



**QA/QC Manual**

**&**

**Field Operations - Local P.W.H.T.**

**Standards and Procedures Manual**

**P.O. Box 1168  
Rocky Mountain House, AB T4T 1A8**

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January, 2008

To Whom It May Concern:

This Manual is the property of Tomco Group of Companies. It has been established to implement our commitment to excellence in the Heat Treatment Community.

We are committed to adhering to the Quality Assurance and Quality Controls identified in this document.

Sincerely,

A handwritten signature in blue ink, appearing to read "Rod Tomy".

Rod Tomy

President & CEO

## **Section 1**

### **A. Quality Assurance Manager Responsibilities**

1. Implementation and maintenance of an efficient Quality Control Program within the TOMCO System.
2. Identification of any quality problems and recommend changes in quality standard where necessary.
3. Verification that quality problems have been alleviated and corrected.
4. Stopping further processing of any work until the quality problem has been corrected.
5. Providing vendor appraisals to ensure the high standard of purchased materials.
6. Conduct training and Qualification in accordance with the Personnel Qualification and Certification Program.
7. Conducting internal audits.
8. Maintaining an accurate set of documents confirming the accuracy and control of the Quality Assurance Program.

### **B. Design Controls**

1. TOMCO does not perform any design of permanent plant systems.
2. Although TOMCO may offer advice on set-up and heat-treating procedures, the procedures must be reviewed and approved by the client prior to commencement of heat treatment activities.

### **C. Quality Assurance Program Objectives**

1. Provide Procurement control documentation that will be traceable to ensure that the quality standards have been met.
2. Implement corrective action procedures on non-conforming services or materials.
3. Provide vendor and supplier audits.
4. Perform internal audits of TOMCO on a regular basis.
5. Set up a system of control for conforming and non-confirming items.
6. Ensure that control and certification of temperature measurement and recording instruments have been done to the standards outlined.

7. Ensure that personnel training programs are in place and sufficient testing has been done to assign the various technicians to the different levels of competence. Personnel records are to be established and updated every three months.
8. Ensure that retention of records is maintained in compliance with industry codes and standards. All applicable Quality Assurance documents and records will be made available to TOMCO's clients.

## D. Procurement Documentation Control

1. A procurement control system will be set up to ensure compliance with codes and design specifications.
2. The purchasing department of each district office will issue purchase orders. All purchase orders pertaining to temperature measuring equipment and material deployed in nuclear related work will be issued only to approved vendors, which have been audited by TOMCO and approved by the TOMCO Quality Assurance Manager. An approved "sources of supply" list will be set up and updated on a regular basis (see Exhibit #3). At the discretion of the Quality Assurance Manager, any supplier who does not conform to the Quality Assurance audit or supplies non-confirming products will be deleted.
3. All pertinent information shall be included on the purchase order -
  - a) Date
  - b) Purchase Order Number
  - c) Supplier Name and Address
  - d) Date of Delivery
  - e) F.O.B. Point
  - f) Terms
  - g) Quantity and Unit Price
  - h) TOMCO Stock Number (if applicable)
  - i) Supplier Stock Code Number (if applicable)
  - j) The description of the product or service shall be completely detailed and include in it any codes or specification information that pertains to the particular product or service of the vendor/supplier.
  - k) Signature of Qualified Purchasing Agent
  - l) If any certificates of compliance or calibration certificates are required, they must be indicated on the purchase order.
  - m) For calibration services, thermocouple wire and other temperature measuring equipment, the purchase order must be reviewed by a Quality Assurance Supt.
4. A Qualified Quality Assurance Supt. Prior to their release to the warehouse, manufacturing facility or job site, shall inspect all incoming shipments.
5. All incoming goods or services conforming completely to the purchase order requirements shall be tagged with an acceptance tag (see Exhibit #4).
6. Shortage in quantity will not necessarily reject the goods received, provided that the quantity has not affected the quality. Any shortages in quantity shall be documented on incoming packing lists and submitted to the purchasing department.
7. Incoming defective goods or goods not conforming to the purchase order shall be tagged with a rejection note (see attached Exhibit #5). The rejected goods will then be placed in a designated quality controlled area to ensure that the goods do not get released into service for manufacturing. Once in the rejection area, all non-conformances shall be documented on a Corrective Action Report for non-conforming products (see Exhibit #6) with copies issued to the purchasing department, Quality Assurance Manager, District

Office File, Quality Assurance Vendor File and one sent to the vendor/supplier of the goods or services.

8. Purchasing Department will contact the supplier and inform them of the non-conforming goods sent to TOMCO. Unless some resolution is reached allowing rework or disposing of the product, the non-conforming goods will then be returned to the vendor/supplier with a copy of the Corrective Action Report for Non-Conforming Products (Exhibit #6).
9. The purchasing department will monitor the return of any non-conforming goods, replacement goods or the cancellation of any part of the purchase order.
10. The Quality Assurance Manager must approve any disposition. Should the disposition be for "rework", the Quality Assurance Manager will monitor rework activity and will not approve and close the Corrective Action Report until the rework has been completed and the product made acceptable.

#### **E. Technical Documentation Control**

1. TOMCO Management will review and approve all technical procedures and drawings related to the design or equipment application of preheat and post weld heat treatment operations. These documents shall be identified by drawing numbers, quotation numbers, procedure numbers or other suitable methods of identification for easy purposes (see Exhibit #10).
2. The issuing group or individual will maintain a distribution list so that updates, changes and revisions may be more readily directed to appropriate individuals. The Quality Assurance Manager shall approve all changes to documents. Prior to the reissuing of these documents, a record of the changes will be maintained by inclusion of a revision sheet attached to the drawing or document (see Exhibit #1, Document Index and Control Form).

