the contract documents. Marking shall, as a minimum, include but not be limited to the following:-

(a) Manufacturer's Works Code.

(b) Unique Identification Number.

(c) Cast/Heat Number.

27. **Check List for Forgings**. The under mentioned check list is to be used whilst checking forgings:-

(a) Is the Material Grade been correctly specified?

(b) Is the grain flow & grain size defined?

(c) Is the heat treatment standard or non-standard, If non standard, are the temperatures, duration & cooling medium specified unambiguously?

(d) Are the acceptance standards clearly indicated?

(e) Are approval submissions required?

(f) Is elevated temperature testing required and at what temperatures?

(g) Do mechanical property variations need to be specified?

(h) Is hardness testing required and if so what test methods are acceptable?

(j) Are properties to be determined in the through thickness direction?

(k) Release properties to be specified for large ruling section forgings.

(l) Are elevated temperature 0.2% Proof Stress tests required? If so than 0.2% Proof Stress Acceptance Standards are to be quoted.

Appendix G
(Refers to Para 19 of Chapter 6)

LIST OF APPROVED BRAND NAMES FOR BOUGHT OUT ITEMS

Seals / Packing Etc.

John Crane, Genseals

Fasteners

TVS, LPS Bossard

Electrical Items

L&T Switchgear, Siemens, Phillips, Bhartia Cutler Hammer, Anchor, Molex

Instrumentation

H Guru, Waree, Pricol, Danfoss / Indfoss

Appendix H
(Refers to Para 14 of Chapter 7)

GUIDELINES FOR QUALITY ASSURANCE OF WELDS

Introduction

1. In production welding, the term "weld quality" is relative. The application determines what is good or bad. Generally, any weld is a good weld if it meets appearance requirements and will continue indefinitely to do the job for which it is intended. But a weld can be "too good". This is the case when a high degree of quality has been obtained at excessive production cost and the customer is getting no discernible value from the added expenditure. Insisting on any method of inspection, x-ray for example, if it serves no function is illogical as well as wasteful.

2. The first step, then, in assuring weld quality is to ascertain the degree required by the application. A standard should be established based on service needs. Engineering performance will be the main consideration in arriving at the standard, but appearance may also be important. A safety factor must, of necessity, be built into the standard, but it should be reasonable. Once the standard has been set, it is the responsibility of everyone concerned with the job to see that it is followed.

3. On the low side, the predetermined standard of quality should never be compromised. On the high side, there is no objection to extra quality, providing it has been obtained at no penalty in cost. If tests repeatedly show that the welds are exhibiting a degree of quality far greater than required by the standard, a cost reduction through modification of weldment design or procedures may be possible.

4. Frequently, the standards are preset by prevailing specifications or engineering and legal codes. Sometimes such standards are ultraconservative, but when they apply, they must be honored. The engineer can do his company or the customer a service by pointing out unrealistic specifications and the opportunities for cost savings, but the specifications must be adhered to rigidly until revised.

The Five Ps

5. After the quality standard has been established, the most important step toward its achievement is the selection of the best process and procedures. By giving attention to the five Ps, weld quality will come about almost automatically, reducing subsequent inspection to a routine checking and policing activity. The five Ps are: -

(a) **Process Selection.** The process must be right for the job.

(b) **Preparation.** The joint configuration must be right and compatible with the welding process.

(c) **Procedures**. To assure uniform results the procedures must be spelled out in detail and followed religiously during welding.

(d) **Pre-testing**. By full-scale mockups or simulated specimens the process and procedures are proved to give the desired standard of quality.

(e) **Personnel.** Qualified people must be assigned to the job.

Process Selection

6. In view of the various automatic and semiautomatic processes available, process selection imposes a challenging decision. Of all the processes, manual welding is the most versatile, but economic considerations necessitate its being ruled out in favor of a partially or fully mechanized process wherever such is applicable.

7. Process selection is tied up integrally with the need of the joint. Some joints require Fast-fill predominantly; others, Fast-follow. The most important needs in still others may be deep penetration or Fast-freeze. Each process has its advantages and limitations, and each introduces problems affecting joint preparation, welding procedures, and operator training.

8. The process that gives the correct balance between the needs of the joint in terms of fill, follow, freeze, and penetration is likely to be the one that gives optimum weld quality.

9. Manual, submerged arc, flux-cored arc and gas-metal arc welding, except short-circuiting transfer, enjoy a prequalified status on certain specific joint configurations. Most are subject to specific thickness limitations as discussed in the AWS Structural Welding Code D1.1.

10. Deviations from these prequalified joints may be accomplished by running qualification tests since practically all codes state that "other welding processes and procedures may be used, provided the contractor qualified them in accordance with the prescribed requirements."

Preparation

11. Joint preparations are standardized and specified by applicable codes. The decision of the joint preparation is made by the designer rather than the fabricator, with the latter usually given the choice of what process and procedure to use to make the weld with the prescribed preparation.

12. Acceptable butt-joint preparations are nothing more than a compromise between the included angle of bevel and the root spacing dimension. A large

included angle will permit a smaller root spacing and, conversely, a small included angle requires a larger root spacing.

13. These and other factors are taken into consideration in prequalified joints. The joint detail influences process selection, electrode size, and welding position. The joint preparation must be correct before welding is started, not only to meet specifications, but to give assurance of weld quality.

Procedures

14. Reliable welding procedures are developed through first-hand experience. They should be completely detailed in advance of production work. A full-scale mockup of the joint, using the same type steel sizes, and shapes that will be used on the job, should be made to test the procedures if such is possible. If a full-scale mockup is not feasible, a simulated setup should be used to produce specimens that can be destructively and nondestructively tested. By trial and error, all the procedure details for making an acceptable weld can be determined.

Pre-testing

15. Pre-testing production-size or simulated production specimens also tests the process as well as the procedures. Once it has been ascertained that the procedures and the process give the desired quality, such test specimens can also be used as a final check on the qualifications of the operator.

16. The closer the conditions of test approach conditions of service, the more meaningful will be the results. The ideal would be service life tests under slightly exaggerated conditions. Since this is usually impractical, simulated service tests are the next best choice. Specimen assemblies may be subjected to radiographic, ultrasonic, or other nondestructive inspection procedures to evaluate the weld quality. Or they may be proof-tested or submitted to destructive tests to determine ultimate limits.

17. By proper use of process-procedure qualification, backed up by convincing test evidence, final inspection takes on the nature of a quality control activity. This is desirable; the intent should be to make the welding so deadly precise in giving the desired quality that all subsequent inspection is for the detection of the unexpected and unexplained, rather than the explainable defects.

Personnel Qualification

18. Personnel qualification - the last of the five Ps, can be evaluated in a preliminary way by the AWS Operator Qualification Test and the contractor's judgement. If a semiautomatic process is to be used, some experience with it is desirable, or the welder may require training. As mentioned previously, the welding

of test specimens with the selected process and procedures will affirm the operator's capability.

The Role of Inspection

19. Inspection determines whether the prescribed standard of quality has been met. This function may be the responsibility of the welding supervisor or foreman, a special employee of the company doing the welding, or a representative of the purchasing organization. The formal welding inspector may have a variety of duties. These may begin with interpretation of drawings and specifications and follow each step to the analysis of test results. His operations are both productive and nonproductive, depending on where they are applied.

20. Inspection after the job is finished is a policing action, rather than a productive function. Important as it is to assure quality, it is a burden added to the overall production cost. No amount of after-the-job inspection will improve the weld; it merely tells what is acceptable and what must be reworked or rejected.

21. Inspection as the job progresses is a different matter. It detects errors in practice and defects while correction is feasible. It prevents minor defects from piling up into major defects and leading to ultimate rejection. Inspection while weld quality is in the making and can be controlled may justifiably be looked upon as a productive phase of cost, rather than an overburden.

22. Any program for assuring weld quality should, therefore, emphasize productive inspection and attempt to minimize the nonproductive type. This should be the guiding philosophy, even though its implementation may fall short. In most cases, such a philosophy means that visual inspection will be the main method of ascertaining quality, since it is the one method that can be applied routinely while the job is in progress.

In Process Visual Inspection

23. In a sense, everyone connected with the job, as well as the formal inspector, participates in visual inspection. A conscientious worker does not knowingly pass on work in which he recognizes defects of his making. Nevertheless, it is usually desirable that someone be assigned responsibility for checking quality of each operation.

24. In addition to good eyesight and good lighting, the tools for visual inspection are simple, such as a pocket rule, a weld-size gauge, a magnifying glass, and sometimes a straight edge and square for determining straightness, alignment and perpendicularity.

25. Visual inspection should begin before the first arc is struck. The following is to be noted:-

(a) The materials should be examined to see if they meet specifications for quality, type, size, cleanliness, and freedom from defects.

(b) Foreign matter, such as grease, paint, oil, oxide film, heavy scale that could be detrimental to the weld should be removed.

(c) The pieces to be joined should be checked for straightness, flatness, and dimensions. Warped, bent, improperly cut or damaged pieces should be ordered for repair or rejected.

(d) Alignment and fit of parts and the fixture should be scrutinized. Joint preparation should be checked.

(e) Often, little more than a passing glance is required in this preliminary inspection, but despite its almost casual nature such inspection can be a significant factor in weld quality.

26. Inspection prior to welding also includes verification that the correct process and procedures are to be employed, that the electrode type and size and the equipment settings for voltage and amperage are as specified, and that provisions are made for the required preheat or post heat.

27. Assuming the preliminary requirements are in good order, the most productive inspection will take place while the weldment is being fabricated. Examination of a weld bend and the end crater may reveal quality deficiencies such as cracks, inadequate penetration, and gas and slag inclusions to a competent inspector. Several types of weld defects can be recognized visually.

28. On simple welds, inspection of a specimen at the beginning of the operation and periodically as the work progresses may be adequate. When more than one layer of filler metal is deposited, it may be desirable to inspect each layer before a subsequent layer is placed.

29. The root pass in a multi-pass weld is the most critical one from the standpoint of weld soundness. It is especially susceptible to cracking, and because it tends to solidify quickly, is prone to trap gas and slag. Subsequent passes are subject to a variety of weld defect creating conditions which result from the shape of the weld bead or change the configuration of the joint. These can be visually detected by the welder and repair cost minimized if the problem is corrected before welding progresses.

30. A workmanship standard, constructed for the specific purpose, can be helpful both to the welder and the inspector in visually appraising the production weld during the stages of its formation.

31. **Under-welding & Over-welding.** Under-welding is in violation of specifications and cannot be tolerated. Over-welding should be of as much concern to the purchaser's inspector as to those members of the shop responsible for monitoring costs, since it is a major cause of distortion. Usually the designer has specified a weld size approaching the limit possible in good practice. The welder (perhaps wanting to make certain that the joint is strong enough, or having been criticized for making undersize welds) takes it upon himself to add, say, 1/16 inch to a 1/4 inch fillet. Since the weld metal deposited increases as the square of the size, the 1/16 inch increase in leg size increases the amount of weld metal deposited 60 percent, and has the same effect on shrinkage stress and cost.

Post Welding Visual Inspection

32. Visual inspection after the weldment has been completed is also useful in evaluating quality, even if ultrasonic, radiographic, or other methods are to be employed. Here, as with visual inspection as welding progresses, surface flaws, such as cracks, porosity, and unfilled craters can be detected, and may be of such consequence that repairs are required or the work is rejected without use of subsequent inspection procedures. There is no point in submitting an obviously bad weld to sophisticated inspection methods.

33. Dimensional variations from tolerances, warpage, and faults in appearance are detected visually at this stage. The extent and continuity of the weld, its size, and the length of segments in intermittent welds can be readily measured or noted.

34. Welds must be cleaned of slag to make inspection for surface flaws possible. A glass with magnification of up to 10 diameters is helpful in detecting fine cracks and other defects. Shotblasting should not be used in preparing the weld for examination, since the peening action may seal fine cracks and make them invisible.

35. The objective of visual inspection here is not only to seek defects not permissible under the quality standard, but also to give clues to what may be amiss in the entire fabrication process. If the inspector has a sound knowledge of the welding, he can read much from what he sees. Thus, the presence of excessive porosity and slag inclusions may be a tip-off to the fact that the current is not adequate, no matter what the dial readings may be. Subsequent tests will also give clues to faults in equipment or procedures, but the information acquired through visual examination permits corrections to be made before the results from complicated tests are available.

Determining Weld Quality

36. Weld quality acceptance criteria can originate from a number of sources. The welding fabrication drawing or blueprint provides weld sizes and other welding dimensional requirements such as length and location. These dimensional requirements are established through design calculations or are taken from proven designs that meet the performance requirements of the welded connection.

37. The number of acceptable and unacceptable weld discontinuities for welding inspection usually is obtained from welding codes and standards. Welding codes and standards have been developed for many types of welding fabrication applications. It is important to choose a welding standard intended for use within the particular industry or application in which you are involved.

Weld Inspector Responsibilities

38. Imperfections within or adjacent the weld may prevent the weld from meeting its intended function. Welding inspection requires knowledge of weld drawings, symbols, joint design, procedures, code and standard requirements, and inspection and testing techniques. For this reason, many welding codes and standards require that the welding inspector be formally qualified, or have the necessary knowledge and experience to conduct the inspection.

39. Weld inspection is only as good as the person running the tests. Here are a few things that a welding inspector should know and tasks he should be able to perform.

40. **Welder Performance & Welding Procedure Qualification**.

(a) Specific procedures must be followed to qualify welders and welding procedures. The qualification process is an integral part of the overall welding quality system, and the welding inspector often is required to coordinate and verify these types of qualification tests.

(b) These qualifications typically involve producing welded samples representative of the welds that will be used in production welding. These welded samples usually are required to be tested after completion. The test results must meet or exceed the minimum requirements as stipulated in the welding code or standard before the procedure can be qualified.

(c) Details of Weld Procedure Specification (WPS) and Procedure Qualification Record (PQR) are given at the end of this Appendix.

41. **Visual Inspection**. This is often the easiest, least expensive, and most effective method of welding inspection for many applications if performed correctly. The welding inspector must be capable of identifying all of the different welding discontinuities during visual inspection. He also must be able to evaluate, in terms of the relevant welding code or standard, the significance of identified discontinuities to determine whether to accept or reject them during testing and production. A welding inspector with good eyesight can be trained relatively quickly by a competent instructor and can prove to be a major asset to the welding quality system (good vision is obviously essential for visual inspection).

42. **Surface Crack Detection**. A welding inspector sometimes is required to conduct weld testing by surface crack detection methods. He also may have to evaluate the test results of these testing methods. The inspector should understand

testing methods, such as liquid penetrant and magnetic particle inspection. Additionally, he must know how the tests are used and what they will find.

43. **Radiographic and Ultrasonic Weld Inspection**.

(a) These two inspection methods are in a group known as nondestructive testing (NDT). These inspection methods are used to examine the internal structure of the weld to establish the weld's integrity, without destroying the welded component. The welding inspector may be required to understand this type of testing and be competent in the interpretation of the results.

(b) Radio-graphic and ultrasonic weld inspection are the two most common methods of NDT used to detect discontinuities within the internal structure of welds. The obvious advantage of both methods is their ability to help establish the weld's internal integrity without destroying the welded component.

44. **Destructive Weld Testing**. Destructive methods to establish weld integrity or performance include sectioning, bending, or breaking the welded component and evaluating various mechanical or physical characteristics. These tests are used during welding procedure or welder performance qualification testing. The welding inspector often is required to conduct, supervise, or evaluate these testing methods.

45. **Interpretation of Welding Details and Weld Symbols**. The welding inspector should be competent in the ability to read engineering and manufacturing drawings, and be able to interpret all details and symbols that provide information about the welding requirements. The weld edge preparations differ for different types of weld joints and also on the material/ welding methodology. The weld inspector is to study the requirements in detail before qualifying the welds.

Typical Defects in Welds

46. **Incomplete Penetration**. This term is used to describe the failure of the filler and base metal to fuse together at the root of the joint. Bridging occurs in groove welds when the deposited metal and base metal are not fused at the root of the joint. The frequent cause of incomplete penetration is a joint design which is not suitable for the welding process or the conditions of construction. When the groove is welded from one side only, incomplete penetration is likely to result under the following conditions:-

(a) The root face dimension is too big even though the root opening is adequate.

(b) The root opening is too small.

(c) The included angle of a V-groove is too small.

(d) The electrode is too large.

(e) The rate of travel is too high.

(f) The welding current is too low.

47. **Lack of Fusion**. Lack of fusion is the failure of a welding process to fuse together layers of weld metal or weld metal and base metal. The weld metal just rolls over the plate surfaces. This is generally referred to as overlap. Lack of fusion is caused by the following conditions:-

(a) Failure to raise to the melting point the temperature of the base metal or the previously deposited weld metal.

(b) Improper fluxing, which fails to dissolve the oxide and other foreign material from the surfaces to which the deposited metal must fuse.

(c) Dirty plate surfaces.

(d) Improper electrode size or type.

(e) Wrong current adjustment.

48. **Undercutting**. Undercutting is the burning away of the base metal at the toe of the weld. Undercutting may be caused by the following conditions:-

(a) Current adjustment that is too high.

(b) Arc gap that is too long.

(c) Failure to fill up the crater completely with weld metal.

49. **Slag Inclusions**. Slag inclusions are elongated or globular pockets of metallic oxides and other solids compounds. They produce porosity in the weld metal. In arc welding, slag inclusions are generally made up of electrode coating materials or fluxes. In multilayer welding operations, failure to remove the slag between the layers causes slag inclusions. Most slag inclusion can be prevented by:-

(a) Preparing the groove and weld properly before each bead is deposited.

(b) Removing all slag.

(c) Making sure that the slag rises to the surface of the weld pool.

(d) Taking care to avoid leaving any contours which will be difficult to penetrate fully with the arc.

50. **Porosity**.

(a) Porosity is the presence of pockets which do not contain any solid material. They differ from slag inclusions in that the pockets contain gas rather than a solid. The gases forming the voids are derived from:-

(i) Gas released by cooling weld because of its reduced solubility as temperature drops.

(ii) Gases formed by the chemical reactions in the weld.

(b) Porosity is best prevented by avoiding:-

(i) Overheating and undercutting of the weld metal.

(ii) Too high a current setting.

(iii) Too long an arc.

51. **Excessive Penetration**. Excessive penetration usually causes burn through. It is the result of too much heat in the weld area. This can be corrected by: -

(a) Reducing the wire-feed speed and increasing the speed of travel.

(b) Making sure that the root opening and root face are correct.

(c) Increasing the stick out distance during welding and weaving the gun.

52. **Whiskers**. Whiskers are short lengths of electrode wire sticking through the weld on the root side of the joint. They are caused by pushing the electrode wire past the leading edge of the weld pool. Whiskers can be prevented by:-

(a) Reducing the wire-feed speed and the speed of travel.

(b) Increasing the stick out distance and weaving the gun.

53. **Voids**. Voids are sometimes referred to as wagon tracks because of their resemblance to ruts in a dirt road. They may be continued along both sides of the weld deposit. They are found in multi pass welding. Voids can be prevented by:-

(a) Avoiding a large contoured crown and undercut.

(b) Making sure that all edges are filled in.

(c) On succeeding passes, using slightly higher arc voltage and increasing travel speed.

54. **Spatter**. Spatter is made up of very fine particles of metal on the plate surface adjoining the weld area. It is usually caused by high current, a long arc, an irregular and unstable arc, improper shielding gas, or a clogged nozzle.

55. **Irregular Weld Shape**. Irregular welds include those that are too wide or too narrow, those that have an excessively convex or concave surface, and those that have coarse, irregular ripples. Such characteristics may be caused by poor torch manipulation, a speed of travel that is too slow, current that is too high or low, improper arc voltage, improper stickout, or improper shielding gas.

56. **Burn-Through**. Burn-through may be caused by the following:-

(a) Current too high.

(b) Excessive gap between plates.

(c) Travel speed too slow.

(d) Bevel angle too large.

(e) Nose too small.

(f) Wire size too small.

(g) Insufficient metal hold-down or clamping.

57. **Weld Crown Too High or Too Low**. The crown of the weld may be incorrect due to the following:-

(a) Current too high or low.

(b) Voltage too high or low.

(c) Travel speed too high.

(d) Improper weld backing.

(e) Improper spacing in welds with backing.