#### **F. Identification & Control of Items Sent to Job Site**

1. TOMCO Management will issue an equipment and material requisition for on-site requirements. All items will be listed using TOMCO code numbers and detailed descriptions. Items requiring certificates of conformance or calibration test certificates shall have a copy of same accompanying the shipment.
2. Only items that have the TOMCO Acceptance Tag will be allowed to be used on-site.

#### **G. Control of Special Processes**

1. All procedures for heat-treating will be approved and accepted by the client prior to the commencement of the heat treatment cycle. The procedures will be outlined in detail on an Operating Procedure. This procedure requires signed acceptance by TOMCO Project Management, a qualified Client Representative and TOMCO Quality Assurance department. Upon approval by all of the above, quality assurance will stamp the Orientation Procedure as a "controlled copy" (see Exhibit #1). TOMCO Quality Assurance

shall be responsible to ensure that procedural revisions are updated to reflect current levels at all times for each "controlled copy".

2. At the completion of the job, complete documentation package will be presented to the client for acceptance and approval.
  - a) Recorder strip chart.
  - b) Calibration certificates, both temperature recorder and potentiometer.
  - c) Approved Operating Procedure.
  - d) Any deviation reports or revisions to the Operating Procedure.
  - e) Certificate of Conformance of the thermocouple and thermocouple extension leads.
  - f) Work acceptance sheets of TOMCO personnel and equipment.
3. It will be the responsibility of the client to decide what non-destructive examination is required on the area of the work piece where the thermocouples were attached.

#### **H. Inspection**

TOMCO will not be responsible for any inspection activities except for the set up and removal of the heat-treating equipment. All activities relating to the set up and removal will be outlined in the Operating Procedures (see Exhibit #11).

#### **I. Testing**

1. TOMCO will not be in charge of any testing.

#### **J. Control of Measuring Equipment**

1. TOMCO shall ensure that the calibration system used meets or exceeds the manufacturer's specifications required for the calibration of the measuring equipment. Equipment used for calibration purposes shall have a standard of accuracy higher than the measuring equipment the standard value is being transferred to.
2. An approved laboratory shall certify all calibration instruments used by TOMCO. All TOMCO calibration equipment shall be calibrated by the approved laboratory, minimum of once every six months, and issued a certificate showing the description of the calibration traceable to the laboratory.
3. For nuclear related work, recorders are calibrated prior to shipping and then checked after set-up at the job site location.

## **Section 2**

### **A. Handling, Storage and Shipping**

1. Storage of equipment and supplies shall be kept indoors and protected from outside weather conditions.
2. All items shall be packed, palletted and protected to assure no damage will occur during normal common carrier shipping conditions.
3. Upon arrival at site, TOMCO Site Technicians will inspect all items for:
  - a) Any damage to items during shipping.
  - b) Assure that all items have acceptance tag and appropriate certificates.
  - c) All items conform to the equipment listed on the Equipment and Material Requisition form.

### **B. Inspection, Test and Operating Status**

1. Equipment and material required for recording and measuring temperature must carry the acceptance tag (Exhibit #4) at all times from initial acceptance of the material to storage to shipping to job site.

### **C. Control of Non Conformance Items**

1. Upon inspection, any equipment or material found to be damaged during shipping, to be not conforming to the purchase order data, to lack certificates of conformance, to lack calibration certifications that are current, or any other reason, which may make the item non-conforming, will be immediately tagged with a rejection tag (see Exhibit #5). At this time the equipment or material will be moved to a segregated area and clearly marked NOT TO BE USED.
2. A copy of the rejection tag will be forwarded to the District Manager and the Quality Assurance Department.
3. On service work performed that has been found unacceptable, a Non-Conforming Service Form will be issued (see Exhibit #7). Site Superintendent or District Manager outlining the non-conforming service will then fill out this form. An investigation will be performed by the Quality Assurance Department as to cause of the non-conforming service. Copies will be sent to the District Manager and the Quality Assurance Manager for steps as outlines on the Corrective Action Report for Non-Conforming Service (Exhibit #8).

### **D. Corrective Action**

A formal documentation system for obtaining corrective action products and services shall be organized and monitored as follows.

## **Products Non-Conforming**

1. Products found to be not conforming to the specifications as ordered shall be found in a segregated area and tagged with a Rejection Tag (Exhibit #5). The Quality Assurance Department shall then inspect the products and issue a Corrective Action Report for Non-Conforming Products (see exhibit #6).
2. The disposition will be one of the following as determined by the Quality Assurance Manager or Supt.:
  - a) Return to the vendor
  - b) Scrap the product
  - c) Rework the product to meet Quality Assurance standards and approved by the Quality Assurance Manager or Designee.

One copy to the vendor.

One copy to the purchasing agent.

One copy to the District Manager.

One copy to the Quality Assurance Manager.

3. It will be the responsibility of the Quality Assurance Manager to follow up on this corrective action. The Quality Assurance Manager will verify this by signing off that the corrective action has been completed. This document will then be filed in the complete corrective action file.

## **Services Non-Conforming**

Services found to be non-conforming with the client's requirements or TOMCO's Quality Standards will be addressed by a Corrective Action Report for Non-Conforming Services Form (Exhibit #8).

The Quality Assurance Manager and the District Manager will work together and take the appropriate steps to correct the problem with service and assure that it will not happen again.

The Quality Assurance Manager will follow up to assure that the corrective actions have been taken and will verify this by signing the corrective action document and filling in a completed corrective action file.

## **E. Quality Assurance Records**

All records generated by the TOMCO Quality Assurance Program, resulting from the work performed, shall be submitted to the client upon completion of the job. Secondary non-permanent copies will be retained at the TOMCO Home Office.

Responsibility of the retention of all documentation will be that of the client. TOMCO will assist and inform to the best of our ability, utilizing all copies of records retained to that particular job, should the need arise.

## **F. Audits**

The Quality Assurance Manager or his delegate will perform audits.

2. A qualified Quality Assurance Department representative as per Exhibit #2, Vendor/Supplier Audit Form, will do EXTERNAL AUDITS.
3. INTERNAL AUDITS will be done to ensure that the district office is complying with the TOMCO Quality Assurance Standards and Procedures. A written report and checklist (see Exhibit #12) will be prepared and submitted to the District Manager. If any non-conformances are noted, a corrective action document will be issued. They will then be allowed a reasonable length of time to carry out the corrective action and then re-audit to verify the Quality Assurance Standards have been met.
4. When all Quality Standards are met the Quality Assurance Manager will submit an approval letter to the District Manager.
5. Both external and internal audits will be performed a minimum of 'once yearly' intervals.



INTERNAL AUDIT CHECKLIST

District Office \_\_\_\_\_ Date \_\_\_\_\_

District Office Manager \_\_\_\_\_

Audit Performed By \_\_\_\_\_

Audit Approved By \_\_\_\_\_

DOCUMENTATION	COMMENTS
I. TEMPERATURE MEASUREMENT	_____
Recorder Certificates (current and past)	_____
Potentiometer Certificates (current and past)	_____
QQ-20-K Thermocouple Wire Certificates (purchase orders, packing list balance sheets)	_____
UP/AL-PTW Extension Wire Certificates (purchase orders, packing list balance sheets)	_____
Female Thermocouple Jacks Certificates (purchase orders, packing list balance sheets)	_____
Male Thermocouple Jacks Certificates (purchase orders, packing list balance sheets)	_____
Miscellaneous Material	_____
1. _____	_____
2. _____	_____
3. _____	_____
	_____
	_____
	_____
	_____
	_____
	_____
	_____
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	_____
	_____



**INTERNAL AUDIT CHECKLIST**

<b>DOCUMENTATION</b>	<b>COMMENTS</b>
II. PERSONNEL	<hr/> <hr/>
Personnel File (updates and evaluations)	<hr/> <hr/>
Personnel Training and Testing Reports	<hr/> <hr/>
Personnel Non Conformance Reports	<hr/> <hr/>
Training Material Available	<hr/> <hr/>
Miscellaneous	<hr/> <hr/>
III. CLEINT JOB FILES	<hr/> <hr/>
Completed Prewrite Order Forms	<hr/> <hr/>
Completed On-Site Job Logs	<hr/> <hr/>
Completed Work Acceptance Forms	<hr/> <hr/>
Procedures and Document Control Index	<hr/> <hr/>
Procedures and Non Conforming Service Reports	<hr/> <hr/>
Miscellaneous	<hr/> <hr/>
	<hr/> <hr/>
	<hr/> <hr/>
	<hr/> <hr/>
	<hr/> <hr/>
	<hr/> <hr/>



**INTERNAL AUDIT CHECKLIST**

<b>DOCUMENTATION</b>	<b>COMMENTS</b>
IV. SUPPLIER AUDITS	_____ _____
Audits - Current and Updated	_____ _____ _____ _____
Audit Samples and Evidence	_____ _____ _____ _____ _____
V. INTERNAL AUDIT	_____ _____
Audit Reports Filed	_____ _____ _____ _____
Internal Quality Assurance Communications Filed	_____ _____ _____ _____ _____
VI. SAFETY	_____ _____
Meetings and Reports	_____ _____ _____ _____ _____



INTERNAL AUDIT CHECKLIST

DOCUMENTATION	COMMENTS
<b>I. TEMPERATURE MEASUREMENT</b>	
Recorders with Calibration Stickers	
Potentiometer with Calibration Stickers	
QQ-20-K Thermocouple Wire, UP/AL-PTW Thermocouple Wire, Female Thermocouple Jacks, Male Thermocouple Jacks:	
Material Acceptance Tags Attached	
Properly Segregated	
Proper Storage - "Acceptance & Rejection"	
Non Conforming Product Reports	
<b>II. HEAT TREATMENT EQUIPMENT</b>	
Heat Treatment Control Consoles serial numbers, controllers, panel mount thermocouples and camlocks, breakers, meters, switches, storage, callum grips, etc.	
Heating Elements	
Triple Cable Sets and Splitters	
Spare Parts Inventory	
Miscellaneous	



INTERNAL AUDIT CHECKLIST

DOCUMENTATION	COMMENTS
III. SHOP	
Tidiness and Condition	
Storage of Equipment	
Vehicle Inspection	
Current Insurance Certificates	
Current Ownership Certificates	
Body Condition	
Mechanical Condition	
Miscellaneous	

COMMENTS AND RECOMMENDATIONS: \_\_\_\_\_  
 \_\_\_\_\_  
 \_\_\_\_\_  
 \_\_\_\_\_  
 \_\_\_\_\_  
 \_\_\_\_\_  
 \_\_\_\_\_

Please note all findings that require corrective action must be submitted and/or prepared for re-audit within a maximum of 30 days.

Quality Assurance  
 Manager: \_\_\_\_\_



**GENERIC**  
**FIELD OPERATIONS**  
**LOCAL POST WELD HEAT TREATMENT**  
**STANDARDS AND PROCEDURES**  
**MANUAL**

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ITEM: 1.0

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TITLE: Personnel Competence

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### 1.1    COMPETENCE OF ON-SITE SUPERVISION AND MANPOWER

TOMCO maintains a formal training program for all levels of employees. Training records for off and on the job training are maintained at the District Office in the individual employee personnel file. These programs are essential in achieving consistent quality performances as necessary to meet the specifications listed in this manual.

Supervisors should be well versed in the relevant electrical, metallurgical and thermal technology and all applicable code requirements.

Personnel directly involved in preparing the work, or operating the equipment shall have received formal training in the method of the heat-treating being performed. Their training shall enable them to ensure that:

- a)    Equipment is maintained in safe operating conditions and fully calibrated.
- b)    Temperature monitoring includes all potential hot or cold spots, and that the heat treatment complies with all applicable code requirements.
- c)    Electrical or mechanical connections are secure to eliminate failures at elevated temperatures.
- d)    Thermal insulations are suitable to provide acceptable temperature gradients.
- e)    Maximum temperature limitations are not exceeded through causes of incorrect procedures, equipment malfunction or misjudgement of heat flow characteristics at elevated temperatures.