(f) Workpiece not level.

58. **Penetration Too Deep or Too Shallow**. Incorrect penetration may be caused by any of the following:-

(a) Current too high or low.

(b) Voltage too high or low.

(c) Improper gap between plates.

(d) Improper wire size.

(e) Travel speed too slow or fast.

59. **<u>Reinforcement Narrow and Steep-Sloped (Pointed)</u>**. Narrow and pointed reinforcements may be caused by the following:-

(a) Insufficient width of flux.

(b) Voltage too low.

60. **<u>Mountain Range Reinforcement</u>**. If the reinforcement is ragged, the flux was too deep.

<u>Testing of Welds (As per ASME Section IX)</u>

61. **<u>General</u>**.

(a) The tests described in this section have been developed to check the skill of the welding operator as well as the quality of the weld metal and the strength of the welded joint for each type of metal used in ordnance materiel.

(b) Some of these tests, such as tensile and bending tests, are destructive, in that the test specimens are loaded until they fail, so the desired information can be gained. Other testing methods, such as the X-ray and hydrostatic tests, are not destructive.

62. **<u>Acid Etch Test</u>**.

(a) This test is used to determine the soundness of a weld. The acid attacks or reacts with the edges of cracks in the base or weld metal and discloses weld defects, if present. It also accentuates the boundary between the base and weld metal and, in this manner, shows the size of the weld which may otherwise be indistinct. This test is usually performed on a cross section of the joint.

(b) Solutions of hydrochloric acid, nitric acid, ammonium per sulfate, or iodine and potassium iodide are commonly used for etching carbon and low alloy steels.

63. **<u>Guided Bend Test</u>**.

(a) The quality of the weld metal at the face and root of the welded joint, as well as the degree of penetration and fusion to the base metal, are determined by means of guided bend tests. These tests are made in a jig.

(b) These test specimens are machined from welded plates, the thickness of which must be within the capacity of the bending jig. The test specimen is placed across the supports of the die which is the lower portion of the jig. The plunger, operated from above by a hydraulic jack or other device, causes the specimen to be forced into and to assure the shape of the die.

(c) To fulfill the requirements of this test, the specimens must bend 180 degrees and, to be accepted as passable, no cracks greater than 1/8 inch (3.2 mm) in any dimension should appear on the surface. The face bend tests are made in the jig with the face of the weld in tension (i.e., on the outside of the bend). The root bend tests are made with the root of the weld in tension (i.e., on outside of the bend).

64. **Free Bend Test**.

(a) The free bend test has been devised to measure the ductility of the weld metal deposited in a weld joint. A test specimen is machined from the welded plate with the weld located.

(b) Each corner lengthwise of the specimen shall be rounded in a radius not exceeding one-tenth of the thickness of the specimen. Tool marks, if any, shall be lengthwise of the specimen. Two scribed lines are placed on the face 1/16 inch (1.6 mm) from the edge of the weld. The distance between these lines is measured in inch and recorded as the initial distance X.

(c) The ends of the test specimen are then bent through angles of about 30 degrees, these bends being approximately one-third of the length from each end. The weld is thus located centrally to ensure that all of the bending occurs in the weld.

(d) The specimen bent initially is then placed in a machine capable of exerting a large compressive force and bent until a crack greater than 1/16 inch (1.6 mm) in any dimension appears on the face of the weld. If no cracks appear, bending is continued until the specimens 1/4 inch (6.4 mm) thick or under can be tested in vise.

(e) Heavier plate is usually tested in a press or bending jig. Whether a vise or other type of compression device is used when making the free bend test, it is advisable to machine the upper and lower contact plates of the bending equipment to present surfaces parallel to the ends of the specimen. This will prevent the specimen from slipping and snapping out of the testing machine as it is bent.

(f) After bending the specimen to the point where the test bend is concluded, the distance between the scribed lines on the specimen is again measured and recorded as the distance Y. To find the percentage of elongation, subtract the initial from the final distance, divide by the initial distance, and multiply by 100.

(g) The usual requirements for passing this test are that the minimum elongation be 15% and that no cracks greater than 1/16 inch (1.6 mm) in any dimension exist on the face of the weld.

(h) The free bend test is being largely replaced by the guided bend test where the required testing equipment is available.

65. **Back Bend Test**. The back bend test is used to determine the quality of the weld metal and the degree of penetration into the root of the Y of the welded butt joint. The specimens used are similar to those required for the free bend test, except they are bent with the root of the weld on the tension side, or outside. The specimens tested are required to bend 90 degrees without breaking apart. This test is being largely replaced by the guided bend test.

66. **Nick Break Test.**

(a) The nick break test has been devised to determine if the weld metal of a welded butt joint has any internal defects, such as slag inclusions, gas pockets, poor fusion, and/ or oxidized or burnt metal. The specimen is obtained from a welded butt joint either by machining or by cutting with an oxyacetylene torch.

(b) Each edge of the weld at the joint is slotted by means of a saw cut through the center. The piece thus prepared is bridged across two steel blocks and stuck with a heavy hammer until the section of the weld between the slots fractures.

(c) The metal thus exposed should be completely fused and free from slag inclusions. The size of any gas pocket must not be greater than 1/16 in. (1.6 mm) across the greater dimension and the number of gas pockets or pores per square inch (64.5 sq mm) should not exceed 6.

(d) Another break test method is used to determine the soundness of fillet welds. This is the fillet weld break test. A force, by means of a press, a testing machine, or blows of a hammer, is applied to the apex of the V shaped specimen until the fillet weld ruptures. The surfaces of the fracture will then be examined for soundness.

67. **Tensile Strength Test.**

(a) This test is used to measure the strength of a welded joint.

(b) The width thickness of the test specimen are measured before testing, and the area in square inch or mm is calculated by multiplying these before testing , and the area in square inch or mm is calculated by multiplying these two figures.

(c) The tensile test specimen is then mounted on a machine that will exert enough pull on the piece to break the specimen. The testing machine may be either stationary or portable type. A machine of the portable type, operating on the hydraulic principle and capable of pulling as well as bending test specimens is to be used.

(d) As the specimen is being tested in this machine, the load in pounds/ kgf is registered on the gauge. In the stationary types, the load applied may be registered on a balancing beam. In either case, the load at the point of breaking is recorded.

(e) The tensile strength, which is defined as stress in psi or kgf/sq. mm, is calculated by dividing the breaking load of the test piece by the original cross section area of the specimen. The usual requirement for the tensile strength of welds is that the specimen shall pull not less than 90 percent of the base metal tensile strength.

(f) The shearing strength of transverse and longitudinal fillet welds is determined by tensile stress on the test specimens. The width of the specimen is measured in inch or mm. The specimen is ruptured under tensile load, and the maximum load in pounds is determined.

(g) The shearing strength of the weld in pounds/inch or kg/mm is determined by dividing the maximum load by the length of fillet weld that ruptured. The shearing strength in psi or kg/sq.mm is obtained by dividing the shearing strength in pounds/inch or kgf/mm by the average throat dimension of the weld in inch or mm. The test specimens are made wider than required and machined down to size.

68. **Hydrostatic Test**. This is a nondestructive test used to check the quality of welds on closed containers such as pressure vessels and tanks. The test usually consists of filling the vessel with water and applying a pressure greater than the working pressure of the vessel. Sometimes, large tanks are filled with water which is not under pressure to detect possible leakage through defective welds. Another method is to test with oil and then steam out the vessel. Back seepage of oil from behind the liner shows up visibly.

69. **Magnetic Particle Test**. This is a test or inspection method used on welds and parts made of magnetic alloy steels. It is applicable only to ferromagnetic materials in which the deposited weld is also ferromagnetic. A strong magnetic field is set up in the piece being inspected by means of high amperage electric currents. A leakage field will be set up by any discontinuity that intercepts this field in the part. Local poles are produced by the leakage field. These poles attract and hold magnetic particles that are placed on the surface for this purpose. The particle pattern produced on the surface indicates the presence of a discontinuity or defect on or close to the surface of the part.

70. **Radiography Test**. This test method is used to reveal the presence and nature of internal defects in a weld, such as cracks, slag, blowholes, and zones where proper fusion is lacking. The radiographic film, when developed, the defects in the metal show up as dark spots and bands, which can be interpreted by an operator experienced in this inspection method.

71. **Fluorescent Dye Penetrant Test**. Fluorescent dye penetrant inspection is a nondestructive test method by means of which cracks, pores, leaks, and other discontinuities can be located in solid materials. It is particularly useful for locating surface defects in nonmagnetic materials such as aluminum, magnesium, and austenitic steel welds and for locating leaks in all types of welds. This method makes use of a water washable, highly fluorescent material that has exceptional penetration qualities. This material is applied to the clean dry surface of the metal to be inspected by brushing, spraying, or dipping. The excess material is removed by rinsing, wiping with clean water-soaked cloths, or by sandblasting. A wet or dry type developer is then applied. Discontinuities in surfaces which have been properly cleaned, treated with the penetrant, rinsed, and treated with developer show brilliant fluorescent indications under black light.

72. **Hardness Tests**.

(a) Hardness may be defined as the ability of a substance to resist indentation or localized displacement. The hardness test usually applied is a nondestructive test, used primarily in the laboratory and not to any great extent in the field. Hardness tests are used as a means of controlling the properties of materials used for specific purposes after the desired hardness has been established for the particular application.

(b) A hardness test is also used to determine the hardness of weld metal. By careful testing of a welded joint, the hard areas can be isolated and the extent of the effect of the welding heat on the properties of the base metal determined.

(c) **File Test**. The simplest method for determining comparative hardness is the file test. It is performed by running a file under manual pressure over the piece being tested. Information may be obtained as to whether the metal tested is harder or softer than the file or other materials that have been given the same treatment.

(d) **Brinell Hardness Test**.

(i) In the Brinell tests, the specimen is mounted on the anvil of the machine and a load of 6620 lb (3003 kg) is applied against a hardened steel ball which is in contact with the surface of the specimen being tested. The steel ball is 0.4 in. (10.2 mm) in diameter. The load is allowed to remain 1/2 minute and is then released, and the depth of the depression made by the ball on the specimen is measured. The resultant Brinell hardness number is obtained by a formula.

(ii) It should be noted that, in order to facilitate the determination of Brinell hardness, the diameter of the depression rather than the depth is actually measured. Charts of Brinell hardness numbers have been prepared for a range of impression diameters. These charts are commonly used to determine Brinell numbers.

(e) **Rockwell Hardness Test**. The principle of the Rockwell tester is essentially the same as the Brinell tester. It differs from the Brinell tester in that a lesser load is impressed on a smaller ball or cone shaped diamond. The depth of the indentation is measured and indicated on a dial attached to the machine. The hardness is expressed in arbitrary figures called "Rockwell numbers." These are prefixed with a letter notation such as "B" or "C" to indicate the size of the ball used, the impressed load, and the scale used in the test.

73. **Magnaflux Test**.

(a) **General**. This is a rapid, non-destructive method of locating defects at or near the surface of steel and its magnetic alloys by means of correct magnetization and the application of ferromagnetic particles.

(b) **Basic Principles**. For all practical purposes, magnaflux inspection may be likened to the use of a magnifying glass. Instead of using a glass, however, a magnetic field and ferromagnetic powders are employed. The method of magnetic particle inspection is based upon two principles: one, that a magnetic field is produced in a piece of metal when an electric current is flowed through or around it; two, that minute poles are set up on the surface of the metal wherever this magnetic field is broken or distorted.

(c) When ferromagnetic particles are brought into the vicinity of a magnetized part, they are strongly attracted by these poles and are held more firmly to them than to the rest of the surface of the part, thereby forming a visible indication.

74. **Eddy Current (Electromagnetic) Testing**. Eddy currents are induced into the conducting test specimen by alternating electromagnetic induction or transformer action. The path of the eddy current is distorted by the presence of a discontinuity. A crack both diverts and crowds eddy currents. In this manner, the apparent impedance of the coil is changed by the presence of the defect. This change can be measured and is used to give an indication of defects or differences in physical, chemical, and metallurgical structure. Subsurface discontinuities may also be detected, but the current falls off with depth.

75. **Acoustic Emission Testing**. Acoustic emission testing consists of the detection of acoustic signals produced by plastic deformation or crack formation during loading. These signals are present in a wide frequency spectrum along with ambient noise from many other sources. Transducers, strategically placed on a structure, are activated by arriving signals. By suitable filtering methods, ambient noise in the composite signal is notably reduced. Any source of significant signals is plotted by triangulation based on the arrival times of these signals at the different transducers.

76. **Ferrite Testing**.

(a) Fully austenitic stainless steel weld deposits have a tendency to develop small fissures even under conditions of minimal restraint. These small fissures tend to be located transverse to the weld fusion line in weld passes and base metal that were reheated to near the melting point of the material by subsequent weld passes. Cracks are clearly injurious defects and cannot be tolerated.

(b) On the other hand, the effect of fissures on weldment performance is less clear, since these micro-fissures are quickly blurted by the very tough austenitic matrix. Fissured weld deposits have performed satisfactorily under very severe conditions. However, a tendency to form fissures generally goes hand-in-hand with a tendency for larger cracking, so it is often desirable to avoid fissure-sensitive weld metals.

(c) The presence of a small fraction of the magnetic delta ferrite phase in an otherwise austenitic (nonmagnetic) weld deposit has an influence in the prevention of both centerline cracking and fissuring. The amount of delta ferrite in as-welded material is largely controlled by a balance in the weld metal composition between the ferrite-promoting elements (chromium, silicon, molybdenum, and columbium are the most common) and the austenite-promoting elements (nickel, manganese, carbon, and nitrogen are the most common).

(d) Excessive delta ferrite, however, can have adverse effects on weld metal properties. The greater the amount of delta ferrite, the lower will be the weld metal ductility and toughness. Delta ferrite is also preferentially attacked in a few corrosive environments, such as urea. In extended exposure to temperatures in the range of 900 to 1700°F (482 to 927°C), ferrite tends to transform in part to a brittle inter-metallic compound that severely embrittles the weldment.

(e) Portable ferrite indicators are designed for on-site use. Ferrite content of the weld deposit may be indicated in percent ferrite and may be bracketed between two values. This provides sufficient control in most applications where minimum ferrite content or a ferrite range is specified.

Weld Procedure Specification (WPS) & Procedure Qualification Record (PQR)

77. Welding requires skill. Determining "how to weld" requires knowledge regarding the materials being welded and welding process, among numerous other factors. Because of huge number of variables involved, the knowledge of the welding engineer and the skill of the welder need to be validated by a series of tests. All this information is documented on Welding Procedure Specification (WPS), Procedure Qualification Record (PQR), Welding Procedure Qualification Record (WPQR), and associated Test Reports.

78. **<u>Welding Procedure Specification (WPS).</u>** A WPS is a document that describes how welding is to be carried out in production. Its purpose is to aid the planning and quality control of the welding operation. They are recommended for all welding operations and most application codes and standards make them mandatory.

79. **<u>Procedure Qualification Record (PQR)</u>**. A PQR is required when it is necessary to demonstrate that your company has the ability to produce welds possessing the correct mechanical and metallurgical properties.

80. **<u>Qualification Procedure</u>**. A welding procedure must be qualified in accordance with the requirements of an appropriate welding procedure standard, such as ASME Sec IX, as follows:-

(a) Produce a welding procedure specification (WPS) as stated above.

(b) Weld a test piece in accordance with the requirements of your specification. The joint set up, welding and visual examination of the completed weld should be witnessed by a certified welding inspector such as an AWS certified CWI or an Inspection Body. The details of the test such as the welding current, pre-heat etc., must be recorded during the test.

(c) Once the welding is complete the test piece must be subject to destructive and non destructive examination as defined by the welding procedure standard. This work must be carried out in a qualified laboratory but the Inspection Body may require witnessing the tests and viewing any radiographs.

(d) If the test is successful the appropriate documents are endorsed by the test body's surveyor.

81. **<u>Information to be Contained in WPS/ PQR</u>**

(a) Sufficient details to enable any competent person to apply the information and produce a weld of acceptable quality. The amount of detail and level of controls specified in a WPS is dependant on the application and criticality of the joint to be welded.

(b) For most applications the information required is generally similar to that recorded on a Procedure Qualification Record (PQR), except that ranges are usually permitted on thicknesses, diameters, welding current, materials, joint types etc..

(c) If a WPS is used in conjunction with an approved procedure qualification record (PQR) then the ranges stated should be in accordance with the approval ranges permitted by the PQR. However careful consideration should be given to the ranges specified to ensure they are achievable, so that these ranges represent good welding practice.

82. **Prequalified WPS**. Some codes, such as AWS D1.1, allow "Prequalified WPS", whereby it is established that the WPS written as per the code will produce welds with correct mechanical and metallurgical properties. It is not necessary to prepare a PQR in such cases. However, the pre-qualified WPS have a specified range of parameters under which the weld must be produced. When welding variables fall outside these ranges, a WPS with supporting PQR must be prepared.

83. **Standard WPS (SWPS).** In an effort to standardize and harmonize the process of WPS approvals, AWS started writing "Standard Welding Procedure Specifications (SWPSs)" with input from the pioneers and experts in the welding industry. An extensive testing program was undertaken, whereby, these SWPSs were then supported by numerous PQRs. When the use of SWPSs is permitted by referencing code section, the firm does not have to perform one or more procedure qualification tests.

84. **Welder Performance Qualification Record (WPQR)**. Once the procedure is approved it is necessary to demonstrate that all welders working to it have the required knowledge and skill to put down a clean sound weld. If the welder has satisfactorily completed the procedure test then he is automatically approved but each additional welder must be approved by completing an approval test to an appropriate standard such as ASME Sec IX as follows:-

(a) Complete a weld test as stated above. The test should simulate production conditions and the welding position should be the position that the production welds are to be made in or one more severe.

(b) For maximum positional approval a pipe inclined at 45 degrees (referred to as the 6G position) approves all positions except vertical down.

(c) Test the completed weld in accordance with the relevant standard to ensure that the weld is clean and fully fused. For a butt weld this is normally a visual examination followed by radiography or bend tests.

(d) Once the test is completed the necessary forms have to be completed by you or the test body and signed by the test body's surveyor. Note that any changes that require a new WPS may also apply to the welders approval, refer to the referencing code/ standard for precise details

85. **AWS Accredited Test Facility (ATF)**. An AWS ATF is a facility which has been accredited by the American Welding Society to perform Welder Tests. Under this program the Welder Performance Qualification Test is witnessed by an authorized CWI of the Accredited Test facility, which then conducts the necessary tests and sends the results to the AWS. If a candidate welder passes the test, a CW (Certified Welder) certificate is then issued directly by the American Welding Society. This program has no prerequisite courses or certifications requirement. This certification will provide the firm and the welders with international recognition.

86. **Acceptance Standards**. In general welds must show a neat workman like appearance. The root must be fully fused along the entire length of the weld, the

profile of the cap should blend in smoothly with the parent material and the weld should be significantly free from imperfections. Reference should be made to the acceptance standard for precise details.

87. **Documentation.** The necessary documents for a successful Welding Program are as follows:-

(a) Welding Procedure Specification (WPS), Procedure Qualification Record (PQR), Independent Laboratory Test Report for the PQR, Welder Performance Qualification Record (WPQR), and Independent Laboratory Test Report for the WPQR; or

(b) Pre-qualified Welding Procedure Specification (Applicable to some Codes only), Welder Performance Qualification Record (WPQR), and Independent Laboratory Test Report for the WPQR; or

(c) Code adopted Standard Welding Procedure Specification (SWPS), Welder Performance Qualification Record (WPQR), and Independent Laboratory Test Report for the WPQR.

88. **Tests for PQR/ WPQR**. The following tests by Independent Test Laboratory may be required on your PQR and WPQR Coupons:-

(a) Weld Visual Examination by a AWS Certified Welding Inspector.

(b) Bend/ Hardness/ Transverse Tensile Test.

(c) All Weld Metal Tensile Test/ Charpy Impact Test.

(d) Weld Metal Chemical Analysis/ Macroetch Test.

(e) Torque Test/ Peel Test/ Nick Break Test.

(f) Radiography/ Ultrasonic/ MPI/ LP Test by at least Level II inspector.

89. **Indian Standards.** Various Indian Standards on welding processes are placed at Annexure.