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**TITLE: Measuring Equipment and Documentation**

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2.1 MEASURING AND RECORDING EQUIPMENT

All measuring and recording devices shall be dependable and capable of sustaining a high level of accuracy.

All thermocouples, associated extension leads and connectors shall be made of Cr/Al (Type K alloys). No other combination of thermocouple wires and extension leads shall be permissible. All thermocouple wire shall be Guaranteed Millivolt Grade (GMV) and the certificate of conformance shall be traceable for each batch, coil or specified unit acceptable to the established QA/QC policy.

All thermocouples shall be attached to the work using the capacitance discharge method; refer to section 4.02 (a through i) thermocouple attachment Section.

Recorders shall be potentiometric to ensure:

- a) A high degree of sensitivity
- b) Compensation for ambient temperature
- c) Compensation for external resistance
- d) Elimination of incorrect calibration due to shock

Chart speeds and chart graduations shall be such that temperature variations of twenty (20) degrees can be clearly determined. Recorder accuracy shall be plus/minus one percent (1%) of span or point five percent (.5%) of full-scale deflection or better.



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TITLE: Measuring Equipment and Documentation

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Temporarily mounted temperature recorders shall have the veracity of calibration checked prior to being used, all thermocouple extension leads shall be checked for secure connections and checked that double reverse connections between recorders and thermocouples are not present. Permanently mounted recorders will be calibrated every six months. Each recorder shall have a calibration sticker securely attached in a prominent place indicating the date of calibration and the next due date.

Instruments used for calibration shall have an accuracy of plus/minus point two five percent (.25%) scale range or better. This master instrument shall be calibrated and tested using a standard source traceable to the National Institute of Standards and technology (NIST), formerly know as the National Bureau of Standards (NBS).

## 2.2 DOCUMENTATION

Complete and permanent records of all work shall be compiled. Before any work is to commence, senior technicians along with client shall prepare the Pre-Work Order form (see attached form). Detailed information on the methods and procedures for heat-treating each different set-up shall be outlined on this form. After close review of this pre-work order form the client acknowledges that the procedures and work descriptions are in accordance with his plan specifications and instructions.

The client will then sign the pre-work order form at the bottom right-hand corner. The three-part form will then be distributed, one copy to the client, one copy to be retained by the senior technician for the office job file, and one copy to be displayed at the work control/recorder/heat treating machine location.



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TITLE: Measuring Equipment and Documentation

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Each recorded chart shall show the thermocouple temperatures for incline hold and decline as specified in the Pre-work order form. Each thermocouple recording point shall be identified to the weld number, size and exact thermocouple location so that the complete heat cycle history at each point can be determined. Details of and complex configurations shall also be included on the chart. Each recording chart shall be dated and signed prior to being submitted to the client.

Upon completion of the work, the senior technician will complete a work acceptance form, outlining the equipment, labour and material used. After the client review of the temperature recording chart and inspection of the work, the client can sign the work acceptance form in the bottom right-hand corner. The senior technician assigned will then assemble a copy of the pre-work order form, the temperature recording charts and a copy of the work acceptance form to be submitted to the client for his records.

The client's inspection department shall verify that the PWHT is acceptable and has been performed according to the applicable code and is responsible for the final acceptance.



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TITLE: Material Condition (work)

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### 3.1    CONDITION OF PIPING OR VESSELS

Heat treatment shall not be attempted on piping, vessels or boilers that contain liquids, sludge or flowing gases. All blanks and flanges shall be checked and tagged to ensure that no liquids or gases are suddenly introduced into the heated zone.

### 3.2 VALVES AND FLANGE ADJUSTMENT

Where valves are in close proximity to welds that require heat treatment, the valve manufacturer's recommendations for the gate position and temperature limitations shall be followed.

Where torqued flanges are within a heated area, all bolts shall be loosened and gaskets removed.

### 3.3 STRESSES ON HEATED SECTIONS

A section requiring heat treatment shall have no detrimental stresses acting on it due to material weight or restraining attachments that could create distortion. All piping and horizontal vessels shall be adequately supported to prevent bending moments acting on the heated zone due to the weight of the material.

Consideration shall be given to material strength, wall thickness and attachment of heavy sections.



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TITLE: Material Condition

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When heating all or part of a vertical vessel, stress shall be calculated to ensure that there will be no detrimental effects due to compressive stresses or bending moments. Calculations shall include the weight of the vessel above the heated section, stress due to thermal expansion, and shall allow for possible wind velocities.

Any attachments that will create restraint during thermal expansion shall be released.

#### 3.4 INITIAL AND FINAL TESTING OF SYSTEMS

Initial testing shall not detrimentally affect the quality of the subsequent heat treating; also all heat treated areas shall be included in the final inspection and system test.

Preliminary hydrostatic testing of welds shall not be performed prior to post weld heat treating unless essential. Where hydrostatic testing is performed, all water shall be drained from the system within the weld area, and shall be vented to allow for the escape of steam. Preliminary testing with explosive gases or fluids shall not be permitted prior to heat treatment.

**There shall be no pressure testing of any nature on a system undergoing post weld heat treatment.**



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TITLE: Preparation for Heat Treatment

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#### 4.1      PREPARATORY WORK INVOLVING WELDING

Welding of support structures, temporary attachments and thermocouples shall be performed in accordance with qualified welding procedures for that particular material. On all piping, vessels or structures requiring post-weld heat treating, no welding shall be performed outside the heat band produced by the post-weld heat treatment. Certified welders using filler metal and welding parameters that are compatible with the parent material shall perform all welding. Preheating shall be applied as required by the parent material.

#### 4.2      THERMOCOUPLE ATTACHMENT

Thermocouples shall be attached using the direct capacitance discharge welding method, this direct wire attachment method spot welds thermocouple wires directly to the work piece and insures accurate temperature measurement, and the work piece becomes the thermocouple hot junction. Other methods of thermocouple attachment can result in errors.

Operating Instructions for thermocouple Attachment Unit

- a)      Clean all loose scale or rust from the work piece where the wires are to be attached. Do not clean to brightness or polish, as the process requires a certain amount of resistance at the attachment point to initiate a discharge arc.
  
- b)      Clean an area close to the thermocouple position to bright metal, attach the return magnet at this point, it should be very secure so as to reduce resistance to a minimum.



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TITLE: Preparation for Heat Treatment

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- c) Strip the insulation from each of the thermocouple wires to leave approximately one quarter inch (1/4") of bare on each wire.
- d) Set the discharge welder output control at about eighty percent (80%).
- e) **Put on your tinted "flash guard" Safety Glasses**
- f) Grasp one of the wires with the tip of the jaws of the application pliers leaving about one eighth (1/8") of an inch exposed.
- g) Press the **"end of the wire"** to the work piece at ninety (90) degrees to the surface and maintain a firm pressure (**without directly grounding the pliers to the work**). Press the charge button and wait for the ready light to glow. The output level meter should read the required preset level (80%).
- h) Press the discharge button and the wire should arc weld to the work piece. There will be a sharp crack and a slight arc flash.
- i) Gently press the wire over at right angles. This is required in most jobs, so as to bring out the thermocouple wires along or parallel to the surface of the work piece. It also tests the strength of the weld. If the weld shows signs of breaking, remove the wire and re-prepare the ends and try again, (**do not try without re-preparing the ends**).
- j) If successful, repeat the process with the other wire placing it approximately one quarter inch (1/4") away from the first.

Thermocouple points under resistance heating elements shall be insulated from incidental element radiation using hi-temperature insulating putty. Where material thickness within the heat zone varies considerably, thermocouples shall be attached to both the thickest and the thinnest sections to insure no overheating or under heating occurs.



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TITLE: Preparation for Heat Treatment

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Supervisors shall use discretion in attaching spare thermocouples at critical locations in case of malfunction. Where more than one power source is required to heat an area, a minimum of one thermocouple shall monitor each independently controlled heating element.

#### 4.3 THERMOCOUPLE LOCATION

Thermocouples shall be located to provide a survey map of heating uniformity and enable time and temperature control.

There shall be a minimum of one thermocouple located on every heat band.

For preheating, thermocouples shall be located one and one half inches (1 ½") from the weld groove. For standard post weld heat treatment, thermocouples shall be located with the reference point in contact with the weld cap. For wide heat bands, the thermocouple shall be situated to ensure that the full width of the required heat band is maintained.

All nozzles and other welded attachments that cause potential heat sinks through metal mass or cause cold spots due to heat convection or conduction shall be monitored by thermocouples.

#### 4.4 MANDATORY CIRCUMFERENTIAL HEAT BANDS

In cases where welding or localized heating has caused circumferential stresses and heat treatment is required a circumferential heat band shall be obligatory. Post weld heat treatment of welded attachments such as nozzles, patches, pipe shoes, anchors and re-pads shall require a circumferential heat band around the pipe or vessel and shall include the welded addition.



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#### 4.5    WIDTH OF HEATING BANDS

Heat bands shall be extended to ensure stresses within the weld heat affected zone and adjacent materials are reduced to an acceptable level in accordance with code requirements

Heat bands on vessel welds shall be extended not less than two (2) times the shell thickness on both sides of the finished weld.

Heat bands on pipe welds shall be extended not less than three (3) times the width of the weld reinforcement (cap) on both sides of the weld.

Heat bands on nozzle welds shall be extended not less than six (6) times the plate thickness of the vessel on both sides of the weld area.

Heat bands on welded shoes, reinforcing pads, or other attachments shall not be less than six (6) times the plate thickness on both sides of the weld. Where local or circumferential heat has been applied for alignment purposes, heat bands shall include the entire area and six (6) times the thickness of the material on all sides.

#### 4.6    CONTINUITY AND OVERLAPPING OF HEAT BANDS

On post weld heat treatment of piping, vessels and/or boilers where multiple or overlapping heat bands are required, assurance is essential that all material has experienced uniform heating, holding and cooling.

Note: B31.1 is a piping standard requiring that the heating band extend 3” or 1.5 times the thickness (t) of the pipe, whichever is greatest. ASME Section I require the band to be 3t both sides of the weld minimum. ASME Section VIII, Div-1 requires the band to be not less than 3” either side of the weld. In all instances and as a minimum the applicable code requirement shall prevail whilst adopting the client’s local requirements.



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#### 4.7 HEATING UNIFORMITY

All post weld heat treatment of piping, vessels and/or boilers shall conform to the following minimum thermal insulating standards to ensure temperature uniformity.

##### 4.7.1 INSULATION PROCEDURE

All bands shall have a 2" thickness of high temperature insulation extended on either side of the weld to provide gradual thermal gradients. No insulation shall be used which contains material that may contaminate the metal being heated. Insulating procedures for materials up to two inches (2") thick shall be as follows:

- a) For wall thickness up to and including one inch (1"), insulation shall be extended a minimum of nine inches (9") on both sides of the heat band.
- b) For wall thickness between one inch (1") and one and one half inches (1.5"), insulation shall be extended a minimum of twelve inches (12") on both sides of the heat band.
- c) For wall thickness in excess of one and one half inches (1.5"), insulation shall be extended a minimum of eighteen inches (18") on both sides of heat band.

##### 4.7.2 Insulating procedures for materials in excess of two inches (2") thick and four feet (4') and greater outside diameter shall be as follows:

- a) Medium material (2" to 4") insulation shall be extended an additional twelve inches (12") minimum on both sides of the heat band.
- b) Thick material (in excess of 4") twenty-four inches (24") minimum on both sides of the heat band.