Annexure to Appendix H
(Refers to Para 89)

INDIAN STANDARDS ON WELDING PROCESSES

1.	812-1957	Glossary of terms relating to welding and cutting of metals
2.	813-1961	Scheme of symbols for welding
3.	1323- 966	Oxy - acetylene welding for structural work in mild steel
4.	3600-1973	Testing of fusion welded joints and weld metal in steel
5.	1278-1972	Filler rods and wire for gas welding
6.	1393-1961	Code of practice for training and testing of Oxy-acetylene welders
7.	818-1968	Code of practice for safety and health requirements in electric and gas welding and cutting operation
8.	5139-1969	Recommended procedure doer repair of grey casting by Oxy-acetylene and manual metal arc welding
9.	4943-1968	Assessment of butt and fillet fusion in steel sheet, plate and pipe
10	3016-1965	Code of practice for fire precaution in welding and cutting operations
11	6016-1982	Hose connections for welding and cutting equipment
12	7653-1975	Manual blow pipes for welding and cutting
13	6409-1971	Code of practice for Oxy-acetylene flame cleaning
14	1323-1966	Code of practice for Oxy- acetylene welding for structure work in mild steel
15	6901-1981	Pressure regulators for gas cylinders used in welding, cutting and related processes
16	2927-1975	Brazing alloys
17	4548-1067	Methods of analysis for copper-gold brazing alloys
18	4354-1967	Methods of chemical analysis of magnesium-aluminium brazing alloys
19	4667-1968	Methods of chemical analysis of silver-copper brazing alloys
20	4703-1968	Methods of chemical analysis of silver-manganese brazing alloys
21	999-1959	Methods of chemical analysis of solder brazing alloys
22	964-1956	Methods of chemical analysis of solder silver
23	193-1977	Soft solder
24	998-1959	Methods of chemical analysis of soft solder
25	7318-1974	Approval tests for welders when welding procedure approval is not required
26	7310-1974	Approval tests for welders working to approved welding procedures
27	7307-1074	Approval tests for welding procedures
28	1179-1967	Equipment for eye and face protection during welding
29	822-1970	Code of procedure for inspection of welds
30	7273-1974	Methods of testing fusion welded joints in aluminium and aluminium alloys
31	4972-1968	Resistance spot-welding electrodes
32	819-1957	Code of practice for resistance spot welding for light assemblies in mild steel
33	1261-1959	Code of practice for seam welding in mild steel
34	3613-1974	Acceptance test for wire flux combination for submerged are
35	8987-1978	welding structure steels

36	5897-1970	Recommended practice for air carbon arc gouging and cutting
		Aluminium and aluminium alloys welding and wires and magnesium
37	7318-1974	alloys welding rods.
38	7310-1974	Approval tests for welders when welding procedure approval is not required
39	7307-1974	Approval tests for welders working to approved welding procedures
40	4943-1968	Approval tests for welding procedures
41	8363-1976	Assessment of butt and fillet fusion welds in steel sheet, plate and pipe
42	5898-1970	Bare wire electrodes for electro slag welding of steels
43	8666-1977	Copper and copper alloy bare solid welding rods and electrodes
44	5856-1970	Copper and copper alloy covered electrodes for manual metal arc welding
45	5206-1969	Corrosion and heat resisting chromium-nickel solid welding rods and bare electrodes
46	5511-1969	Corrosion resisting chromium and chromium-nickel steel covered
47	5462-1969	electrodes for manual metal arc welding
		Covered electrodes for manual metal arc welding of cast iron
48	815-1974	Colour code for identification of covered electrodes for metal arc welding
49	814-1974	Covered electrodes for metal arc welding of structure steels,
50	1179-1967	classification and coding of
51	6916-1973	Covered electrodes for metal arc welding of structure steels
52	3016-1965	Equipment for eye and face protection during welding
53	822-1970	Code of practice for fabrication welding of stéel castings
		Code of practice for fire precautions in welding and cutting
54	823-1964	operations
55	2812-1964	Code of procedure for inspection of welds
		Code of procedure for manual metal arc welding of mild steel
56	2811-1964	Recommendations for manual tungsten inert gas arc- welding of aluminium and aluminium alloys
57	9595-1980	Recommendations for manual tungsten inert gas arc- welding of stainless steel
58	1395-1971	Recommendations for metal arc welding of carbon and carbon manganese steels
59	5857-1970	Molybdenum and chromium molybdenum vanadium low alloy steel
60	6560-1972	electrodes for metal arc welding
		Nickel and nickel alloy care solid welding rods and electrodes
61	8736-1977	Molybdenum and chromium molybdenum low alloy steel electrodes
	5530-1969	for gas shielded arc welding
62		Nickel and nickel alloy covered electrodes for metal arc welding
63	4353-1967	Code of procedure for repair and rectification of steel casting by metal arc welding process
64	7273-1974	Recommendations for submerged arc welding of mild steel and low
	817-1966	alloy steels
65	816-1969	Methods of testing fusion joints in aluminium and aluminium alloys

66	816-1969	Code of practice for training and testing of metal arc welders
67	6227-1971	Code of practice for use of metal arc welding for general construction in mild steel
68	6419-1971	Code of practice for use of metal arc welding in tubular structure Welding rods and bare electrodes for gas shielded arc welded of structural steel

Appendix J
(Refers to Para 1 of Chapter 9)

GUIDELINES FOR PERFORMANCE / VALIDATION TESTS

General

1. The performance and or validation tests conducted on various categories of equipment are significantly exhaustive. Further, a number of tests depend on the intended function of the equipment and therefore will need to be specially derived.

2. Notwithstanding, there are certain tests which will be commonly applicable across all categories of equipment. This chapter aims to enumerate guidelines for such commonly conducted performance / validation tests.

Raw Material Tests

3. Tests for raw material mainly comprises of Chemical and Mechanical Tests. However, the type and extent of test depends on the end use of material. For example, forgings and castings may require microstructure test in addition to routine mechanical tests.

4. All tests are to be conducted as per established international standards. Details of tests and applicable standards are given at **Annexure I**.

NDT Tests

5. NDT tests such as Ultrasonic Examination, Radiography Test, Liquid Penetrant Test, Magnetic Particle Impregnation and Eddy Current test are commonly conducted for Castings, Forgings, Welds and fabricated structures. The guidelines for such tests are given at **Annexure II to VI.**

6. The guidelines only give a broad framework. However the acceptance norms will be as per established international standards such as ASTM, IS etc..

Tests for Fasteners

7. Fasteners form an important part of any equipment. With particular reference to Naval shipbuilding, fasteners form an important shipbuilding component. Therefore there is a requirement to subject the fasteners for various performance tests. Tests for fasteners will be done as per provisions of IS 1367 Parts 1 to 19. Some commonly

conducted tests for fasteners are:-

(a) **Wedge Test.** The wedge tensile strength of a hex or square-head fastener, socket-head cap screw, or stud is the tensile load that the product is capable of sustaining when stressed with a wedge under the head. The purpose of this test is to obtain the tensile strength and to demonstrate the head quality and ductility of the product.

(b) **Axial Load Test.** Axial tension of fasteners are tested in a holder with a load axially applied between the head and a nut or in a suitable fixture.

(c) **Proof Load Test.** Proof Load testing of a nut is assembled on a hardened threaded mandrel or a test bolt using the tension or compression method. A specified proof load is applied for the nut against the nut. The nut should resist this load without stripping or rupture and should be removable form the test bolt or mandrel by hand after the load is released.

(d) **Torque-Tension Tests.** Determination of the torque-tension relationship for a threaded fastener allowing the appropriate tightening torque is to be determined. Such tests will allow the nut factor (sometimes referred to as the torque coefficient or *k* factor) to be determined and the overall coefficient of friction. By completing several similar tests, the variation in the torque-tension relationship, due to friction variation, can be established for an application.

(e) **Friction Determination Tests.** Test fasteners can be mounted in a test rig to allow the thread and head friction torques to be determined. From these results the thread and nut face friction coefficients can be determined. These values are of importance to allow an assessment of what effect various joint surfaces can have on the bolt torque-preload relationship. Such tests can be completed, for example, to assess the effect the introduction of new fastener finishes will have on a joint's performance.

(f) **Torque/Preload to Failure Tests.** Tests can be performed by tightening the fastener to failure. This can be completed on actual assemblies and/or test fixtures to allow torque-angle-force characteristics to be established. From this information torque-angle tightening specifications can be derived allowing accurate controlled tightening to be completed. Such tests can also be used to determine the maximum preload that an assembly will sustain.

(g) **Torque to Yield Tests.** Tests can be performed on actual assemblies to obtain torque-angle graphs that can be used to establish the torque to reach the yield strength of the bolt. Such graphs can be used to establish the appropriate torque-angle specification. They can also be used, with analysis software such as our BOLTCALC program, to assist in assessing the structural integrity of an assembly. The advantage of measuring the applied torque and angle of rotation of the fastener is that tests on the actual joint can be completed without having to change the joint stiffness by introducing a load cell.

(h) **Vibration Loosening Characteristics of Fasteners.** Fasteners coming loose is a common problem across many industries. We can complete an assessment of a fastener's self loosening characteristics using a transverse vibration test machine (often referred to as a Junker machine). The fastener preload decay graphs produced can allow an assessment to be made of a fastener's resistance to self-loosening.

(j) **Coating Thickness Test**. This is to determine the thickness of the coating – phosphating, chromating, electroplating etc..

(k) **Salt Spray Test**. This test is done to determine the effectiveness of the coating. It is specified in terms of hours varying between 48 -72 hours.

(l) **Stress Durability (Hydrogen Embrittlement) Test.**

Environmental Tests

8. Environmental tests is another important aspect of Naval equipment. Environmental tests are mandatory for all equipment – both engineering and electrical.

9. **Marine Engineering Equipment**. Commonly conducted environmental tests for marine engineering equipment are Shock, Noise, Vibration and Tilt tests.

10. **Shock, Noise & Vibration Tests**. Details on these tests are given at **Appendix K.**

11. **Tilt Test.** This test is done to ascertain that the equipment performs satisfactorily when subjected to a permanent tilt of 45 degrees from the horizontal. A test rig is to be setup wherein the equipment is mounted on a base frame tiled at 45 deg from the horizontal and the equipment run at its rated capacity for the duration as specified in the SOTR.

12. **Electrical Equipment**. Environmental tests for electrical equipment are conducted as per the provision contained in Joint Services Specification No 55555 JSS Penta Five). These tests generally cover provisions required for protection against environment variations. The tests to be conducted for each equipment shall be specified in the SOTR. The various types of tests generally conducted on electrical equipment are given below:-

(a) Steady State Acceleration Test.

(b) Acoustic Noise, Shock or Impact, Vibrations.

(c) Altitude, Bounce, Bump, Drop.

(d) Contamination, Acid, Alkaline and Salt Corrosion.

(e) Damp Heat, Drip Proof, Driving Rain, Fine Mist, Dust.

(f) Explosion, High Temperature, Rapid temperature cycling.

(g) Icing, Low Temperature, Immersion, Tropical Exposure.

(h) Mould Growth, Sealing, Solar Radiation, Toppling.

13. **Ingress Protection Test**. All electrical equipment are specified for certain type of Ingress Protection (IP). Conformity of the equipment to IP test is to be ascertained by tests. An IP specification is given in terms of two numerals. The first numeral indicates the size of solid particle the equipment to be insulated against. The second numeral indicates the insulation against various types of fluids. The details of the two numerals are given below:-

(a) **First IP Numeral.**

(i) **0** - Non-protected No special protection

(ii) **1** - Protected against solid objects > than 50 mm (2 in.) A large surface of the body, such as a hand (but no protection against deliberate access). Solid object exceeding 50 mm (2 in.) in diameter.

(iii) **2** - Protected against solid objects greater than 12 mm (0.5 in.) Fingers or similar objects not exceeding 80 mm (3.15 in.) in length. Solid objects exceeding 12 mm (0.5 in.) in diameter.

(iv) **3** - Protected against solid objects greater than 2.5 mm (0.1 in.). Tools, wires, etc. of diameter or thickness greater than 2.5 mm (0.1 in.). Solid objects exceeding 2.5 mm (0.1 in.) in diameter

(v) **4** - Protected against solid objects greater than 1 mm (0.04 in.) Wires or strips of thickness greater than 1 mm (0.04 in.). Solid objects exceeding 1 mm (0.04 in.) in diameter.

(vi) **5** - Dust protected Ingress of dust is not totally prevented, but dust does not enter in sufficient quantity to interfere with satisfactory operation of the equipment.

(vii) **6** - Dust-tight. No ingress of dust.

(b) **Second IP Numeral.**

(i) **0** - Non-protected No special protection.

(ii) **1** - Protected against dripping water. Dripping water (vertically falling drops) is to have no harmful effect.

(iii) **2** - Protected against dripping water when tilted up to 15°. Vertically dripping water is to have no harmful effect when the enclosure is tilted at any angle up to 15° from its normal position.

(iv) **3 -** Protected against spraying water. Water falling as spray at an angle up to 60° from the vertical is to have no harmful effect.

(v) **4** - Protected against splashing water. Water splashed against the enclosure from any direction is to have no harmful effect.

(vi) **5** - Protected against water jets. Water projected by a nozzle against the enclosure from any direction is to have no harmful effect.

(vii) **6 -** Protected against heavy seas. Water from heavy seas or water projected in powerful jets is not to enter the enclosure in harmful quantities.

(viii) **7** - Protected against the effects of immersion. Ingress of water in a harmful quantity is not to be possible when the enclosure is immersed in water under defined conditions of pressure and time.

(ix) **8 -** Protected against submersion. The equipment is suitable for continuous submersion in water under conditions which are to be specified by the manufacturer. **Note** that normally this will mean that the equipment is hermetically sealed. However, with certain types of equipment, it can mean that water can enter but only in such a manner that it produces no harmful effects.

Annexure I
(Refers to Para 4 of Appendix J)

APPROVED TEST METHODS FOR CHEMICAL & MECHANICAL PROPERTIES

Metallographic Tests

1. **Examination of Macro Structure**.

   (a) **Ferrous Alloys**.

      (i) IS: 13015 -1991.

      (ii) ASTM Part 31, E 381.

      (iii) ASME Vol. 8.

   (b) **Metal & Alloys**.

      (i) ASME Vol. 7 and 8.

      (ii) ASTM, Part 31, E 340.

   (c) Reference Book on Practical Microscopic Metallography by Richard Henry Greaves & Harold Wrighton.

2. **Examination of Macrostructure.**

   (a) ASTM Part 31, E -3 – Preparation of Specimens.

   (b) ASME Vol 7.

   (c) Reference Book on Practical Microscopic Metallography by Richard Henry Greaves & Harold Wrighton.

3. **Estimation of Average Grain Size of Metals**.

   (a) IS: 4748-1988 Reaffirmed 2003.

   (b) ASTM Part 31, E-112.

4. **Determination of Inclusion Rating in Steel By Microscopic Method.**

   (a) IS: 4163-1982.

   (b) ASTM Part 31 E-45.

5. **Determination of De-Carburized Depth of steel By Microscopic Method**.

    (a) IS: 6396.

6. **Determination of Case Depth of Steel By Microscopic Method.**

    (a) IS: 6416, Reaffirmed 2003.

7. **Evaluation of Graphite Flakes (Distribution & Size)**.

    (a) IS: 7754, Reaffirmed 2003.

    (b) ASTM Part 31 A -247.

8. **Measurement of Coating Thickness by Microscopic Method**.

    (a) IS: 3203, Reaffirmed 2001.

9. **Mercurous Nitrate Test**.

    (a) IS: 2305, Reaffirmed 1998.

Mechanical Properties

10. **Tensile Test**.

    (a) **Metallic Materials - Tensile Testing at Ambient Temp (III Revision**).

        (i) IS: 1608- 2005.

        (ii) BS: 18-1987.

        (iii) Instruction manual of testing machine.

    (b) **Benchmark Test for Metallic Materials.**

        (i) IS: 1599-1985, Reaffirmed 1996.

11. **Wrapping Test (Metallic Wires)**. IS: 1755, Reaffirmed 2001.

12. **Flattening Test on Metallic Tubes**. IS: 23281983, Reaffirmed 2001.

13. **Drifting Expansion Test -Metallic Tubes**. IS: 2335, Reaffirmed 2001.

14. **Hardness Test - Metallic material (Third Revision).**

    (a) **Brinell Hardness**. IS: 1500-2005 (Third Revision).

(b) **Vickers Hardness**. IS: 1501-2002.

(c) **Rockwell Hardness.** IS: 1586-1988 for scales B & C.

15. **Impact Test (at Ambient Temperature)**.

(a) **Izod Test** . IS: 1598 , Reaffirmed 2003.

(b) **Charpy Test (V-Notch)**. IS: 1757, Reaffirmed 2003.

(c) **Charpy Test (U-Notch)**. IS: 1499, Reaffirmed 2003.

16. **Cupping Test (Metal Sheets /Strips)**. IS: 10175, Part I, Reaffirmed 2003.

17. **Twist Test**. IS:3063-94 & IS: 6735-94 (Not covered under NABL Accreditation)

18. **Permanent Set Test**. IS: 3063-94 & IS: 6735-94 (Not covered under NABL Accreditation)

Chemical Analysis

19. **Iron and Steel**.

(a) **Steel**.

(i) IS 228 Parts 1,2 3,5 & 6, Reaffirmed 2002, Part 7, Reaffirmed 2001, Part 8 & 9, Reaffirmed 2004 and Part 15, Reaffirmed 2004

(ii) Standard Methods of Analysis of Iron., Steel & Ferro Alloys. By Sheffield

(iii) ASTM Part 32

(iv) C & S by LECO - CS – 400

(v) Complete Chemical Analysis by Optical Emission Spectrometer.

(b) **Cast Iron**.

(i) IS 228 Parts 1,2 3,5 & 6, Reaffirmed 2002, Part 7, Reaffirmed 2001, Part 8 & 9 , Reaffirmed 2004 and Part 15, Reaffirmed 2004.

(ii) IS 12308 Part 4, Reaffirmed 1999, Parts 5,6,7,10,11 Reaffirmed 2001.

(iii) C & S by LECO - CS – 400.

(iv) Complete Chemical Analysis by Optical Emission Spectrometer.

20. **Copper and Copper Based Alloys**.

(a) **Copper**.

(i) IS : 7212, Re-affirmed 2005.

(ii) IS : 440, Re-affirmed 2000.

(b) **Brass.**

(i) IS 3885, Reaffirmed 2000.

(ii) ASTM Part 32.

(iii) Indigenous method help from BS 3630 Part 6 1965.

(c) **Bronze.**

(i) IS 4027, Reaffirmed 2000.

(ii) Relevant parts of IS 7212, Reaffirmed 2005.

(iii) IS 440, Reaffirmed 2000.

(iv) ASTM Part 32.

(v) Indigenous method help from BS 3630 Part 6 1965.

(vi) IS 3685, Reffirmed 2000.

(d) **Copper- Nickel Alloys.**

(i) IS: 6517 Part I.

(ii) IS: 7212, Reaffirmed 2005.

(e) Complete Chemical Analysis of Cu based materials by Optical Emission Spectrometer.

(f) Analysis of Copper based alloys by Optical Emission Spectrograph – ASTM part 32, E 115. Comparison with standards of International Traceability.

21. **Aluminium Alloys**.

(a) IS: 504 Part 1 to 12 – 2002 and Part 13 to 16 – 2003.

(b) ASTM Part 32.

(c) Complete chemical analysis of Aluminium base by Optical Emission Spectrometer.

(d) Analysis of Aluminium based alloys by Optical Emission Spectrograph – ASTM Part 32, E 101 and E 115., IS:11035 and IS 7658. Comparison with standards of International Traceability.

22. **Zinc Based Alloys**.

(a) BS 3630 Part 6 / BS EN12441-1:2002.

(b) ASTM Part 32.

(c) Complete chemical analysis of Aluminium base by Optical Emission Spectrometer.

(d) Analysis of Zinc based alloys by Optical Emission Spectrograph – ASTM Part 32, E 115, IS:2599. Comparison with standards of International Traceability.

23. **Mild Steel Tin Coated Plates**. IS:1327, Reaffirmed 2001. Determination of mass coating of Tin coating in gm/ sq. m.

24. **Lead & Tin Based Alloys**. Not covered under NABL accreditation.