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4.7.3 When external heating is employed on medium and thick sections, insulation shall be applied to both the inside and outside of the material where access can be reasonably and safely obtained to the internal area.

4.7.4 Insulation shall under no circumstances be removed from P-Number 3 through P-Number 5 materials where the temperature is in excess of six hundred (600) degrees. The preference shall be to leave insulation intact until the material has returned to ambient temperature.



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### 5.1 HEAT CYCLES

Determination of heat cycles shall be such that the material is in the optimum condition after heat treatment.

Please refer to the recommended heat cycles (section 7), which incorporate the A.S.M.E. Code Sections III and VIII, and the A.N.S.I Codes B31.1 and B31.3 as guidelines.

### 5.2 DISSIMILAR THICKNESS

Where dissimilar thicknesses have been welded together the thicker material shall govern.

The post weld heat treatment heating rate, the holding time and the cooling rates shall conform to the requirements for the thicker material, **providing** both materials are the same composition.

When heating reinforcing pads the total heat cycle must be adjusted accordingly to allow for the increase material thickness.

### 5.3 DISSIMILAR MATERIAL

Where dissimilar materials of P-Number 1 through P-Number 5 groups have been welded together or dissimilar welding rod has been used, heating specifications for the higher alloy material shall govern with certain provisions.

- a) The preheat temperature shall be that of the higher alloy material.
- b) When pressure parts are welded to non-pressure parts, the post weld heat treatment for the pressure part/s shall govern.



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The post weld heat treatment holding time shall be for the higher of the two temperatures given for the materials providing that this temperature is not in excess of the transformation temperature of the lower alloy material, otherwise the holding temperature shall be reduced to fifty (50) degrees below the transformation temperature for the lower alloy material and the holding time extended proportionately (see table 5.4)

Where different cooling rates are specified, the slower rate shall govern.

Where stainless steel subject to carbide precipitation has been welded to a P-Number 1 through P-Number 5 material there is no perfectly satisfactory stress relieving heat cycle. If carbide precipitation is of little consequence, the normal heat cycle for the low or medium alloy steel may be used. Alternatively, a normalizing treatment may be used for the lower alloy steel.

**5.4    DECREASE IN POST WELD HEAT TREATMENT HOLDING TEMPERATURE**

If it is considered essential to employ a decreased holding temperature, then an increase of holding time shall apply only by the client's inspection department's acceptable procedures.

Where there is an unavoidable decrease in the specified code holding temperature, then the holding time shall be extended as given below or as by the client's inspection department's acceptable procedures:

DECREASE IN HOLDING TEMPERATURE	HOLDING TIME MULTIPLICATION FACTOR
50	2
100	3
150	5



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Engineers should consider that residual stresses would not be reduced as effectively as when the correct temperature range is employed.

Please note - the allowance to decrease the holding temperature while increasing the holding time period **does not apply to material** P-Number 4 and P-Number 5.

5.5      INTERRUPTION OF HEATING DURING POST WELD HEAT TREATMENT

If the post weld heat treatment cycle is interrupted immediate steps shall be taken to decrease the cooling rate by applying additional insulation. Subsequent heating shall be in accordance with the relevant heat cycle.



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TITLE: Preheating

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### 6.1    TEMPERATURE UNIFORMITY

All preheat temperatures should be controlled and recorded throughout the welding period.

The preferred method of preheating shall be by resistance heating elements. The temperature shall be continuously recorded using a thermocouple located at one side of the vertical welds and/or at the location estimated to be the coolest part of the weld groove.

No welding shall start until both circumferential sides of the weld groove are above the prescribed minimum preheat temperature.

If the weld groove has been insulated to assist the rise in temperature, an allowance shall be made for the subsequent drop in temperature, when this insulation is removed for welding.

The preferred method of temperature monitoring shall be Nickel Chrome/Nickel Aluminium (Type K) thermocouple attached to the work piece.

The next best method would be to attach a stainless steel sheath thermocouple probe beside the weld to be preheated, this by the use of a T/C clip or T/C slotted nut tack welded or by banding this to the area. Alternatively, if no permanent record is required, a temperature sensitive crayon may be used to repeatedly check the temperature in the immediate area where the material is being welded.

On completion of welding, the weld area shall be wrapped with insulation to allow for slow cooling to ambient temperature. If there is any interruption in welding, the heat shall either be continuously applied until welding recommences or the weld shall be slow cooled as if on weld completion, but only if the amount of weld deposit complies with the code.



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#### INTERRUPTION OF PREHEAT

It is preferred that welding of a preheated joint should be completed without interruption.

For steel piping less than one inch (1") wall thickness, the weld deposit shall be a minimum of one third (1/3) the wall thickness or two passes **whichever is the greater** before any interruption of the welding shall be allowed. For carbon steel welding one inch (1") to two inch (2") wall thickness the minimum thickness of weld deposit shall be one half inch (1/2"). For carbon steel piping over two inches (2") wall thickness, the weld deposit should be three quarters of an inch (3/4") or one quarter (1/4) wall thickness before any interruption of the welding.

For alloy steels containing greater than one percent (1%) chromium, welding may be interrupted as for carbon steels provided that low hydrogen electrodes are used and the welds are not in high restraint configurations.

For alloy steels containing greater than two and one quarter percent (2-1/4%) chromium and over one inch (1") wall thickness, no interruption of welding shall be permitted. It may also be necessary to either immediately post weld heat treat or intermediate heat treat by heating to twelve hundred (1200) to thirteen hundred (1300) degrees F.

*Note: The client may have specific instructions regarding interruption of welding and shall be requested and adhered to.*

Local requirements shall be detailed on pre-work order forms prior to start of work.



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The exact heat cycle for a particular material is often stipulated by an owning company or by the codes. There are five separate segments of any heat cycle.

- a) Initial rapid heating segment
- b) Controlled heating rate segment
- c) Holding time and temperature segment
- d) Controlled cooling rate segment
- e) Final cooling rate segment

#### 7.1 INITIAL RAPID HEATING SEGMENT

At low temperatures, the steel can tolerate fairly rapid heating since it has high tensile strength. However, care must be taken when heating thick sections or brittle materials since the considerable thermal gradients produced could have detrimental effects. The limit to this rapid heating range is generally six hundred (600) degrees F.

#### 7.2 CONTROLLED HEATING RATE SEGMENT

A controlled heating rate is given so that the work is evenly heated to the correct holding temperature, thereby giving sufficient time for thermal gradients and to equalize without producing thermal stresses. These thermal stresses combined with residual stresses could produce yielding or cracking of the material since the tensile strength is decreasing as the temperature increases.

The heating rate for carbon steel and most low to medium alloy steels is four hundred (400) degrees per hour per inch thickness.



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### 7.3    HOLDING TIME AND TEMPERATURE SEGMENT

The holding (soak) period is to allow the stress relieving (relaxation) time to occur, also to allow for thermal gradients to equalize. Most codes require one hour per inch of thickness for carbon steel, and either one or two hours per inch thickness for low and medium alloy steels. The material determines the holding temperature. Carbon steel and low to medium alloy steels essentially consists of two phases, ferrite and pearlite. When heated above a certain temperature called the Transition Temperature, the grain size increases causing considerable loss in strength, and another phase, austenite, starts to replace the ferrite and pearlite phases. To obtain the optimum stress reduction the temperature should be as close to the transition temperature yet provide sufficient allowance for mechanical and human errors, heat concentration, etc. For carbon steel the transition temperature is thirteen hundred and thirty three (1333) degrees and the usual stress relieving temperature is eleven hundred and fifty (1150) degrees. For low and medium alloy steels, the alloy content increases the transition temperature so higher stress relieving temperatures are required to obtain similar amounts of stress relief (refer to the following table on page 21 for guidelines).



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Alloy	P-number	APPROXIMATE TRANSITION TEMPERATURE	APPROXIMATE STRESS RELIEVING TEMPERATURE
Carbon Steel	1	1333	1150
C1/2%Mo	3	1340	1200
1-1/4%Cr ½%Mo	4 Group No.1	1375	1350
1-1/4%Cr ½%Mo	4 Group No.2	1430	1350
2-1/4%Cr 1%Mo	5	1480	1400
5%CR ½%Mo	5	1505	1400
7%Cr ½%Mo	5	1520	1400
9%Cr 1%Mo	5	1490	1400

7.4 CONTROLLED COOLING RATE SEGMENT

The cooling rate is very important, since a too rapid, or unequal cooling rate, will produce thermal stresses which will be retained in the material. Although these will not be in the same magnitude as the original residual stress, the material will not be adequately stress relieved. Controlled cooling is done by reducing the heat input to the steel while the insulation is intact. Carbon steel and low alloy steels containing less than one percent (1%) Cr is generally cooled at five hundred (500) degrees per hour per inch from the holding temperature down to six hundred (600) degrees. Low and medium alloy steels with over one percent (1%) Cr content are either cooled at four hundred (400) to five hundred (500) degrees per hour per inch or cooled in two stages since the initial slower cooling rate has been found beneficial in decreasing weld hardness.



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#### 7.5    FINAL COOLING RATE STAGE

Final cooling rate is from six hundred (600) degrees to ambient temperature. Usually this rate is not stipulated since cooling is naturally slow i.e.: less than approximately four hundred (400) to five hundred (500) degrees per hour. As with initial fast heating, the cooling rate is not critical, however no insulation shall be removed since this may cause unequal cooling.

#### 7.6    P-NUMBERS

The American society of Mechanical Engineers introduced the P-Number grouping of base metals to reduce the number of welding procedure qualifications required. The P-Number grouping of base metals is based essentially on comparable base metal characteristic such as composition, weldability, and mechanical properties. The grouping does not imply that base metals may be indiscriminately substituted for a base metal which was used in a qualification test without due consideration of the compatibility from the standpoint of metallurgical properties, post weld heat treatment, design, mechanical properties, or service requirements. Where notch toughness is a consideration, it is presupposed that the base metals meet the specific requirements.

#### 7.7    RECOMMENDED HEAT CYCLES

The following tables of recommended heat cycles are generic. In each instance of application, they shall be reviewed with the client's inspection department and approved by definition and documentation onto the job specific pre-work order form prior to the start of any PWHT.



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7.8    RECOMMENDED HEAT CYCLES

Material:                    Plain Carbon Steel

P-Number:                    1

Applications:    General Construction, Heavy Fabrication. Shell plates and tube sheets in super heater, boilers, reactors and heat exchangers. Maximum Service 750 degrees (without graphitization), otherwise 900-1000 degrees (with low stresses). Also pipe work if low corrosive environments.

Transformation Temperature:

1333 Degrees

Recommended Preheat Temperature:

60 Degrees minimum, 100 degrees minimum for 1: to 2: sections or greater than 0.3% carbon content.  
200 degrees minimum for greater than 2" sections.

Recommended Post Weld Heat Treatment

Rise from ambient to 600 deg F at a moderate but unrestricted rate.  
600 to 1150 deg F at 400 deg F /hr max (divided by the material thickness).  
Hold at 1150 Deg F for 1 hr /inch of thickness, Minimum of 1 hr.  
Cool to 600 deg F at 500 deg F /hr max (divided by the material thickness).  
From 600 deg F to ambient in still air/under insulation.

Recommended Final Brinell Hardness Number: 200 BHN Maximum



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Material                                      Carbon 1/2% Molybdenum

P-Number:                                      3

Applications: As for carbon steel but can be more highly stressed. Molybdenum increases short time tensile strength and decreases creep rate. Maximum service in graphitizing conditions is 850 degrees. Refinery still, boiler and super heater tubes and reactor shells. Also in chemical and petro-chemical process piping.