Annexure II
(Refers to Para 5 of Appendix J)

GUIDELINES FOR ULTRASONIC EXAMINATION

Purpose

1. Ultrasonic examination is used to detect surface and sub-surface imperfections in welds, cast and wrought materials, brazed pipe joints, and for wall thickness measurement.

2. The effective application of ultrasonic examination may be restricted in materials with inherently high or variable attenuation or which produce severe scattering of the ultrasonic beam. Complex shapes may also limit satisfactory application and the examination should be applied at stages during manufacture when the geometry of the component is relatively simple.

Applicable Standards

3. Relevant sections of BS 3683, Part 4 shall apply.

General Inspection Requirements

4. **Methods**. The methods covered by this specification are basically manual but automatic and mechanically assisted methods should be applied wherever the extent of the examination justifies the initial equipment cost.

5. **Test Procedure**. Examination shall only be performed by qualified personnel in accordance with a IAY/ IAG approved written test procedure.

6. **Qualification Requirements**. Personnel shall be considered qualified when they have demonstrated their ability to meet the requirements of the approved procedure. Personnel shall be conversant with the effects of variations in:-

   (a) Surface condition.

   (b) Material Structure (grain size, attenuation etc.).

   (c) Transducer size and type (compression, shear and surface wave).

   (d) Test frequency.

   (e) Acoustic couplant.

   (f) Method of calibration.

(g) Use of Attenuator.

(h) Display characteristics.

(j) Indication measurement.

7. **Equipment Requirements**. Ultrasonic equipment shall consist of the following:-

(a) Electronic apparatus capable of producing, receiving and displaying high frequency electrical pulses at the required frequencies and energy levels. The display shall include a well defined and permanently marked graticule.

NOTE: For certain applications, a calibrated attenuator is essential.

(b) Probes (Single and Double) capable of transforming electrical impulses into mechanical vibrations at specific frequencies.

(c) Couplant liquid having good wetting properties for the transference of mechanical energy to and from the test surface.

(d) Calibration blocks for the assessment of probe and electronic apparatus characteristics and performance.

(e) Test blocks as aids to interpretation and reproducibility of results.

8. **Equipment Calibration**. Prior to use for production inspection; after maintenance, or at intervals not exceeding one month, the following calibration shall be carried out and the results recorded:-

(a) Using calibration block A2 (BS 2704), check for:-

(i) Time base linearity over the full working range required.

(ii) Probe(s)/ angle(s) of refraction and transmission point(s).

(iii) Beam characteristics, dead zone and resolution.

(b) Using a calibrated attenuator and compression wave probe adjust the equipment sensitivity to display a 20% FSD (Full Screen Deflection) signal from the back wall of the plastic insert with at least 30dB reserve attenuation. Reduce attenuation by 6dB and l2dB and record signal amplitude at each step.

NOTE: For a linear amplifier, the signal amplitudes should be 40% and 80% FSD respectively.

(c) With equipment as sub para (b) above, adjust sensitivity to display a 50% FSD signal from the plastic insert with at least 30 dBs reserve attenuation. This signal shall remain clearly identifiable (approx 5% FSD for linear amplifier) after inserting 20dB attenuation.

(d) When the equipment is not fitted with a calibrated attenuator, checks at sub para (b) and (c) above may be carried out using the calibration block and a compression wave probe 20 to 30 mm dia (or equivalent) as follows:-

(i) Adjust gain to display a 20% FSD peak signal from the 1/32 inch wide slot.

(ii) Record the peak signal amplitudes received from the 1/16 inch and 1/8 inch wide slots without adjusting gain (for a linear amplifier these should be 40% and 80% FSD respectively).

(iii) Adjust gain to display a 50% FSD peak Signal from the 5/16 inch wide slot. Record peak signal amplitude obtained from the 1/32 inch wide slot without adjusting gain (for a linear amplifier this should be approx 5% FSD).

9. **Equipment Qualification**. Equipment shall be considered qualified when records of the calibration in accordance with Para 8 above shows:-

(a) Time base linearity measured between at least 5 multiple echoes is within ± 1%.

(b) Probe indices are accurately marked.

(c) Probe angle of refraction is within ± 1 degree of stipulated angle.

(d) Minimum resolution of compression wave probes complies with BS 2704.

10. For linear amplifiers the signal amplitudes resulting from sub para 8(b) or 8(d) above are within ± 5% of the amplitudes quoted.

NOTE: In the case of non-linear amplifiers the result of calibration shall be referred to IAY/ IAG for approval.

11. The above equipment checks inherently qualify both the probe and electronic equipment. It is essential, therefore, that calibration is carried out for each probe to be used. In addition, any change of the rejection level may very seriously affect the amplifier response and adjustment of the rejection control shall involve re-calibration.

12. **Method of Testing**. The equipment shall always be calibrated to the appropriate reference standards before testing begins. Probe characteristics and movement, as well as signal amplitude, shall be taken into consideration when the significance of defect indications is being assessed. The movement or rotation of

probes shall be maintained at a fairly uniform speed consistent with the repetition rate of the equipment in use; speed during the test shall not exceed that used during calibration. Indications of defects revealed during ultrasonic examination shall be checked, if possible, by the use of another ultrasonic method or by, another non-destructive test method.

13. **Surface Finish**. The surface of the item to be tested shall be clean and free from dirt, loose scale and loose paint. It shall be sufficiently smooth to ensure effective acoustic coupling.

Plate & Sheets

14. **Scope**. The methods described shall be used only for the inspection of plate and sheet of thickness 0.25 inch and greater.

15. **Surface Preparation**. The plate shall be in the pickled, shot or sandblasted condition and the test surface free from loose dirt or any foreign matter which. may interfere with the test. The test surface may have one coat of primer. If necessary the surface shall be smoothed by any suitable mechanical means such as grinding or belt sanding. A thin sheet of varnish impregnated cloth e.g. Empire cloth, between the transducer and plate surface is advantageous in reducing wear on the transducer face and. improving coupling on rough surfaces.

16. **Compression Wave Inspection**.

(a) **Test Frequency**. 2-5 Mc/s transducer size 20-30 mm dia or equivalent.

(b) **Calibration**. Test block(s) shall be prepared from sound material of the same material group (i.e. low alloy steel, austenitic stainless steel, copper nickel, monel etc.) and within + 10% of the thickness to be inspected as per following details :-

(i) For plate material up to and including 1 inch thick a 0.25 inch dia flat bottom hole shall be drilled from one plate surface to a depth of half the test block thickness.

(ii) For thickness over 1 inch, two or more similar 0.25 inch dia holes shall be drilled to depths of 0.5 inch from each surface and not greater than 1 inch difference in hole depths i.e.:-

(aa) 2 holes minimum at 2 inch thick, 0.5 inch and 1.5 inch deep respectively.

(ab) 3 holes minimum at 3 inch thick, 2.5 inch, 1.5 inch and 0.5 inch deep respectively.

(iii) The equipment shall be calibrated and the graticule marked to show the nominal plate thickness.

(iv) Using a calibrated attenuator, adjust the instrument sensitivity to display a 20% FSD echo from the least detectable hole in the test block maintaining the same gain and a 20% FSD echo. Record the attenuator settings for the first back wall echo from the test block, the plate to be inspected and the remaining holes in the test block. For example, assuming the least detectable hole is 2 inch below the test surface:-

Attenuator reading for this	Hole	> A dB
-do-	Hole 1.5 in below surface	> B dB
-do-	Test block back wall	> C dB
-do-	Plate	> D dB

Minimum search sensitivity = D - (C-A) dB.

(v) Assessment of defect significance shall be made relative to the depth of the indication below the test surface.

NOTE: Where the amplitude of the first back wall echo is reduced to 20% FSD or less unaccompanied by evidence of laminar inclusions the plate surfaces must be checked and dressed if necessary to ensure adequate acoustic coupling.

(c) **Method of Examination**. Each plate shall be marked on one major surface with grid lines normal to the direction of rolling. and separated by not more than 5% of the plate width OR 90% of the transducer diameter whichever is greater. Each grid line shall be scanned and the length of any interception which indicates a lamination or causes complete attenuation of the third bottom echo shall be recorded and marked on the plate. Any such areas shall be scanned in width to determine the full extent of the cause of the attenuation. In addition each edge of the plate shall be similarly scanned along a parallel track not exceeding 2 inch from the edge unless included in the grid pattern.

Shear Wave Inspection (Where Specified)

17. **Calibration**. Shear wave inspection shall be performed to a 3% of plate thickness or 0.004 inch notch sensitivity whichever is the greater. Using any suitable means, a calibration reference notch as shown in the Table given below shall be formed in the surface of the plate being inspected. The choice between a ' V ' or a Square notch shall be at the discretion of the testing organization. The notch shall be located so that reflections from it cannot be confused with those from the plate boundaries. Any upset metal adjacent to the notch shall be removed. Instrument calibration shall be carried out using a .shear wave probe of suitable angle and frequency. The time base of the cathode ray tube shall be calibrated by obtaining

peak amplitude reflections from the notch both from the opposing surface and from the surface containing the notch (1st bounce). The instrument sensitivity for testing shall be such that the minimum signal amplitude from the reference notch is 20% full screen deflection.

Parameter	**V or V-NOTCH**	**SQUARE NOTCH**
Depth (%ge of plate thickness or inch)	3% or 0.004 inch	3% or 0.004 inch
Width	300 included angle	2 x depth
Length	Approximately 1.5 inch	Approximately 1.5 inch

18. **Method of Examination**. Shear wave testing shall be performed by scanning one major surface in two directions, causing the sound beam to travel both parallel to and perpendicular to the longitudinal axis or to the direction of rolling of the plate. The probe unit shall be moved in parallel paths. If a defect indication is obtained which approaches in amplitude that, of the reference notch, the adjacent area shall be scanned by the continuous scanning method, indexing approximately 90% of the width of the transducer, sufficiently to establish the size and location of the discontinuity.

19. **Recording**. The following information shall be recorded in addition to the test procedure:-

(a) Location and size of any lamination.

(b) Location and size of any area where the 1st back wall echo is attenuated to 20% FSD or less after plate surface preparation.

(c) Location and size (signal amplitude and probe movement) of laminar inclusions having a reflectivity in excess of the equivalent depth 0.25 inch dia hole.

(d) When using shear waves, the location and signal amplitude *of* any indication above the reference level as indicated at paragraph 17 above.

20. **Extension of Test**. Detection of a lamination or area of attenuation wholly contained within a 3 inch diameter circle shall require 100% check on the adjacent plate within 24 inch of the defect and recording as above. Detection of a laminar inclusion shall require 100% check on the adjacent plate within 12 inch of the defect and recording as above.

Plate Thickness Measurement

21. **Calibration**. Using a test block containing the permitted thickness tolerances allowed by the relevant material specification adjust the time base to show at least two multiple echoes from the full plate thickness and mark the

permitted limits on the graticule. Where a specially designed ultrasonic thickness gauge is used, the meter read out shall be similarly marked. Where no meter read out is available, the thickness limits derived from the test block shall be recorded.

22. **Method of Examination**. Plate thickness measurements shall be taken in accordance with DG Ships 137. Where plate is also examined in accordance with paragraph 16 above, plate thickness measurements shall be made on the grid lines at not greater than 24 inch intervals.

Butt Welds

23. **Scope**. The application of ultrasonic methods to the inspection of butt welds is influenced by the types of materials in use, their thickness and geometry and the required flaw sensitivity. The influence of the structure in the weld and in the heat affected zone may restrict application, and modified probes may be essential where testing is carried out on materials which have different velocities from those for which commercially available probes are normally designed.

24. **Probes**. The following shear wave probes in Table below are recommended for the initial inspection:-

Angle of Refraction	Material Thickness (T)	Probe Type
70 – 80 deg	0.2 inch to 0.6 inch	Single or combined double
60 – 70 deg	0.5 inch to 1.5 inch	
45 – 60 deg 45 deg	1.5 inch to 2.5 inch Over 2.5 inch	Single and separate transmitter and receiver for welds over 2 inch thick

NOTE: In selecting a probe angle, it must be remembered that a beam incident on a reflecting surface at 300 deg will result in mode conversion and in a loss of shear wave energy up to 20 dB. Assessment of defect severity and type can be frequently assisted by using alternate probe angles after the initial detection or alternative methods of NDT.

25. **Surface Preparation**. Test surfaces shall be free from loose scale, weld spatter and other foreign matter which could interfere with the ultrasonic inspection. Preparation of the weld surfaces is usually unnecessary when the surface condition (overfill, undercut etc.) complies with established industry practices. Where excessive noise is reflected from the welded surface, local preparation shall be carried out to reduce the noise to a level consistent with accurate interpretation.

26. **Calibration**. Mark the graticule to show 20% FSD and 20% FSD minus 12 dB in accordance with paragraph 8(b) or (d). Where U/T equipment is fitted with a calibrated attenuator, test sensitivities may be pre-determined from machined test

pieces. Provision shall be made for frequently checking the sensitivity during inspection, e.g. by relating plate response with a vertical probe to the shear wave test sensitivity. Positive probe identification shall be included in procedure submissions. Where U/T equipment is not fitted with a calibrated attenuator the following procedure shall apply:-

(a) For welds up to and including 1.5 inch thick, a test block consisting of a plate at least 3 inch wide and of similar material thickness contour and surface condition to the material to be tested, shall be used. A reference hole shall be drilled situated on the centre line at least 4 inch from one end. The hole diameter shall be as follows:-

Thickness	**Hole Diameter**
Up to and including 0.75 inch	1/16 inch
Over 0.75 inch up to and including 1.5 inch	1/8 inch

(b) The instrument shall be calibrated to show a minimum corner reflection from the holes of 20% full-scale deflection from each surface of the plate.

(c) For welds over 1.5 inch thick, reference notches in accordance with the dimensions given in paragraph 17 above shall be used for instrument calibration.

27. **Method of Examination**. Plate material adjacent to the, weld through which the shear wave must pass shall be inspected in accordance with paragraph 15 & 16 above and any defective areas recorded. Scanning shall be carried out from both sides of the weld on one plate surface. Signal amplitude, location in the weld and probe movement and position shall be taken into consideration in assessing defects as follows :-

(a) **Welds <= 1.5 inch Thick**. Shear wave inspection shall be carried out in a series of scanning movements parallel with the weld at intervals not exceeding 60% of the transducer diameter or length. Alternatively the probe may be oscillated to and from the weld and progressed along the weld at intervals not exceeding the diameter or width of the transducer. The probe system shall be directed normal to the weld centre line, preferably by mechanical means.

(b) **Welds > 2 inch Thick**. Scanning shall be carried out in two stages, first using a single or combined transducer as for thinner materials and then using separate transmitter and receiver probes in tandem, preferably in a mechanically linked system so that the receiver moves towards the welds at the same rate as the transmitter moved away from it.

(c) **Transverse Defects**. For transverse defects, irrespective of thickness, direct inspection from the weld surface is preferred. Where necessary surface preparation cannot be achieved, separation transmitter and receiver probes shall be employed in a mechanical guided straddle scan.

(d) Operators shall at all times be capable of demonstrating that the inspection is in accordance with the approved procedure.

28. **Recording**. Records of indications should be sufficiently detailed.

Tee & Butt Welds

29. **Scope.** Ultrasonic inspection is applied to tee-butt welds for the detection of weld defects, plate defects in the vicinity of the weld etc.. The latter may include defects of laminar form and cracks orientated at an angle with the plate surface. Thus both compression and shear wave techniques are necessary for a complete inspection.

30. **Definitions**. To adequately cover Navy requirements, two types of inspections are defined as follows:-

(a) Type A - Complete examination using compression and shear waves.

(b) Type B - Partial examination using compression waves only. (This application is usually adequate for table-web connections of fabricated frames).

Reference is made to signal amplitudes DL and SL defined as follows:-

DL = 20% FSD signal from the relevant test block target.
SL = DL minus 6 dB in accordance with paragraph 8 (b) or (d) above as applicable.

31. **Surface Preparation**. The test surface shall be free from loose scale and any loose foreign matter which could interfere with the test. Shot blasted surfaces covered with a thin coating of spray primer are usually satisfactory, but any successive layers of paint must be removed and the test surface lightly disc or belt sanded for reproducible results.

32. **Test Blocks**. Two test blocks are required for calibration. The test block thickness shall be within ± 20% of the thickness of the continuous member of the tee butt joint. Suitable test blocks are to be used for both Type A & B examinations.

33. **Probes**.

(a) **Compression Wave**. Test frequency 4 to 6 Mc/s combined double probe. Transducer size should not be less than 50 sq. mm.

Note: This type of probe is subject to varying response with probe orientation for certain types of defect. To obviate this feature all measurements shall be made with the acoustic baffle of the probe at 90 deg to the line of the slots in test block and the weld during inspection.

(b) **Shear Wave**. Test frequency 2 to 4 Mc/s, single or combined double and Transducer size not less than 70 sq. mm. Angle of refraction should be 45 $\pm$ 1 deg.

Note: Angles of refraction greater than 45 deg may be necessary when the continuous member of the joint is less than 1 inch thick.

34. **Calibration.**

(a) **Vertical Probe (All Equipment)**. From test block, obtain a 15 to 20 % full screen deflection signal (hereinafter to as DL) from the flat bottom hole. Using this sensitivity (DL) record the maximum signal amplitude from slots in the test block.

NOTE: Signal amplitudes must not exceed 80% full screen deflection. The number of slots measurable within this limit will depend on the dynamic range of equipment being calibrated.

(b) **Equipment with Attenuator**. From DL sensitivity reduce attenuation by 6 dB's record and mark the new signal amplitude (hereinafter referred to as SL) i.e - 6 dB line.

(c) **Equipment Without Attenuator**. From DL sensitivity add the difference in signal amplitude previously recorded from the 1/32 inch and 1/16 inch slots to obtain SL (- 6 dB line).

35. **Time Base Calibration (Using Test Blocks).**

(a) **Vertical Probe**. Accurately adjust time base to include the continuous members and weld with the probe contact face at zero.

(b) **Shear Wave Probes**. Similar to vertical probe, record horizontal displacement of probe index from the hole.

36. **Search Sensitivities**.

(a) **Vertical Probe (With Attenuator)**.

(i) Using test block, obtain DL first bottom echo from an un-drilled part of test block, attenuation = A.

(ii) Adjust attenuation to obtain DL from the flat bottom hole, attenuation = B.

(iii) Obtain DL first bottom echo from hull plate, attenuation = C.

(iv) Search sensitivity = C - (A - B).

(b) **Shear Wave Probe (With Attenuator)**.

(i) Using test block obtain DL from appropriate corner reflection (direct or first bounce depending on technique) from the reference hole, attenuation = D.

(ii) Search sensitivity = D - (A - C).

(c) **Shear Wave Probe (Without Attenuator)**. Difference in couplant and plate surface cannot be accurately measured. Using the procedure as given at paragraph 8 (a) above and adjusting gain control for the difference between DL plate echo, and DL test block echo, a satisfactory test can be carried out.

37. **Plotting Weld Width**. Using vertical probe, adjust first bottom echo from adjacent hull plate to SL. Plot weld edge at probe datum position when echo is reduced to DL; at intervals not exceeding 2 x T, where T is thickness of the joining member.

38. **Search Scanning - Compression and Shear Wave**. A rectilinear scanning pattern shall be employed, with sufficient traverse to ensure complete examination of the weld, and associated parent plate. Forward progression shall not exceed one transducer width or diameter per traverse.

39. **Defect Indication Measurement**.

(a) **Vertical Probe**. For signals between DL and 80% full screen deflection assess flaw width relative to previously marked amplitude from test block slots (paragraph 8(b) or (d)) For signals in excess of 80% full screen deflection, reduce peak signal amplitude to SL and record widths when signals reduce to DL as for weld edges (paragraph 37 above).

(b) **Shear Wave Probes**. Record signal amplitude of indications above DL.

40. **Recording**. Disregard indications below DL. Records of indications should be sufficiently detailed.

Overlay Cladding

41. **Scope**. The following requirements apply to the ultrasonic inspection of the bond between weld deposited overlay cladding and the base material. Specific requirements due to special shapes or manufacturing processes will be given in the appropriate specifications or weld procedures.

42. **Surface Preparation**. The test surface and the reflecting surface shall be free from loose scale, machining and grinding particles and other loose foreign matter. Surfaces up to 250 micro-inch and free from burrs shall be acceptable provided that the required sensitivity levels can be achieved. Surfaces shall be

sufficiently free from waviness to permit a uniform test over the required area. When inadequate sound transmission is experienced, the test surface or reflecting surface shall be considered suspect until determined otherwise.

43. **Calibration**.

(a) The calibration block shall be prepared by weld depositing cladding metal, using the same welding procedure to obtain cladding of the same approximate thickness and surface finish as the cladding to be inspected, on to a block of the same material as the base material.

(b) A 1/8 inch diameter flat bottomed hole shall be drilled through the base material so that the bottom of the hole lies in the junction of the cladding and base material. The base material should be approximately 1 inch thick. The instrument shall be calibrated to show a 20% FSD signal from the 1/8 inch diameter target.

44. **Method of Examination**.

(a) **General**. Scanning shall be performed manually or automatically by moving the probe in a directed path or by moving the material in a directed path with the probe stationary. Scanning shall be performed at a uniform speed determined during calibration. Where a parallel back wall can be used to obtain a back reflection, the instrument gain shall be increased if necessary to show the back reflection and thus ensure adequate coupling. Defect indications in the cladding shall be compared with the reference standards for assessment.

(b) **Procedure Tests & Hand Deposited Cladding**. Hand deposited cladding shall be examined over the entire surface area. Adjacent scans shall be separated by approximately 80% of the crystal width to ensure adequate overlap.

(c) **Machine Deposited Cladding**. Machine deposited cladding shall be examined along grid lines spaced at 2 inch intervals and normal to the direction of the welding. In addition to grid scanning, continuous scanning shall be applied to penetrations, including edges, to ensure that there are no defects within 2 inch of the edge of the penetrations, and to an area with a minimum radius of 6 inch around any significant defect.

45. **Recording**. When indications in excess of reference standards occur, the material shall be appropriately marked and each defect shall be explored ultra-sonically to determine its size.

Brazed Pipe Joints

46. **Scope**. Ultrasonic inspection is applied to assess the area of bond between the pipe wall and fitting.

47. **Surface Preparation**. Fittings should preferably be machined to provide a concentric uniform surface finish in way of the joint socket. Where machining is impracticable, filing, disc sanding etc. may be essential to provide a satisfactory surface for the ultrasonic inspection.

48. **Calibration**. Using sample joints (brazed/ un-brazed) or a test piece prepared from similar materials adjust the time base and mark the graticule to show:-

(a) The combined pipe and fitting thickness.

(b) The fitting thickness in way of the joint.

(c) The spelter ring groove depth (if fitted).

(d) Adjust sensitivity to obtain a FSD signal from the pipe bore as sub para (a) above.

49. **Method of Inspection**. Apply a band of removable adhesive tape to the pipe adjacent to the fitting. Mark off equal increments not exceeding 1 inch in length in a clockwise direction as viewed facing the fitting from the pipe. Permanently mark the 12 o'clock position on fitting and tape and mark the latter with the number of scans. For fittings with insert grooves*l* scan each land separately with sufficient scans to ensure complete coverage. Fittings without insert grooves shall be scanned as for a single land. .

50. **Recording**. Mark on the tape:-

(a) The extent and percentage of bond for each scan on each land.

(b) Any part-of the joint where lack of access or fitting material prevents satisfactory examination.

Pipes & Tubes

51. **Scope**. Pipe and tube shall be tested for transverse and longitudinal discontinuities.

52. **Calibration**.

(a) As a calibration standard, a convenient length of pipe or tube of same dimensions and type of material to be tested shall be selected. For transverse type defects an internal and external notch shall be cut in accordance with the dimensions given in paragraph 17 above except that the notch may extend wholly around one circumference. The position of the 3% or 0.004 inch depth shall be marked on the reference standard. The notches shall be separated by at least 1.5 inch and shall be located to permit calibration when the probe is situated between the pipe end and the nearest notch.

(b) For longitudinal type defects an internal and external notch shall be cut in accordance with the dimensions given in paragraph 17 above parallel with the pipe axis. The notches shall be separated by at least 1 inch along the length of the pipe. Each notch shall be clearly identifiable on the cathode ray tube display.

53. **Method of Examination.** The shear waves shall be directed into the pipe wall and the pipe scanned longitudinally by advancing the probe assembly as the pipe is rotated. The longitudinal movement of the probe shall be such that the entire area of the pipe wall is examined. Scanning may also be performed by rotating the part and automatically indexing the probe assembly so that a. crystal overlap of at least 10% is obtained on each successive pass. When performing the test by the immersion method, care shall be taken to maintain accurate alignment of the probe assembly with respect to the tube.

54. **Recording**. The location extent and signal amplitude shall be recorded for all indications in excess of the appropriate sensitivity level.

Pipe Thickness Measurement

55. **Calibration**. (see also paragraph 21 above). The instrument shall be calibrated on a section of pipe of the same material and diameter as that being inspected. An area of the pipe wall shall be ground to the minimum acceptable wall thickness.

56. **Method of Examination**. Variations in pipe wall dimensions shall be inspected by a longitudinal wave technique. The frequency and transducer size used shall be compatible with the material and thickness inspected. Each pipe shall be placed on suitable rollers and rotated as the search is conducted. Each end shall be examined by turning the pipe through full revolution with the transducer at the end. Additional scans shall then be made at intervals not exceeding 3 feet along the entire length of the pipe. Areas where the wall thickness approaches minimum tolerances shall be subjected to a more complete search.

Forgings Including Forged, Extruded and Wrought Bars

57. **Scope.** The wide variety of forgings in respect of materials, sizes and geometry required by Navy precludes laying down rigid ultrasonic inspection procedure for general application. Specific procedures must take into account the method of manufacture, type, location and probable distribution of defects likely to be present. Diagnosis of ultrasonic indications in thick sections demands an accurate knowledge of probe characteristics.

58. **Test Procedure**. BS 4124 Part I shall apply for steel forgings (excluding austenitic). For forgings to which BS 4124 Part 1 cannot be applied and extruded/ wrought bars, the Surface Finish will be as per provisions contained in BS 4124 Part 1 clause 6.

59. **Calibration**. Sensitivity of the instrument shall be adjusted until the indication from the least apparent flat bottomed hole in the reference standard occupies at least 20% screen height and not more than 75% screen height. Sensitivity shall then be adjusted to give the same number of back reflections from the forging as are obtained from the reference standard.

60. **Method of Examination**. Whenever possible, forgings shall be examined from surfaces so arranged that three major planes are covered. Suspect areas disclosed under these conditions shall be further evaluated from the side opposite to that from which the original inspection was carried out. Unless otherwise specified the search unit shall be moved in parallel paths so that each path shall overlap the previous and adjacent paths by 10% of the width of the transducer. The size and location of all indications equal to or greater than those obtained from the reference standard holes during calibration shall be marked as the test progresses. This procedure shall be repeated for all surfaces inspected.

61. **Marking Defects**. The location of all defects causing reflectivity which exceeds that of the holes in the reference standard shall be marked as the test progresses.

Castings

62. **Scope**.

(a) Ultrasonic inspection can be applied for the examination of ferrite steel and certain non-ferrous castings. Techniques must be capable of assessing defects to the requirements of stated in Appendix G and not result in a lowering of the acceptance standard nor lead to substantial increase in the number of repairs.

(b) The requirement, therefore, to discriminate between defect types and varying degrees of defect severity demands a most exacting ultrasonic technique. In addition, casting geometry, surface .condition and type of material may preclude the useful and economical use of ultrasonic inspection.

(c) In view of the above, Navy will require radiographic confirmation of the validity of ultrasonic test procedures in selected areas of castings where both inspection methods can be usefully employed.

63. **Recommendations**.

(a) The use of shear and compression waves will assist defect assessment.

(b) The best near zone resolution is obtained using 'combined double' type compression wave probes. This is particularly valuable in areas for sub-sequent machining.

(c) Search sensitivities should be as high as possible before the material grain reflection becomes unacceptable. The procedure should relate sensitivity to the number and amplitude of reflection from the plastic insert or 100 mm radius of the BS 2704 A2 calibration block.

(d) Flaw assessment may necessarily combine amplitude and attenuation methods for different flaw types. Both methods require the use of a calibrated attenuator.

Annexure III
(Refers to Para 5 of Appendix J)

RADIOGRAPHY TEST

Definitions

1. BS 3683, Part 3 shall apply, together with the following additional definitions:-

(a) **Material Thickness**. The thickness of material shall not exceed the finished dimensions for the part by more than 20% or 0.25 inch whichever is the greater subject to no change of type of radiation source.

NOTE: Thickness of welded joints shall conform with the requirements of DG SHIPS/G/I0000, Section 2.

(b) **Multiple Film Technique**. A procedure in which two or more films of the same or different speed with the relevant intensifying screens are used in the same film holder.

(c) **Maximum Effective Radiation Source Dimension**. The maximum source of focal dimension projected on the centre of the radiographic film. For example, a cylindrical isotope source whose length is greater than its diameter will have a greater effective radiation source dimension when orientated coaxially in the centre of a pipe for a panoramic exposure than when the axis of the source is positioned at right angles to the pipe. Similarly, for a focal spot projected as a square image, the diagonal of the square shall be used for calculation.

General Inspection Requirements

2. **Applicability & Methods**. The requirements of this specification shall apply to all items for which the specifications, drawings, or refit/repair instructions call for radiographic inspection and shall include the use of the following radiation sources:-

(a) X-ray equipment.

(b) Thulium 170.

(c) Iridium 192.

(d) Cesium 137.

(e) Cobalt 60.

Use of any other source shall be with written approval of IAY only.

3. **<u>Extent of Radiographic Inspection</u>**. The requirements shall include the number of areas and items to be radiographed, the point in fabrication when radiography shall be performed, the quality level of inspection and the acceptance standard to be applied.

4. **<u>Radiographic Procedure Approval</u>**. IAY/IAG approval of radiographic procedures, including film processing procedures, shall be obtained before the testing agency is permitted to perform radiographic inspection of production components. Radiographic and film processing procedures form a part of the standard procedure approval.

5. **<u>Information Required for Radiographic Procedure Approval</u>**. The testing agency shall submit to the IAY/ IAG production radiographs of items of material and thickness equivalent to that for which approval is sought. Butt welds shall qualify the radiographic procedure for all butt welds within the thickness range shown in Table 1 (given at end of this Annexure). The following information shall be forwarded with sample radiographs:-

(a) The type and thickness range(s) of material to be qualified.

(b) The radiation sources to be qualified (i.e. types of Isotopes & X-ray kilo-voltage rating).

(c) All variables of the proposed radiographic procedure shall be recorded and shall include at least the following information:-

(i) **<u>X-ray Equipment Information</u>**.

(aa) Model and type.

(ab) Manufacturer.

(ac) Focal spot size.

(ad) Focusing current.

(ii) **<u>Isotope source information</u>**.

(aa) Type of Isotope.

(ab) Source Strength.

(ac) Source dimensions.

(iii) Film type.

(iv) Source-to-film distance.

(v) Thickness and type of material radiographed.

(vi) Kilo-voltage and tube current.

(vii) Number of films in cassette.

(viii) Type and thickness of intensifying screens.

(ix) Blocking or masking techniques.

(x) Time of exposure.

(xi) Processing technique.

(xii) Radiographer credentials.

6. **Re-qualification of Radiographic Procedure**. The radiographic procedure shall be re-qualified as follows:-

(a) When the IAY/ IAG has reason to believe that the testing agency cannot meet the required radiographic quality levels in production radiography using a previously approved procedure, the testing agency shall undergo fresh qualification of the affected procedure.

(b) When an isotope source of larger physical size, or X-ray tube with a focal spot size, larger than that used in the approved procedure will affect the final intended purpose. However, a larger radiation source may be used if the source distance is increased as shown in **Table 4.**

(c) When there is a change in the type of isotope source used.

(d) When there is a change in the type of X-ray equipment used.

(e) When the X-ray equipment voltage is greater than that used during initial qualification. However if the voltage used during initial qualification lies within the acceptable region any voltage up to the maximum permissible voltage line may be employed without re-qualifying.

(f) When there is a change in type of film.

(g) When there is a reduction of source-to-film distance beyond the minimum distance used in the approved procedure. However re-qualification is not required if the source-to-film distance is maintained within the limits shown in Table 4; nor is re-qualification required even though inaccessibility prevents compliance with Table 4 or the qualified procedure provided that the IAG representative verifies that the greatest possible source-to-film distance is used and that the radiographic record shows that accessibility limits the source-to-film distance and indicates the actual source-to-film distance used.

(h) When there is an increase in the thickness of intensifying screens beyond the thickness qualified. However, re-qualification is not required if the thickness of intensifying screens is in accordance with Table 2.

(j) When there is a change in the type of intensifying screen material used.

(k) Copies of radiographic procedures shall be made available to the IAY/ IAG.

7. **Radiographic Equipment Qualification**. The adequacy of radiographic test equipment and materials is determined by the successful completion of the procedure approval tests. However all radiographic test equipment previously used for the procedure approval tests shall, in the hands of qualified operator, be capable of consistently, obtaining results of the specified quality levels.

Technique Requirements for Radiography

8. **Direction of Radiation**. Unless otherwise specified the radiation beam shall be directed perpendicular towards the centre of the effective area.

9. **Radiographic Quality Level**. Radiography shall be performed with a technique which will distinguish the applicable Image Quality Indicators (IQI). Radiography quality level shall be determined by using one or more of the IQI's. Unless otherwise specified, 2% IQI sensitivity shall be used as a standard for evaluating radiograph quality for materials up to and including 2 inch thick, and 1% for greater than 2 inch thickness.

10. **Screens, Filters and Masking**. All radiographs produced, with a source of 120 kV or greater shall employ front and back lead .screens in accordance with Table 2.

11. **Films.** Radiographs shall be made on fine grain or extra-fine grain, high contrast, safety base film whenever radio-isotopes are used.

12. **Film Quality**. Radiographs presented for interpretation shall be free from blemishes or film defects which might mask, or be confused with, defects in the material being examined. If doubt exists concerning the true nature of an indication on the film, the radiograph shall be rejected. Typical blemishes are as follows: -

(a) Fogging caused by light leaks in the processing room or cassettes or by defective safelights. Exposure marks caused by improper processing or old film.

(b) Mechanical processing defects such as streaking, air bells or water marks, or chemical stains.

(c) Pressure or lead marks, scratches, gouges, finger marks, crimp marks or static electricity marks.

(d) Loss of detail caused by poor film-to-screen contact in localized areas.

13. **Film Density.** The density of individual films shall be between 2.0 and 3.0 in the area being examined. When the thickness of the part varies considerably in the area under examination, the two films, either of equal or of different speed as employed during procedure qualification, may be exposed simultaneously in the same film holder and the resultant radiographs mat be submitted for interpretation as single film.

NOTE: Densities in excess of 3.0 may be used where adequate viewing conditions are available.

14. **Image Quality**.

(a) All radiographs used as the basis of acceptance shall be of the specified radiographic quality level. The image quality level of radiographs shall not be determined by the image of the wires in the IQI alone, but shall include control of the essential elements of the radiographic procedure within the limitations established by the testing agency at the time it obtains radiographic procedure approval.

(b) If any radiograph presented for interpretation indicates that the procedure used was not in accordance with the above, IAY/ IAG may require that an additional trial radiograph be exposed using a procedure, selected by the testing agency, which meets the minimum requirements of its radiographic procedure approval.

(c) If a significant improvement in image quality is noted, the IAY/IAG may require that other radiographs, which were produced by the same procedure as the questionable film, be re-radiographed using a procedure which is within the limits established during qualification.

15. **Multiple Film Technique**. Film techniques with two or more films of the same or different speeds in the same film holder shall be permitted provided that the applicable radiographic quality level for a specific area is demonstrated.

16. **Film-less Techniques**. The use of film-less techniques shall be limited to In-process Inspection and shall be subject to the approval of the IAY/IAG .

Radiation Sources

17. X-ray and Gamma-ray sources to be used in accordance with established/ stipulated specimen thicknesses as per international standards for optimum radiographic results. Deviations from the recommended values will be permitted as indicated in the notes referring to Table 1.

Source to Film Distance

18. Recommended minimum source-to-film distances are shown in Table 4. The film shall be located as close to the object being examined as possible.

Radiographic Location Markers

19. The image of the location markers used to co-ordinate the part with the film shall appear on the film so that it is evident that complete coverage was obtained without interfering with the interpretation. These marker positions shall be marked on the part and maintained on the part during radiography. When radiographing a weld whenever possible the edge of the image of the location marker shall be 1 inch from the edge of the weld.

Film Identification

20. A system of positive identification of the film and IQI should be provided. The following information shall appear on each radiograph or in the records accompanying each radiograph:-

(a) Identification of the testing agency making the radiograph.

(b) Date of exposure.

(c) Identification of the part, component or system and, where applicable, the weld joint in the part, component or system.

(d) Whether the radiograph is of the original area or a repair area.

Storage of Radiographs and Radiographic Records

21. Radiographs shall be retained for seven years after completion of the contract. Where work is performed under continuing contracts, or on other than contractual basis, these records shall be retained for seven years from the date the work was performed. At the end of the seven years period the testing agency shall request instructions from the IAY/IAG as to whether the records shall be destroyed, forwarded to the IAY/IAG or retained by the testing agency for a longer period agreed upon by the testing agency and the IAY/IAG. Complete records of the technique details, including radiographic inspection location sketches, evaluation and disposition sheet shall be retained for the same period as the radiographs to which they apply.

22. When the firm subcontracts work which requires radiography to be performed by the subcontractor, the subcontractor shall make available to the installing Shipbuilder or private contractor the necessary radiographic records so that they may be retained for the specific period.

Dark Room Facilities

23. Darkroom facilities, including equipment and materials, shall be capable of producing uniform, blemish-free radiographs. Processing logs shall be maintained for the purpose of assuring control of the life and quality of the photographic solutions.

Film Viewing Facilities

24. Viewing facilities shall be constructed to afford the exclusion of objectionable background lighting of an intensity that may cause reflection on the radiographs.

25. Equipment used for radiographic interpretation shall provide the following minimum features:-

(a) A suitably controlled light source of sufficient intensity to allow the selection of optimum intensities for viewing film densities specified in paragraph 13 above. The required intensity range may be provided by use of a separate high intensity viewing port. The light enclosure shall be designed to provide a uniform level of illumination over the entire viewing surface.

(b) Masking facilities to suit the sizes of radiographs to be viewed.

(c) Densitometers shall be provided to ensure compliance with film density requirements.

Surface Preparation

26. Castings may be inspected without surface preparation or conditioning, except as required to remove scale, slag, adhering, or embedded sand or other surface conditions which may interfere with proper interpretation of radiographs.

27. Accessible surfaces of welds to be radiographed shall be prepared as, necessary so that the valleys between beads, weld ripples and other surface irregularities are blended to such a degree that the resulting radiographic contrast due to surface condition cannot mask or be confused with that of any defect.

Safety

28. Radiographic exposures shall be made under protected conditions in accordance with statutory requirements.

Interpretation of Radiographs

29. **Mandatory Information**. To assist in the proper interpretation of radiographs, a **sketch drawing and written procedure or equivalent record shall**

be prepared to show the arrangement used to make each radiograph. The information shall accompany each radiograph, or group of radiographs if the same information applies. Reference to a standard arrangement shall be acceptable if descriptions of the standard arrangements are made available. The information shall include:-

(a) Number of films.

(b) Location of each film on the radiographed item.

(c) Orientation of location markers.

(d) Location of radiation source, including source-to-film distance and angle of beam.

(e) The Kilovoltage and focal spot size.

(f) The isotope type, intensity in curies, and physical dimensions.

(g) Type of material and material thickness.

(h) Type of weld.

(j) Whether original or repair.

(k) Part and drawing number.

(l) Film type.

(m) Details of visible surface imperfections.

30. Before the IAY/ IAG review for acceptance is requested, radiographs shall be examined and interpreted by each testing agency to assure compliance with the requirements stated in this Annexure.

Image Quality Indicators (IQIs)

31. **Types**.

(a) Wire type DIN 54109 IQIs shall be used to assist in determining the quality level of all radiographs.

(b) For welds between dissimilar metals, IQIs shall be used to correspond with each group of base materials. The correct series of IQI for each material group, as laid down in Table 1, is given below:-

Material Group	**IQI Series**
1	FE
2	CU
3	AL

(c) Each series of 16 wire numbers covering a material group is contained in three IQIs, each of which contains 7 wires, numbered 1 to 7, 6 to 12 and 10 to 16.

32. **IQI Identification**. IQIs are identified by a combination of the following symbols which appear on the radiograph:-

(a) DIN – 62 – FE or CU or AL.

(b) 1 ISO 7, 6 ISO 12 or 10 ISO 16.

IQI Location – General

33. One IQI shall represent an area within which radiographic densities do not vary more than from +30% to -15% from the density measured adjacent to the IQI. At least one IQI per radiograph shall be used except. as specified in section on IQI Location – Pipe Welds. When the film density varies more than from -15 to + 30 %, two IQIs used as follows will be satisfactory:-

(a) If one IQI shows an acceptable sensitivity at the most dense portion of the radiograph and the second IQI, placed in accordance with the other requirements of this standard, shows an acceptable sensitivity at the least dense portion of the radiograph, these two IQIs shall serve to qualify the radiograph within these density limits.

34. The IQI shall be located on the source side of the section being examined wherever possible.

35. For weld examination the IQI shall be placed at one or both ends of each section to be radiographed. The wires shall lie transversely across the weld with the thinnest wire towards the central beam.

36. For double-wall, double-image exposures such as pipe welds the IQI shall, where practicable, be placed on the outside of the pipe across the weld nearest to the source of radiation. The selected wire may be placed over the centre line of the pipe.

37. For double-wall, single-image exposures in which only the portion of the specimen next to the film is viewed, the radiographic technique shall be demonstrated on a similar specimen section with the applicable IQI placed on the inside compared with an IQI placed on the film side.

38. Where a gap necessarily exists between specimen and film, the IQI shall be placed on the part of the object furthest from the film.

IQI Location – Pipe Welds

39. **Circumferential Welds**. The number and location of IQIs shall be in accordance with Table 3.

40. **Longitudinal Welds**. One IQI shall be placed at each extremity of each film along the weld; only the weld image between the thinnest wire of the IQIs shall be viewed for acceptance.

41. **Double Wall Radiography (where both walls are viewed for acceptance)**. If both walls are inspected, the IQIs shall be .based on the double wall thickness. The minimum source-to-film distance shall be calculated using the outside diameter of the pipe or section as the specimen thickness as shown on Table 4. Double-wall radiography shall be used only for pipe welds and non-critical regions of castings unless otherwise specifically approved by the IAY/ IAG. For double-wall radiography, the source may be offset from the plane passing through the weld, so that the weld images are not superimposed, but the offset should be kept at a minimum. Offset shall not be employed in the radiography of consumable root inserts.

Welds With Overlay Cladding

42. Radiography shall be performed on the completed base metal weld prior to cladding.

Radiography by Simultaneous Exposures

43. When a single film or series of films is exposed in a 360 degree radiation beam on a single component, a minimum of one IQI shall be located in each quadrant. If multiple components or parts are exposed simultaneously, at least one IQI shall be required on each film plus additional IQIs as required in Section on IQIs for Pipe Joints.

Radiography of Small Parts

44. At the discretion of the IAY/IAG, IQIs may not be required on each film when radiographing small parts, or limited areas of larger parts, when location of the IQI on the part would obscure part or all of the area of interest and where it would not be practicable to place the IQI on a block adjacent to the part. However, an initial technique shot, with the applicable IQI on the parts, shall demonstrate the specified IQI sensitivity. Subsequent exposure without an IQI shall be made only if exposed in the same manner as the technique shot. Whenever the arrangement is changed, additional technique slots shall be made in proper sequence to assure that. the

process is being properly controlled. The technique shots shall accompany the subsequently exposed film when presented for interpretation.

Radiography of Repair Welds

45. When repairs to castings or forgings have been made by welding, weld repair details shall accompany the radiographs when offered for review. The original radiographs of the previously defective area shall also be available for review upon request.

Radiography of Castings

46. **Radiographic Standard Shooting Sketch**. Each testing agency shall demonstrate the adequacy of its procedure by submitting a radiographic standard shooting sketch for each casting design to the IAY/ IAG. Wherever possible a single wall technique shall be used for the examination of critical regions. A suitable sketch or drawing shall be prepared which contains the following:-

(a) Number of films and type.

(b) Location of each film on the casting.

(c) Location of markers.

(d) Location of radiation source including angle and source-to-film distances.

(e) Voltage or isotope type and intensity.

(f) Focal spot size or physical dimensions of source.

(g) Type and thickness of intensifying screens.

(h) Material and thickness of area to be radiographed.

(j) Details of visible surface imperfections.

47. **Technique Shot Films**. The production films on the first casting shall be employed to demonstrate the adequacy of the radiographic procedure. The IAY/ IAG shall approve the procedure when satisfactory quality is obtained on all films and the extent of coverage required by the applicable specification or drawings has been obtained.

48. **Techniques.** Radiography of critical test regions should be limited to single wall techniques. Double wall-single image and double wall-double image techniques may be employed for Class II castings and Class I castings excluding

critical test regions. Defects shown by double wall exposures may require additional radiography to establish the severity of the defects relative to single wall thickness.

TABLE 1

THICKNESS RANGES FOR QUALIFICATION

Groups 1 and 2	**Group 3**
Up to & including 0.25 inch	Up to & including 0.25 inch
Over 0.25 inch up to & including 0.75 inch Over 0.75 inch up to & including 1.5 inch	Over 0.25 inch up to & including 0.75 inch Over 0.75 inch up to & including 1.5 inch
Over 1.5 inch up to & including 2.5 inch	Over 1.5 inch up to & including 4.0 inch
Over 2.5 inch up to & including 4.0 inch	Over 4.0 inch up to & including 6.0 inch
Over 4.0 inch up to & including 6.0 inch	
Over 6.0 inch up to & including 10.0 inch Over 10 inch	

Materials are grouped as follows:-

Group 1	Carbon Steel, Chromium Molybdenum Steel, Nickel Chrome Iron Alloy, Manganese Molybdenum Steel, Manganese Nickel Molybdenum Steel, Nickel Chrome Molybdenum Steel, Nickel Aluminium Bronze, etc.
Group 2	Nickel Copper, Copper Nickel, Copper, Gunmetal, Stainless Steel etc.
Group 3	Light Metals, Aluminium, Magnesium etc.

Notes:

(a) Where the thickness range specified in Table 1 extends above and below the, specified thickness range as per the standard, the upper and lower limit of the material thickness qualified shall be the actual thicknesses used for the sample radiographs.

(b) For materials having substantially different radiographic absorption characteristics from those in Group 1, 2 and 3, procedure approval shall be related to reference samples simulating production' requirements.

TABLE 2

SCREENS, FILTERS. AND MASKING

Radiation	Thickness of Lead Screen	
	Front	**Back**
X-rays generated from 120 to 250 kV	0.001 in to 0.005 in	0.005 in min
X-rays generated above 250 kV to 6meV	0.004 in to 0.006 in	0.005 in min
X-rays generated above 6meV	0.030 in to 0.060 in	0.010 in
Gamma Rays excluding Thulium 170	0.004 in to 0.010 in	0.005 in min

NOTES:

(a) **Intensifying Screens**. Intimate contact between the screens and the films shall be maintained during exposure. The use of fluorescent screens requires specific approval of the IAY/ IAG.

(b) **Back Filters**. Lead filters shall be used behind the film holder to prevent scattered radiation from the floor, walls, air or surrounding objects from fogging the film. Each film holder shall have a lead letter ‘B‘, a minimum of 0.5 inch high and a minimum of 1/16 inch thick, fastened to the back of the film holder, within the area of the film to be read. If the image of the lead letter appears on the film, additional back filter thickness shall be required. The image of this letter ‘B’ showing as a light image on a darker background shall be cause for rejection of any radiographic film.

TABLE 3

IQI LOCATION FOR CIRCUMFERENTIAL WELDS

Radiation passes through one wall only		
Pipe diameter	**Number of walls viewed for acceptance**	**Number and location of IQIs**
4- inch up to but not including 10 inch	1	One IQI on the outside surface of the pipe on the source side along the centre line of the pipe.
10 inch and over	1	If the length to be inspected is less than 5 inch, one IQI. If over 5 inch, two IQIs, one at each extremity of the area to be inspected or one at the centre of the radiation beam and one at an extremity of the area to be inspected.
Radiation passes through two walls		
Under 4 inch	1 or 2	One IQI on the outside surface of the pipe on the source side along the. centre line of the pipe
4 inch up to but not including 10 inch	1	See paragraph 36 above. The IQI shall lie along the centre line of the pipe.
10 inch and over	1	Two IQIs, one at each extremity of the area to be inspected or one at the centre of the radiation beam and one at an extremity of the area to be inspected.

TABLE 4

MINIMUM VALUES OF FOCUS-TO-FILM DISTANCE & SOURCE-TO-FILM DISTANCE

Material Thickness	**Calculated per mm of focal spot**		**Calculated per mm of source size**
	Minimum focus-to-film distance using fine grain film	**Minimum focus-to-film distance using medium speed film**	**Minimum Source-to-Film distance**
0.5 inch	3 inch	2.5 inch	3 inch
1 inch	5 inch	4 inch	5 inch
2 inch	8 inch	6 inch	7 inch
3 inch	9 inch	7 inch	9 inch
4 inch	10 inch	8 inch	10 inch
6 inch	11 inch	10 inch	10 inch

NOTES:

(a) All calculations shall be based on the maximum effective source dimensions.

(b) For focal spot or source projected as a rectangle with sides of N and Y millimetres, the effective dimension will be:-

$$\sqrt{\left(N^2 + Y^2\right)}$$

(c) For a focal spot projection consisting of divided images, the effective dimension shall be the diameter of the smallest circumscribing circle.

(d) Where a gap unavoidably exists between the film and specimen, the maximum gap width shall be added to the specimen thickness for calculation of focus to film distance.

(e) For double wall-double image radiography, the material thickness to be used for calculation of minimum source to film distance is the maximum dimension between the specimen surface and the film, e.g. the OD of pipe irrespective of wall thickness.

(f) For thicknesses of steel greater than 3 inch reference should also be made to BS 2600.

Annexure IV
(Refers to Para 5 of Appendix J)

LIQUID PENETRANT TESTING

Purpose

1. This process is used to detect surface discontinuities in ferrous and non-ferrous materials.

General Inspection Requirements

2. **Methods**. For the purpose of this specification, penetrants fall into one of the following groups:-

(a) GROUP 1 - Solvent removable.

(b) GROUP 2 - Water washable.

(c) GROUP 3 - Post emulsified.

Note: Penetrants in the above groups may be Dye, Fluorescent or Dual Purpose (eg. Ardrox 9 VFI).

3. **Test Procedure**. Liquid penetrant inspection should be performed in accordance with a written test procedure. Firms are to forward the procedure in accordance with this specification to the IAY/ IAG for written approval.

4. **Personnel Requirements**. Personnel performing & interpreting liquid penetrant tests should be able to perform an operational type test, using the test method or technique which will be used in production. In addition, the QAO/ IAG personnel should be able to interpret the results and be thoroughly familiar with the standards to which they are working.

5. **Equipment Requirements**. The test equipment, in the hands of qualified non-destructive test personnel should be capable of consistently obtaining results of specified quality level.

Method of Testing

6. **Applicability**. Areas to be tested should be specified in the drawings, specifications, contracts or repair/ refit instructions.

7. **Surface Preparation.** Surfaces to be inspected should be free from scale, slag and adhering or imbedded sand or other extraneous materials. Welded surfaces

from which slag has been removed should be considered suitable without grinding if satisfactory interpretation of the test results is possible and if the weld contour blends into the base metal without undercutting. Surfaces should not be shot, grit, milled or vapour blasted unless specifically approved by IAY/ IAG.

8. **Finished Surfaces**. Surfaces on which a specific finish is required should be given this surface finish before the final liquid penetrant inspection prescribed by the applicable specifications.

9. **Pre-Test Cleanliness**. All surfaces being tested should be thoroughly cleaned of extraneous material. If a non-volatile liquid is used for cleaning, the surface should be heated or dried with hot air to ensure complete removal of the cleaner. As a final cleaning operation each surface should be dipped, sprayed, wiped or brushed with acetone and dried thoroughly be removing the excess with a clean, dry cloth or absorbent paper and allowing the remainder to evaporate for at least five minutes. Before liquid penetrant inspection, the surface to be tested and any adjacent area within one inch of the surface to be tested , should be dry and free from dirt, grease, lint, scale and salts, coatings and other extraneous matter that would obscure surface openings or otherwise with the test.

10. **Temperature**. Maximum penetration into extremely small openings requires that the penetrant and the test surface be maintained at the temperature recommended by the penetrant manufacturer, i.e. never less than 10 deg C nor more than 40 deg C. Because of the flammability of most liquid penetrant inspection materials, the use of an open flame for heating purposes should be prohibited.

11. **Application of Penetrant**. The surface to be tested should be thoroughly and uniformly coated with penetrant by flooding/ brushing/ immersion/ spraying and should be kept wetted for the time recommended by the penetrant manufacturer or **15 minutes** whichever is longer.

12. **Application of Emulsifiers - Group 3 Penetrants**. The emulsifiers should be applied either by immersion, flooding or spraying.

13. **Removal of Penetrants and Emulsifier (if used)**.

(a) **Group 1 Penetrants**. To extent possible, excess penetrant should be removed by wiping the surface thoroughly with a clean dry cloth or absorbent paper. The remaining penetrant should be removed by wiping the surface with a clean cloth or absorbent paper dampened with a penetrant remover. Acetone should not be used to remove excess penetrant. Other methods of removal viz. air/ water spray gun are not precluded for use under controlled conditions, but in all cases care should be taken to avoid over washing.

(b) **Group 2 Penetrants**. The penetrant should be removed from all surfaces by swabbing with a clean, lint-free cloth saturated with clean water or by spraying with hot water at a temperature not exceeding 500 deg C and a pressure not exceeding 40 lb/sq in. Alternatively, the penetrant should be removed by wiping the excess penetrant from the test surface with a clean, dry, lint-free cloth followed by wiping the partially cleaned surface with a clean cloth dampened with a suitable solvent, until all traces of penetrant have been removed.

(c) **Group 3 Penetrants**. After a suitable emulsification period, the surface film of penetrant and emulsifier should be removed by washing with water at a temperature not exceeding 500 deg C.

14. **Surface Drying**.

(a) **Group 1**. The drying of test surfaces after ‘removal' of the excess penetrant should be accomplished only by normal evaporation, or by blotting with absorbent paper or clean, lint-free cloth. Forced air circulation in excess of normal ventilation in the inspection area should not be used. The time for surface drying after removal of excess penetrant and before application of the developer should be limited to a minimum of 10 minutes.

(b) **Groups 2 & 3**. The drying of test surfaces should be accomplished by using circulating air, blotting with paper towels or clean, lint-free cloth, or by normal evaporation. It is important that during the drying operation no contaminating material be introduced on to the surface which may lead to misinterpretation during the inspection operation.

15. **Application of Developer**.

(a) **Group 1**. A non-aqueous wet developer recommended by the penetrant manufacturer should be used. Immediately prior to application the developing liquid should be kept agitated in order to prevent settling of solid particles dispersed in the liquid. The developer should be applied in a thin coating to the test surfaces by spraying. If the geometry of the item being inspected precludes the use of a spray, brush or similar applicator should be used provided it results in a thin coating of developer. Pools of wet developer in cavities on the inspection surface should not be permitted since these pools will dry to an excessively heavy coating in such areas resulting in the masking of indications. Inspection should be conducted after a minimum of 7 minutes but no later than 10 minutes after the developer has dried for the assessment of relevant indications.

(b) **Dry Developer**. Dry developing powder should be applied only on dry surfaces so that matting will be prevented. The powder should be thinly applied to provide a dusty appearance immediately after drying of the test surface. Time for development of indications after the developing powder has been applied should be controlled and kept to a minimum.

(c) **Wet Developer**. This type of developer should be applied to surfaces by dipping or spraying as soon as possible and never more than 15 minutes after removal of all excess penetrant. When liquid type developers are used it is necessary that they be continually agitated in order to prevent settling of solid particles dispersed in the liquid. Concentrations of wet developer in cavities on the inspection surface should not be permitted since these pools will dry to an excessively heavy coating in such areas, resulting in the masking of indications.

16. **Final Cleaning**. When the inspection is concluded, the penetrant materials should be removed as soon as possible using water or solvents in accordance with applicable specifications.

CAUTION: Highly volatile solvents should be used cautiously. Their vapours are relatively toxic and the liquid is a primary skin irritant. Extreme care should be exercised in handling the volatile solvents as many of them are highly flammable liquids.

Lighting in Test Area

17. When dye penetrants are in use the test area should be adequately illuminated for proper evaluation of indications revealed on the test surface. When fluorescent penetrant is used, the inspection should be accomplished in a darkened area using an ultra-violet lamp with a minimum brilliance of 90. candles, measured in third center of the beam at a distance of 15 inch from the lamp, using an unfiltered Light Meter - model Weston 703 or equivalent. A suitable period should be allowed for the lamp to obtain full brilliance before beginning the inspection. Equipment should be maintained and calibrated in a manner to ensure reliable and uniform operation and fluorescent lamps should be checked at least once a week.

Non-Relevant / False Indications

18. All indications revealed by liquid penetrant inspection do not necessarily represent defects since non-relevant indications are sometimes encountered. However, all indications in weld craters or the line of fusion between base, material and weld metal should be considered relevant and should be evaluated in accordance with applicable acceptance standards. If other indications are believed to be non-relevant, at least 10% of each type of indication should be explored by removing the surface roughness, or other condition believed to have caused the type of indication, to determine if defects are present. The absence of indications upon re-inspection by liquid penetrant inspection after removal of the surface roughness should be considered to prove that the indications were non-relevant with respect to actual defects. If re-inspection reveals any indications, these indications and all of the original indications should be considered relevant and should be evaluated in accordance with applicable acceptance standards.

19. Unless the surface has been thoroughly cleaned, fluorescent penetrant should not be used for re-testing an area previously subjected to dye penetrant since residual dye may react with the fluorescent penetrant resulting in complete or partial quenching of the fluorescent.

Annexure V
(Refers to Para 5 of Appendix J)

GUIDELINES FOR MAGNETIC PARTICLE TESTING

Scope

1. These guidelines specify the minimum requirements for methods of detection of surface and near-surface discontinuities in ferromagnetic materials using magnetic particle examination techniques. BS 6072/ equivalent ASTM/ IS standards shall be the guiding document unless specifically stated otherwise.

2. These guidelines apply to all items for which specifications, standards, drawings or refit/ repair instructions require magnetic particle examination. These are also applicable to the Quality Assessment of Examining Authorities who perform magnetic particle examination. These guidelines do not cover the following:-

(a) The extent to which magnetic particle examination is required as this is to be stated in the SOTR/PO.

(b) Acceptance criteria for defects – to be stated in the SOTR/PO.

(c) Examination of nuclear plant and machinery.

Acceptance Standards

3. The standards for acceptance of defect indications detected by magnetic particle examination are to comply with Def Stan 02-773 or Def Stan 02-745 Part 2 as appropriate unless otherwise specified in the Contract Document.

Examination Procedure Requirements

4. **General.** Magnetic particle examination is to be performed in accordance with a written examination procedure. The IAY/IAG is to certify that the procedure is in accordance with the applicable standards and provide a written approval.

5. **Personnel Requirements.** The IAG is to ensure that all personnel associated with the magnetic crack detection have been trained and certified to the levels appropriate to their responsibilities. This certification is to relate to a national or international accreditation scheme. The firm is to submit a list of qualified personnel prior undertaking the testing.

6. **Procedures.**

(a) Separate procedures, or a comprehensive detailed procedure, to be produced to cover the requirements for the magnetic particle inspection of structural welds, castings, forgings, and pipe welds. The relevant contract is to define the extent of the magnetic crack detection examination and the appropriate acceptance standards to apply.

(b) Inspections to the magnetic particle crack detection procedure(s) are to be carried out by approved personnel qualified in accordance with paragraph 5 above.

(c) The magnetic particle crack detection procedure(s) are to be recorded and maintained by the examining authority for audit purposes.

7**.** **<u>Technical Prerequisites</u>.** The magnetic particle crack detection procedure(s) must cover the prerequisites, technical requirements and give general guidance associated with the inspection method(s). Separate technique sheets may be produced for specific applications and contain specific guidance information including the following parameters as applicable:-

(a) Details of component(s) to be examined - material, shape, size etc..

(b) Magnetising equipment details, i.e. make and type of equipment to be used.

(c) Type and direction of magnetisation.

(d) Surface preparation, finishing and cleaning before and after test.

(e) Method used, i.e. wet or dry, make and type of detecting medium.

(f) Details of contrast coating, if used.

(g) Magnetising current values.

(h) Demagnetising method.

(j) Controls of concentration of particle suspension.

(k) Controls during test to check continuing efficiency of the examination.

(l) Details and sketches of the inspection pattern to be used.

(m) Type and strength of viewing illumination.

8. **<u>Production Examination Techniques and Reporting</u>.** Details on techniques for magnetic particle examination may be found in BS EN ISO 9934-1/ Eqv. ASTM standard. All magnetic crack detection is to be recorded in a Magnetic Crack Detection Report in which the information below is to be recorded:-

(a) Relevant magnetic detection procedure

(b) Names of Qualified Operator(s).

(c) Contractual details.

(d) Details of the component, weld, etc..

(e) Magnetic crack detection techniques.

(f) Examination coverage.

(g) Date and time of the examination.

(h) Results of the examination.

Equipment

9. **Functioning Test.** Prior to the commencement of testing, the correct functioning of the testing equipment and magnetic ink is to be verified.

10. **Magnetising Equipment.**

(a) The magnetising equipment should be capable of inducing in the item under test a magnetic flux of suitable intensity and in the required direction(s), e.g. longitudinal, transverse or circumferential.

(b) For longitudinal or transverse magnetisation, the equipment is to provide for the use of a solenoid or coil, to induce magnetic flux in the item to be examined.

(c) For circumferential magnetisation the equipment is to provide for the use of low voltage high amperage current passed either through the item, or through a conductor which passes through the item. The latter is used to induce the required magnetic flux in terms of cylindrical form such as pipes.

(d) Provision for measuring the applied current is to be included in the equipment employed for current flow techniques.

(e) Magnetising apparatus and ancillary equipment is to be checked for accuracy and efficiency, at regular intervals not exceeding three months, by suitably qualified personnel.

11. **Demagnetising Equipment.** Demagnetising equipment is to be of one of the following types, depending on the size and portability of the item, assembly or structure under examination:-

(a) Aperture type coil; constant AC; component passed through.

(b) Aperture type coil; diminishing AC; component stationary.

(c) Reversing DC magnetisation; stepwise magnetic field reduction.

(d) AC yoke; fixed structures; stroking action.

(e) Diminishing AC flow; stepwise current reduction.

12. **Value of Residual Magnetic Field.** If demagnetisation is a requirement specified in SOTR/PO or Magnetic Inspection Procedure, the magnitude of the residual magnetic field, unless otherwise agreed, is not to exceed 3 gauss (1 gauss = 10^{-4} T, where T = tesla, the SI unit of magnetic flux density).

Detecting Media

13. Magnetic Ink.

(a) Magnetic ink, consisting of finely divided magnetic particles suspended in a carrier fluid, is to comply with BS EN ISO 9934-2/ Eqv. ASTM or IS standard. The ink may be fluorescent or non-fluorescent. It is to be non-toxic and is to exhibit good visual contrast. Fluorescent particles are to be readily visible when exposed to a filtered UV-A source.

(b) Thorough mixing of fluid and solids in magnetic ink is to be maintained at all times and its efficiency is to be verified prior to the commencement of working periods. Magnetic inks are to be checked for total solids content immediately prior to use and at least once a week if in continuous use, to determine that the suspension complies with BS EN ISO 9934-2/ Eqv. ASTM or IS standard.

(c) The ink is to be discarded and replaced if it becomes discoloured or contaminated with foreign substances that interfere with the proper distribution and concentration of the suspension.

14. **Magnetic Powder.** Magnetic powders used in dry testing are to comply with BS EN ISO 9934-2 and to be of a non-toxic, finely divided ferromagnetic material of high permeability and low retention. They are to be free from rust, grease, paint, dirt and other material which might interfere with their proper functioning. Particle size, shape and colour are to provide adequate sensitivity and contrast.

Application of Detecting Media

15. **Wet Technique.** Magnetic ink is to be applied to the item by spraying or by immersion to ensure thorough coverage of all areas to be tested. Application is to be immediately prior to and continued during magnetization unless residual magnetisation techniques are used. The application is to cease before magnetisation is terminated.

16. **Dry Powder Technique.** Dry magnetic particles are to be applied in such a manner that a light, uniform, dust-like coating settles upon the surface under test. Excess powder is to be removed using a current of air of sufficient force to remove the excess particles without disturbing those particles which are indicative of discontinuities.

Preparation for Examination

17. **Surface Condition.** Unless otherwise specified in the SOTR/PO, magnetic particle examination for final acceptance is to be performed on an item in the final surface condition and after all heat treatment has been completed.

18. **Demagnetisation.** Items containing residual magnetic fields are to be demagnetised before magnetic particle examination is commenced.

Surface Preparation

19. Surfaces are to be dry and free from loose rust, scale, grease and any contamination which might interfere with the proper interpretation of the magnetic particle patterns. Surfaces are not to be peened, abrasive or vapour blasted without specific approval of IAY/ IAG.

20. Where wire brushing or grinding is applied to remove imperfections that would interfere with the examination, the material thickness is not to be reduced below the minimum thickness permitted by the design specification and the dressed areas are to be faired with the surrounding surface.

21. Welded surfaces from which the slag has been removed and with weld contours that blend smoothly into the base material without undercutting, are to be considered acceptable for examination without grinding, provided interpretation of the test results is possible.

22. Protective coatings that would interfere with the magnetisation are to be removed at the areas of contact and repaired when the examination is complete. Surface coatings or plating may remain on the surface to be examined provided that it has first been established that the examination sensitivity will not be impaired.

23. All openings are to be plugged wherever necessary to prevent accumulation of magnetic particles or other material which cannot be subsequently removed by washing or air blasting. On machined items, the inability to post-clean restricted passageways effectively may limit the application of magnetic particle examination. Holes in items that have been in service are not to be plugged if there is a possibility of cracking in the internal surfaces. Plugs are not to be materially affected by the magnetic fluid and are not to obstruct examination of adjacent external surfaces.

Contrast Aid Coatings

24. For weld examination a strippable contrast aid coating is to be applied as a thin uniform layer to test surfaces except in the electrode/product contact areas. It is to be established that the strippable contrast aid coating does not produce a loss of sensitivity. Contrast coatings are to be compatible with the test media to be used. For contrast aid paints, BS EN ISO 9934-2 / Eqv ASTM /IS standard is to apply.

Magnetisation Technique

25. **Magnetic Fields.** Magnetic fields may be generated by any of the following techniques:-

(a) Magnetic Flow.

(b) Current flow.

(c) Threading bar.

(d) Coil.

(e) Induced current flow.

26. **Continuous Magnetisation Method.** The item is to be magnetised before the stream of suspension is diverted, or just before removal from the suspension if testing is by immersion, and the magnetising current maintained for a further 0.2 - 0.5 seconds.

27. **Residual Magnetisation Method.** The item is to be magnetised by the application of current for at least 0.5 seconds, after which the magnetising current is to be turned off and the suspension is to be applied, either by spraying or by immersing the item in the suspension, care being taken to ensure that the indications are not washed off. When a fluorescent medium is used, carefully rinsing off the item in the carrier used for preparing the suspension may be necessary to obtain an acceptable pattern of indications.

28. **Direction of Magnetisation.** To ensure detection of discontinuities whose axes may lie in random directions at least two separate examinations are to be carried out in each test area. The direction of the magnetic flux in the second examination is to be at right angles to that in the first examination. A different means of magnetising may be employed for the second examination.

29. **Current Values.** The peak current value is the relevant Quantity which determines magnetic field strength. The current values quoted in the following clauses are AC RMS values and to obtain peak values, if required these are to be multiplied by the appropriate factor in **Table 1** below.

Table 1 - Factor by which indicated current values are multiplied to obtain peak values

VALUES		
WAVEFORM	**TYPE OF AMMETER**	
	A	**B**
	PERMANENT MAGNET, MOVING COIL OR OTHERS MEASURING MEAN VALUES	**MOVING IRON. INDUCTION, ELECTRODYNAMIC OR OTHERS MEASURING RMS VALUES**
Direct Current	1.00	1.00
Alternating Current	Not applicable	1.41
Full-wave rectified, 1 Ø current	1.57	1.41
Half-wave rectified, 1 Ø current	3.14	2.00
Full-wave rectified, 3 Ø current	1.05	1.05
Half-wave rectified, 3 Ø current	1.21	1.19

30. **<u>Magnetic Flow Technique</u>.**

(a) Magnetisation is to be produced in the item by means of an electromagnet or permanent magnet, the pole pieces of which are to be in close contact with the item under test.

(b) Defects are most effectively detected when their major axes are transverse to the direction of the flux that flows from one contact to the other.

(c) Magnetic particle flaw detection is to be carried out at levels of magnetic flux density equal to or greater than 0.7 T.

(d) The optimum strength of the magnetic field induced by an electromagnet may be obtained by applying a current sufficient to produce saturation of the item, shown by ‘furring’ of the magnetic particles and then reducing the applied current by 40 - 50%.

(e) To ensure that magnetisation conditions are effective, a magnetic field strength meter or a portable flux indicator may be used.

31. **Permanent Magnets.**

(a) Generally the use of permanent magnets is to be limited to inspections for surface-breaking defects except as agreed by IAY/ IAG where conditions preclude the use of other magnetising techniques or their use may cause damage to the item.

(b) To induce the required magnetic field strength into specimens with irregular geometry eg Tee Butt welds, it is recommended that permanent magnets of the flexi-type be employed.

(c) Prior to the use of a permanent magnet, its suitability for purpose is to be assessed by its ability to lift a piece of ferritic steel by magnetic attraction alone, in accordance with the following:-

(i) For pole spacing up to 75 mm the lifting force is to be not less than 0.24 kgf per mm pole spacing.

(ii) For pole spacing greater than 75 mm and up to a maximum of 150 mm, the minimum pull-off force (1 pole) is to be 9 kgf and minimum lifting force (2 pole) is to be 18 kgf.

(d) The effective area covered by each application of a permanent magnet (and DC or AC yoke magnets) is to be considered as the area of the circle inscribed between the pole pieces or yokes. Full coverage of all defect orientations is to be achieved by two applications at 90° to each other centered around the inscribed circle.

32. **Portable DC Magnets.** The lifting requirements of DC portable magnets are the same as those detailed for permanent magnets in paragraph 31 above. The use of DC portable magnets is not recommended, however, owing to the low surface flux densities induced in the item under test.

33. **Portable AC Magnets.** This type of magnet is preferred to either permanent or DC electro-magnets owing to its superior sensitivity in detection of surface breaking defects and is to be used wherever possible. The effective area covered is defined in para 31(d) above. The lifting force requirements of portable AC magnets whose pole spacing is not to exceed 300 mm are as follows:-

(a) Pull-off force (1 pole) not to be less than 2.25 kgf.

(b) Lifting force (2 poles) not to be less than 4.5 kgf.

34. **Current Flow Techniques.**

(a) These techniques require the passage of current from a low voltage external source between two contact areas on the surface of the item and include prod and through-component techniques.

(b) When using direct magnetisation by current flow, the part being tested, the size and type of contacts used and the time of application of the current are to be such that overheating of the item under test does not occur either locally or generally.

(c) For the detection of longitudinal defects, the magnetic field is to be induced with the electrode contact points on a line parallel to the longitudinal axis of the item and at right angles to the longitudinal axis for the detection of transverse defects.

35. **Through - Component Techniques.**

(a) The through-component technique is the preferred technique for detecting longitudinal flaws.

(b) The magnetising current is to be not less than 20A per mm of diameter for basically round items and not less than 6.5A per mm of section perimeter for non-round items.

(c) All contact areas are to be clean. Items are to be mounted horizontally, and large and heavy items are to be mounted in suitable fixtures to ensure suitable head pressure and uniform magnetism. Where it is necessary to pass current through cylindrically shaped items, contact-balls are to be used.

36. **Prod Technique.**

(a) When using the prod technique, full coverage is to be achieved by adopting the scanning pattern shown in BS 6072 / Eqv ASTM or IS standard.

(b) Prod contact areas are to be sufficiently large to reduce the possibility of overheating or arcing which may cause local damage. Contact pads may be employed to minimise the risk of damaging the surface by arc strikes. The materials of prods or contact pads are to have no adverse effect on the material of the item under examination. Zinc contact pads are not to be used. Copper is to be used only where no metallurgical damage can result.

(c) In the prod technique, magnetising current is to be calculated on the basis of 4 to 5 amperes per mm of spacing between the prod contact areas.

(d) The magnetising current is not to be turned on until the prods have been properly positioned in contact with the material surface and is to be turned off before the prods are removed. Current is to be applied for at least 0.5 seconds unless otherwise stated in the Contract. The current application time is to be limited in order to prevent overheating of the test item.

37. **Threading Bar Technique.**

(a) In this technique, current is passed through a conductor placed within a bore or aperture in the item. The technique is appropriate for testing the internal and external surfaces of enclosed or cylindrically shaped items of small diameter. A central conductor may also be used for circular magnetisation of other shapes. The size of the conductor is to be as near the size of the opening as practicable.

(b) When multiple small items are to be simultaneously magnetised on a central conductor, they are to be spaced to avoid contact and, if the quantity of work involved warrants their use, suitable fixtures are to be used for proper orientation.

(c) The threading bar technique favours the detection of flaws where the major axes lie parallel to, or within 45° of the direction of the current flow. In a tubular specimen longitudinal flaws on both inner and outer surfaces and radial flaws on the end faces may be revealed.

(d) When using the threading bar technique, minimum values of current given for through component techniques at sub para 35(b) above are to apply. Outside diameter or periphery of the item is to be the criterion for selecting current value. Where the threading bar is not concentric with the centre of the item, the item is to be turned and test repeated for effective coverage.

(e) Though some departure from the ideal flux direction may be experienced the technique can also be applied to the examination of bores or lugs on complex components.

(f) When the shape of the bore in the item precludes the insertion of a rigid conductor, use may be made of heavy flexible cable.

38. **Coil Technique.**

(a) Magnetisation is to be produced by placing the item within a current carrying coil so that the item becomes the core of a solenoid. Magnetisation is in the direction parallel to the axis of the coil and hence favours the detection of defects that are transverse to the axis of the coil.

(b) Flaw detection sensitivity depends upon the shape and size of the item, the coil dimensions and the ampere-turns produced. The coil is to be no larger than is necessary to accommodate the item. Items are to be orientated within the coil to ensure uniform distribution of flux. For long items, the test is to be repeated at coil length intervals over the full length of the item.

(c) Magnetising coil is to produce a maximum level of flux below saturation level for the material at the relevant section, but not less than a third of saturation (see para 30(d) above). Saturation will be made evident by furring.

39. **Induced Current Flow Technique.**

(a) Indirect magnetisation is to be accomplished by passing magnetisation current through an auxiliary conductor, for a minimum period of 0.2 seconds.

The magnetising current is induced into the item under examination by means of a detachable laminated iron transformer coil, threaded through the item in such a way that the item in effect becomes the secondary of the transformer.

(b) The current induction technique may be used for the detection of circumferential flaws in ring type components. The magnetising current induced is to be not less than 6.5 amperes per mm of the section perimeter of the item.

Magnetic Field Strength Indicators

40. Where it is necessary to establish the path of the magnetic flux in an item, a tangential field strength meter or a portable flux indicator may be used.

41. Portable magnetic flux indicators are to be used only to confirm the field direction or to provide a rough guide to field and flux levels. It is essential that they are placed in intimate contact with the item under test to show that magnetising conditions are effective.

42. Magnetic field strength meters and portable magnetic flux indicators may be used in conjunction with permanent magnets or with DC electromagnets but only to establish the magnetic field direction.

Viewing

43. **General.** The test area is to be adequately illuminated to permit proper evaluation of the indications revealed on the test surfaces.

44. **Non-Fluorescent Media.** Illumination for non-fluorescent media is to be even i.e. without highlights or shadows, and at a level of at least 500 lux daylight or artificial light.

NOTE: As a guide, the above illumination level can be achieved using either a fluorescent tube of 80W at a distance of approximately 1 m or a tungsten filament pearl lamp of 100W at a distance of approximately 0.2 m.

45. **Fluorescent Media.**

(a) A darkened area or booth, with ambient white light level not greater than 10 lux and a properly filtered UV-A (black light) source, is to be provided for examination using fluorescent inks. A suitable period not less than 15 minutes is to be allowed for the UV-A lamp(s) to achieve full intensity prior to use and for the eyes to adjust to the low ambient lighting.

(b) The UV-A irradiance level at the surface being examined is to be not less than 0.8 mW/cm^2 when checked in accordance with BS EN ISO 3059.

(c) The intensity of UV-A lamps may decrease due to age, variations of line voltage, tarnishing of the reflector and dirt on the filter. Lamps are to be regularly maintained in a manner that will ensure reliable and uniform operation.

(d) Protective goggles are to be worn if the UV-A source is not filtered. For the assessment of UV-A lamps BS EN IS 3059 is to apply.

(e) Photochromic lenses react to ultraviolet light by darkening. Viewing through photochromic spectacles when examining by fluorescent magnetic particle methods is therefore prohibited.

Evaluation

46. Magnetic particle patterns are not to be disturbed after magnetisation has ceased until they have been examined and recorded. Relevant indications are those caused by discontinuities and may be classified as, for example, cracks and crack-like flaws, inclusions, rounded indications and linear indications.

47. Non-relevant or false indications are spurious effects not caused by discontinuities. Examples of such indications are:-

(a) Magnetic writing i.e. spurious indications arising from random local magnetisation.

(b) Changes in section.

(c) Furring i.e. local build-up of magnetic particles due to excessive magnetisation of the component under examination.

(d) Changes in permeability.

48. All indications in weld metal, or in the fusion line between base material and weld metal, are to be considered ‘relevant’ and are to be evaluated in accordance with applicable acceptance standards.

De-magnetisation

49. Items containing residual fields which may interfere with subsequent magnetic particle examination or prevent post-cleaning are to be demagnetised. Demagnetisation may also be required between tests when the flux direction is changed, and on completion of magnetic particle examination. After de-magnetisation, components are to be removed from the vicinity of the de-magnetising coil or machine to avoid re-magnetisation by local magnetic fields.

Post-Examination Cleaning

50. After test and demagnetisation, items are to be cleaned to remove all magnetic ink, powders and contrast coatings. All temporary plugs are to be removed from holes and cavities.

Records

51. All records of magnetic particle examination are to be sufficiently detailed, in compliance with the agreed procedure, for the proper application of the standard of acceptance as specified.

Annexure VI
(Refers to Para 5 of Appendix J)

GUIDELINES FOR EDDY CURRENT TEST

Scope

1. These guidelines give the minimum requirements for methods of detection of surface and near-surface discontinuities in electronically conductive materials, which may be ferromagnetic or non-ferromagnetic, using eddy current examination techniques.

2. The requirements for the use of manually operated portable eddy current instruments designed specifically for the detection of surface-breaking cracks in welds are included.

3. The requirements of these guidelines are applicable to all items for which specifications, standards, drawings, refit or repair instructions require eddy current examination. These guidelines are also applicable to the Quality Assessment of Examining Authorities who perform eddy current examination.

4. These guidelines do not cover:-

(a) The extent to which eddy current examination is required. This requirement is to be stated in relevant SOTR/PO.

(b) Acceptance criteria for defects.

(c) The examination of nuclear plant and machinery.

Normative References

5. BS EN 1330-5 Non-Destructive Testing. Terminology. Terms used in Eddy Current Testing.

6. BS EN 1971: 1999 Copper & Copper Alloys. Eddy Current Test for Tubes.

7. BS EN 10246-2: 2000 Non-Destructive Testing of Steel Tubes. Automatic Eddy Current Testing of Seamless & Welded (Except Submerged Arc Welded) Austenitic and Austentitic-Ferritic Steel Tubes for Verification of Hydraulic Leak-Tightness.

Definitions

8. **Calibration Test Piece**. A conveniently sized sample of material of similar electromagnetic properties to the item to be tested and in which reference standards are located.

9. **Reference Standard.** An artificially produced imperfection of predetermined dimensions, usually a notch or a hole, used for the sole purpose of establishing the test sensitivity of the eddy current equipment.

10. **Trigger/Alarm Level**. The level at which the electronic equipment is required to differentiate between acceptable and suspect items.

11. **Terms**. BS EN 1330-5 is to apply to the terms used in this Part. The standards for acceptance of defect indications detected by eddy current examination are to be as specified in the SOTR/PO.

General

12. Eddy current effects are susceptible to physical and chemical changes in materials. Eddy current methods used for flaw detection are therefore most effective for the examination of materials which have a homogenous structure, low permeability and precisely controlled sectional dimensions. Slight variations in these parameters, which in themselves are within the permitted tolerances, may influence the results of this method of examination.

13. Unless specified otherwise herein, mandatory requirements of BS EN 1971 and BS EN 10246-2 are to apply to eddy current testing of ferrous and non-ferrous pipes and tubes. These standards may be also used for guidance, wherever applicable, in the eddy current testing of other forms of material.

14. It is not the intented to exclude proven eddy current inspection procedures which can be demonstrated to the satisfaction of the IAY/IAG to meet the quality requirements. Prior approval is to be obtained before such procedures are used.

Examination Procedure Requirements

15. **Personnel Requirements.** The Examining Authority is to ensure that all personnel associated with eddy current examination have been adequately trained to the levels appropriate to their responsibilities, personnel should have a certificate from a nationally or internationally accredited scheme. Personnel performing and interpreting eddy current examination are to be able to perform an operational type test using the test method of the technique that will be used in production. In addition the IAY/IAG is to be able to interpret the results and be familiar with the standards to which it is working.

Procedures and Inspections

16. Eddy current examination is to be performed in accordance with a written examination procedure. The firm is to certify that the procedure is in accordance with these guidelines and is to submit each procedure to the IAY/AIG for written approval. Separate procedures are to be written to cover the requirements of the eddy current inspection of welding or wrought products.

17. The relevant SOTR/PO is to define the extent of eddy current examination and the appropriate acceptance standard.

18. Inspection to eddy current procedures is to be carried out by approved personnel certified in accordance with para 15 above. Procedures are to reference all relevant documents, specifications and acceptance standards. The procedures are to be recorded and maintained by examining authorities for audit purposes.

19. Eddy current procedures are to cover all prerequisites and technical requirements associated with the application and are to contain specific guidance information including the following, as applicable:-

(a) Material type and descriptive details of the item to be tested including size and shape. In case of weldments, the type of weld, location and surface condition.

(b) Equipment description:-

(i) Make/Model.

(ii) Details of monitoring and recording method.

(iii) Type of test coils or probes, size and current frequency.

(c) Details of the technique to be used:-

(i) Coil or probe arrangement.

(ii) System used, e.g. absolute, differential or combined mode.

(iii) Saturation (if used).

(iv) Speed of test.

(v) Probe scanning method or grid to be used.

(d) Description of the calibration procedure and sensitivity checks including:-

(i) Full details of the calibration test pieces.

(ii) Method and frequency of production sensitivity checks.

(e) Method of recording the results of tests.

Production Eddy Current Testing, Techniques and Reporting

20. Eddy current inspections are to be recorded in an eddy current report. The report is to include the following information:-

(a) Relevant eddy current inspection procedure.

(b) Name(s) of operator(s).

(c) Description of component or weld, material and location.

(d) Contract number and details.

(e) Eddy current inspection technique.

(f) Inspection coverage.

(g) Date and time of the examination.

(h) Results of the examination.

Equipment

21. Depending upon the application, eddy current examination is to be performed using approved automated or manually operated equipment and methods. Manually operated equipment that has been designed specifically for the detection of surface-breaking cracks in ferromagnetic and non-ferromagnetic welds is to be used only for the intended purpose.

22. Preferably the required coverage is to be achieved by automatic methods with positive control of:-

(a) Coil/ material configuration.

(b) Speed of scanning.

(c) Scanning helix, where applicable.

23. **Test Coils**.

(a) The equipment is to be capable of energising test coils with alternating currents of suitable frequencies and of sensing the changes in the electrical characteristics of the test coils.

(b) The test coils are to be capable of inducing current in the item under test and of sensing changes in the electrical characteristics of the item. Coils may be encircling types or probe types depending upon the application.

24. **Driving Mechanism**. In automated or semi-automated systems, means are to be provided for passing the item through the test coil system or for traversing the test coil system across the item, at a uniform speed with minimum vibration of the coil system and of the item under test and for maintaining the item substantially concentric with the test coil system. The equipment is to be capable of imparting relative movement which is rotational and or translational, thereby permitting a helical test pitch to be obtained.

Calibration Standards

25. Test pieces are to be prepared from suitable lengths of material which simulate the item to be tested with regard to sectional dimensions, material type, metallurgical condition and surface finish. Reference standards are to be incorporated in the test pieces, in the form of holes, notches or slits. When using manually operated equipment, a flaw-free calibration test piece of the same material type as that under examination is to be additionally provided for reference.

26. For tubing, the reference standards are to be either of the following:-

(a) Internal and/or external notches aligned either longitudinally or transversely as appropriate and whose dimensions are:-

(i) Length: 25 mm nominal.

(ii) Depth: t / 20 or 0.1 mm whichever is greater. ‘t’ is the nominal wall thickness of the tube being examined.

(iii) Width: 1.6 mm maximum

.

Note: The notches in the material surfaces are to be separated in such a way that they can be clearly and individually resolved under production conditions.

(b) Three holes of the same nominal diameter drilled through the tube wall perpendicular to the surface and displaced circumferentially 120 degrees from each other. Axial separation from each other and the ends of the calibration test piece is to be such that the holes can be resolved clearly and individually under production conditions; the hole diameter is to be in accordance with Table 1.

Tube Nominal OD mm	**Hole Nominal Diameter mm**
Over 6.3 up to and including 19 mm	0.65 max

Over 19 up to and including 25 mm	0.80 max
Over 25 up to and including 32 mm	0.92 max
Over 32 up to and including 38 mm	1.10 max
Over 38 up to and including 44 mm	1.20 max
Over 44 up to and including 50 mm	1.40 max
Over 50 up to and including 63 mm	1.60 max

27. Calibration test pieces for welded tubing are to contain reference standards in the weld method and additionally in the parent metal when both materials are to be examined.

28. For bar material, notches or slits are to be cut in the material surface and spaced as for tubes.

29. The reference standard disposition, dimensions, orientation and numbers for components other than tubes or bars are to be as agreed between the Design Authority and the Examining Authority. The reference standards are to be spaced such that they can be clearly and individually resolved under production conditions.

30. The introduction of the reference standards into the calibration test piece whether by drilling, spark erosion or other methods, is to be carried out under controlled conditions in order to minimize disturbance in adjacent material.

31. The preferred methods of introducing the reference targets are respectively:-

(a) Holes – drilling.

(b) Notches - spark erosion or by thin cutting wheel.

32. The accuracy of the calibration test piece, and reference standard dimensions and positions, is to be verified to the satisfaction of IAY/ IAG.

33. Calibration test pieces are to be frequently examined for signs of damage which may impair performance and are to be renewed accordingly.

Equipment Calibration

34. The equipment is to be calibrated immediately prior to any test or series of tests to ensure that sensitivity is adequate and that the equipment is functioning in a consistent and stable manner. The calibration is to be in accordance with manufacturer’s recommendations.

35. A test piece containing reference standard(s) is used to calibrate the equipment, to establish the test sensitivity and to execute routine calibration checks and re-calibration.

36. The calibration test piece is to be passed through the test unit or the test unit is to traverse the test piece at the same relative speed and in the same direction and manner as that to be used in the production examination.

37. The selected current frequency for production examination is to produce clear and distinctive indications in the test unit by all the reference standards in the calibration test piece.

38. Where specified, a battery check is to be carried out prior to the calibration of portable manually operated test units used for the examination of weldments. If a low battery condition is indicated, the batteries are to be replaced or recharged.

39. **Acceptance Level**. To set the equipment to the agreed acceptance level, the appropriate calibration test piece is to be subjected to the procedure at para 36 above. The trigger alarm or monitor level is then to be adjusted until the acceptance standard will just indicate rejection.

Extent of Examination

40. Items to be examined are to be completely examined wherever practicable so that all significant defects are detected irrespective of their orientation. When complete coverage cannot be obtained, actual extent of that achieved is to be stated on the record of test. Examination of weldments is to be as specified in SOTR/PO.

Surface Condition

41. Unless otherwise specified in the Contract, acceptance inspection is to be performed on an item in the final surface condition and final heat-treated condition.

42. All surfaces to be examined are to be free from metallic particles, loose scales and other foreign matter. Methods used for surface preparation are not to be detrimental to the material or the surface finish.

43. Surface preparation of weldments to be examined by instruments designed for the purpose, is to be limited to the removal of loose scale, paint and corrosion products from the areas to be traversed by the search probe.

Performance Specification

44. Surface coatings of a conductive nature, eg. electroplating, metal spraying or aluminising, may give misleading results and make balancing of certain instruments impossible and consequently prevent detection of defects in the base metal. In such

cases, it is first to be verified by examination of a similarly coated test sample, with due consideration of the equipment manufacturer's recommendations, that meaningful results can be obtained.

Production Examination Techniques

45. **Testing Speed**. The relative speed between the item and the test coil is not to vary from that used during the calibration procedure by more than ± 10%. The speed of test as applied to the examination of weldments using equipment with meter indication and hand held probes is not to exceed 1 metre per minute. Where LED indication and gate circuits are provided, probe speed may be increased to 3 metres per minute.

46. **Manual Testing**. The probe is to be held at a constant attitude to the contact surface and moved in a path parallel to the weld and adjacent to it. Rocking of the probe and placing of the probe near to the edge of the work piece are to be avoided as both may cause spurious indications which may be misinterpreted as defects.

47. **Sensitivity Level**.

(a) Specified sensitivity level is to be assured and maintained under all prevailing examination conditions for full duration of examination of the complete area. A sensitivity check system is to be applied before production examination begins, at intervals of approximately 2 hours as examination proceeds and again on conclusion, using appropriate calibration test piece.

(b) Manually operated equipment is to be checked frequently throughout the examination of the welds to ensure the correct sensitivity is being maintained and to take account of any local variations in response to eddy currents in the material. An indicated sensitivity reduction of more than 2dB will necessitate both re-calibration and the re-examination of all the material examined since the most recent satisfactory check.

48. **Defect Indications**. All defect indications are to be evaluated in accordance with the specified acceptance standard.

49. **Additional Tests**. Areas containing defect indications observed during the examination of ferromagnetic weldments are to be additionally tested by magnetic particle examination in accordance with guidelines given at Annexure 5 in order to verify the relevance of these indications and extent of confirmed defect.

Records

50. All records of eddy current examinations are to be sufficiently detailed and in compliance with the agreed procedure in order to permit proper application of the specified standard of acceptance. Details of retest and additional tests, as specified above, are to be included with the records.

Appendix K
(Refers to Para 8 of Chapter 9)

GUIDELINES FOR TYPE TESTS

1. **Ambient Air Temperature**.

(a) **Main & Auxiliary Machinery Spaces**.

(i) Temperature: +35 to + 40 deg C.

(ii) Relative Humidity: 95 ± 3%.

(b) The temperature of the compartment would be +15 to + 45 deg C during refit and laid up conditions. A maximum of + 50° C for a short duration is envisaged.

2. **Ambient Pressure**. Between 900 to 1330 mbar.

3. **Ship Motion**. Satisfactory and reliable operation of equipment is to be ensured at rated power under following conditions:-

(a) Constant heel : ± 15 deg ; Constant trim: ±15 deg.

(b) Temporary heel : ± 30 deg (3 minutes).

(c) Roll : Upto ± 45 def (Period of 6 - 9 seconds).

(d) Pitch: Upto ±15 deg (Period not less than 5 seconds).

Note: Conditions at sub para (a) and (b) above will generally not occur concurrently.

Shock Test by Shock Test Machine

4. The applicability of this method will be specified in the SOTR. However, it is generally applied for equipment weighing less than or equal to 500 kgs. The strength of the equipment under shock is to be verified by shock testing in an impact test machine. The equipment will be considered passed shock requirement if tested successfully in the machine.

5. The mounting of equipment is onto the shock test stand will require special fixtures, which are to be arranged by the firm. IAG is to ensure that firms are given adequate information/ notice in this regard.

6. The shock is given in the form of an impact onto the table of the test machine.

The equipment is never directly subjected to any impact. The shock value given depends on the weight of the equipment. The impact can be given in any wave form.

Design for Shock by Analysis

7. The applicability of this method will be specified in the SOTR. However the method is generally applied to equipment of complicated contours or weighting more than 500 kg.

8. Shock analysis of the equipment is to carried out to ensure the proper functioning of the equipment under the shock loading specified in the statement of requirement. The shock analysis may be performed either by **equivalent static load method** or **transient dynamic analysis method**. The requirement of the above two methods varies from equipment to equipment and therefore the methods are to be applied as applicable.

9. The shock analysis is to be undertaken in the most appropriate software for the purpose. Commonly approved software are ANSYS, LS-DYNA, PRO E & I-DEAS.

10. In case of small equipments, manual calculation may be permitted. However, the designer/ manufacturer shall obtain prior approval from IAY to undertake manual calculation. In such case, the designer/ manufacturer shall justify that the manual calculation will cover all aspects of the analysis to ensure proper functioning of the equipment under shock loading.

11. Apart from the above analysis, the designer / manufacturer shall carry out the normal mode dynamic analysis of the equipment to estimate the natural frequency of the equipment. The normal mode analysis is to be carried out by Block-Lanczos method.

12. The shock mount need not be modelled in the analysis as the shock amplitude specified in the SOTR is above the shock mount. Therefore, the fixed points of the equipment (the shock mount locations) is to be modelled as translational restraint which means that all three translational degrees of freedom will be fixed and all three rotational degrees of freedom will be free.

13. For equivalent static load approach, maximum shock amplitude is to be applied as inertia load and the response of the equipment is to be obtained. The stresses and deflections under the shock loading should not exceed the allowable limit.

14. For the transient dynamic analysis, the shock pulse indicated in the statement of requirement is to be carried out if there is no nonlinearity involved in the model. However, if the model has got inherent non-linearity, non-linear transient analysis has to be carried out.

15. Generation of solid/ surface model of the equipment and consequent development of finite element model will vary from equipment to equipment depending on the shape, size, dimension and functioning of the equipment. Therefore, it is not possible to generalize the method of preparing the finite element model. The designer/ manufacturer shall discuss with IAY/ IAG before undertaking the analysis regarding above aspects. The shock analysis report is to be submitted in hard and soft copy. The manufacturer should submit the shock analysis in CD to IAY/ IAG including model file.

Computational Fluid Dynamic (CFD) Analysis

16. In general, CFD analysis should be carried out to establish that the various fluid flow parameters like pressure drop, flow velocities, mass flow rate, heat transfer rate, temperature distribution etc., are adequate and optimum to meet the designed performance of the equipment. This requirement is in addition to the conventional thermal hydraulics design practices followed for basic design.

17. The objective of CFD analysis will be different for different types of equipment. For example, in pump design, the objective is to ensure that optimum design of the blade profile and volute casing etc., is achieved to generate the required head and discharge. Similarly, in case of a heat exchanger, the objective is to ensure that desired heat exchange is achieved for the designed flow rate. For other equipment, the objective could be to optimize process design of the equipment. In all cases objective of CFD analysis is to establish optimum design to achieve performance parameters. Wherever heat transfer of different kinds like conduction and convection are involved along-with fluid flow, the firm should carry out conjugate analysis.

18. CFD analysis is required to be carried out using a competent software. It is not possible to indicate the detailed methodologies for CFD analysis as it will vary from equipment to equipment depending on the design requirement, fluid flow and heat transfer etc. Therefore, the vendor should discuss the detailed methodology with IAY/ IAG before finalization of their offer.

19. In all cases, the firm should follow the basic norms of CFD analysis and selection of elements and boundary conditions. However, it is desirable that the firm should discuss this with IAY/IAG before undertaking the analysis so that any difference of technical opinion can be resolved in advance. The firm should submit the full report of CFD analysis along with heat transfer calculations to IAY/ AIG in hard and soft copies including model file.

Finite Element Stress Analysis

20. Stress analysis by finite element method can be carried out in IDEAS or ANSYS software. In certain cases NASTRAN software can also be used with prior approval of IAY/IAG. The firm should discuss with IAY/ IAG in advance, regarding the type of model and meshing required to be developed and the various boundary conditions to be used.

21. The basic procedure of modelling, meshing and FEM analysis are required to be followed. The stress analysis should be undertaken for normal operating condition. The boundary condition should simulate all the operating condition parameters like various forces, temperatures, restraints etc..

22. It is not possible to specify the detailed procedure of analysis as it will vary from equipment to equipment. However, the objective of the analysis is to ensure that the equipment will meet the design requirement under operating condition and stresses and deflections are within the acceptable limits. The firm should submit full report of stress analysis in hard and soft copies including the model file.

Structure & Airborne Noise (SBN / ABN)

23. Air borne noise test is to be conducted at anechoic conditions to the extent possible. Test in reverberation chambers is to be conducted if essential as per SOTR. The permissible level of noise is specified in the SOTR for various types of equipment. The maximum levels of sound pressure in the test bed according to ISO 3744 in dB(A) at a distance of 1.0 meter from the equipment should not exceed the values as specified in the SOTR.

24. Since, conduct of test at anechoic conditions may not be practically feasible, noise levels are to be measured using Sound Intensity Meter (SIM) and not Sound Power Meter (SPM). This is because the SPM does not cancel the background noise. The SIM on the other hand, measures noise as a vector quantity, wherein it is possible to separate the background noise.

25. Noise and vibration, being related aspects, the analysis for meeting the specifications of SOTR for noise and vibration has to be done together and not in isolation.

Vibration

26. Vibration is a phenomenon inherent to any moving machinery. All rotating/ reciprocating equipment shall be subjected to vibration test to ascertain conformance to values mentioned in the SOTR.

27. Vibration test at factory premises to be conducted on a test bed that is adequately rigid to avoid influence of test bed vibrations on the equipment. The equipment is to be mounted on the S&V mounts as specified in the SOTR. It is preferable to hire an expert agency for measurement of vibrations. The measuring points, type of sensors for measurement and such other issues are to be resolved between the QAO, firm and measurement agency before start of trials. QAO is to ascertain validity of calibration before trials.

28. Vibration analysis is done in both 1/3 Octave and Narrow band. The 1/3 Octave band is an approximate indicator of the vibration levels. The values given for 1/3 Octave band can be at least taken as the limiting value around a given centre

frequency. Narrow band analysis is to be done to analyse abnormalities observed in the 1/3 Octave.

29. To the extent possible, the IAG should resolve all issues related to noise and vibrations before clearing the equipment. Necessary help from IAY, MTU, professional agencies should be solicited to resolve all issues. Unresolved issues should be clearly indicated in the I-Note.

<u>Analysis of Vibration Resistance</u>

30. Analysis of Vibration resistance is essential to ensure that the equipment will perform its duties under either propeller/ hull induced vibrations or sympathetic vibrations from other equipment. The frequency and the amplitude of the propeller induced vibration are indicated in the SOTR.

31. Vibration resistance analysis should be carried out by finite element method. Most preferable software would be LS-DYNA or ANSYS software. The objective is basically frequency response analysis. The FEM model generated for stress analysis or shock analysis can also be used for vibration resistance analysis. The objective of the analysis is to establish the response of the equipment, under external vibration spectrum.

32. It will not be possible to describe the details of analysis as it will vary from equipment to equipment. Therefore, the firm's rep should discuss the detailed methodology of the analysis with IAY/ IAG in advance so as to ensure proper modelling and analysis. The firm should submit full report of vibration analysis in hard and soft copies including the model file.