Transformation Temperature:

1340 Degrees

Recommended Preheat Temperature:

60 Degrees minimum  
200 Degrees for greater than 1/2" sections.

Recommended Post Weld Heat Treatment:

Rise from ambient to 600 deg F at a moderate but unrestricted rate.  
600 to 1200 deg F at 400 deg F /hr max (divided by material thickness).  
Hold at 1200 deg F for 1 hr /inch of thickness, minimum of 1 hr.  
Cool to 600 deg F at 500 deg F /hr max (divided by the material thickness).  
From 600 deg F to ambient in still air/under insulation.

Recommended Final Brinell Hardness Number: 225 BHN Maximum

N.B. If pre-stress relief hardness is in excess of 265 BHN the holding temperature should be increased to 1250 degrees.



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Material:                    1-1/4% Chromium 1/2% Molybdenum

\*P-Number:    4

Application:    Chromium supplements Molybdenum to minimize graphitization, which does not occur when greater than 1/2% Cr. Maximum operating temperature 1100 degrees. All Cr Mo alloys with less than 10% Chromium have good creep properties. Used for main steam lines and pressure vessels.

Transformation Temperature:

1430

Recommended Preheat Temperature:

300 degrees minimum  
400 degrees minimum  
for greater than 3/4" thick sections.

Recommended Post Weld Heat Treatment:

Rise ambient to 600 deg F at a moderate but unrestricted rate.  
600 to 1350 deg F at 400 deg F max (divided by material thickness).  
Hold at 1350 deg F for 2 hrs min + 1 hr /each additional inch of thickness.  
Cool to 600 deg F at 400 deg F max (divided by material thickness).  
From 600 deg F to ambient in still air/under insulation.

Recommended Final Brinell Hardness Number: 225 BHN Maximum.



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N.B. If pre-stress relief hardness is in excess of 265 BHN the holding temperature should be increased to 1400 degrees.

If in excess of 285 BHN, the cooling rate from hold to 1100 degrees should be 150 degrees maximum per hour per inch. Then from 1100 degrees to 600 degrees at 400 degrees maximum per hour per inch.

If a final weld hardness of 215 BHN is required, the pre-stress relief hardness requirements should be reduced accordingly.

\*This includes material referred to as "P-11" which is P-Number 4 Grade P11.



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Material:                    2-1/4% Chromium 1% Molybdenum

\*P-Number:    5

Applications: 1% Molybdenum improves short time tensile strength and creep strength over 1/2% Molybdenum. This alloy has the highest creep strength of low and medium alloy steels. Suitable for 1200 degrees service if only moderate corrosion/oxidation required. Main steam lines, boiler and condenser tubes, pressure vessels and steam chests.

Transformation Temperature:

1480 Degrees

Recommended Preheat Temperatures:

400 degrees minimum  
500 degrees minimum  
For greater than 3/4" sections.

Recommended Post-Weld Heat Treatment:

Rise ambient to 600 deg F at a moderate but unrestricted rate.  
600 to 1400 deg F at 400 deg F (divided by material thickness).  
Hold at 1400 deg F for 2 hrs min + 1 hr /each additional inch of thickness.  
Cool to 600 deg F at 400 deg F max (divided by material thickness).  
From 600 deg F to ambient in still air/under insulation.

Recommended Final Brinell Hardness: 241 BHN Maximum



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N.B. If pre-stress relief hardness is in excess of 290 BHN, the cooling rate from hold to 1100 degrees should be 150 degrees maximum per hour per inch.

If in excess of 310 BHN, the cooling rate from hold to 600 degrees should be 150 degrees maximum per hour per inch.

If a lower final weld harness is required, the pre-stress relief hardness requirements should be reduced accordingly.

\*This includes material referred to as "P-22" which is P-Number 5, Grade P22.



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Material: 5% Chromium 1/2% Molybdenum

\*P-Number: 5

Applications: Excellent combination of creep, stress corrosion and oxidation resistance. Suitable for 1150 degrees service and in sulfur environments. General refinery piping, sub heaters, heat exchanger and expansion chambers.

Transformation Temperature:

1505 Degrees

Recommended Preheat Temperature:

500 Degrees Minimum

Recommended Post Weld heat Treatment:

Rise ambient to 600 deg F at a moderate but unrestricted rate.  
600 to 1400 deg F at 400 deg F max (divided by material thickness).  
Hold at 1400 deg F for 2 hrs min + 1 hr /each additional inch of thickness.  
Cool to 600 deg F at 400 deg F max (divided by material thickness).  
From 600 deg F to ambient in still air/under insulation.

Recommended Final Brinell Hardness Number: 241 BHN Maximum



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N.B. If pre-stress relief hardness is in excess of 300 BHN, the cooling rate from hold to 1100 degrees should be 150 degrees maximum per hour per inch. Then from 1100 to 600 degrees at 400 degrees maximum per hour per inch.

If a lower final hardness is required, the pre-stress relief hardness requirements should be reduced accordingly.



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Material: 7% Chromium 1/2% Molybdenum

P-Number: 5

Applications: Excellent combination of creep, stress corrosion and oxidation resistance. Used for severe corrosion and oxidation requirements to 1200 degrees. Used in refineries where sour crudes and sulfur bearing materials are processed.

Transformation Temperature:

1520 Degrees

Recommended Preheat Temperature:

500 Degrees Minimum

Recommended Post Weld heat Treatment:

Rise ambient to 600 deg F at a moderate but unrestricted rate.  
600 to 1400 deg F at 400 deg F max (divided by material thickness)  
Hold at 1400 deg F for 2 hrs min + 1 hr for each additional inch of thickness.  
Cool to 600 deg F at 400 deg F max (divided by material thickness).  
From 600 deg F to ambient in still air/under insulation.

Recommended Final Brinell Hardness Number: 241 BHN Maximum



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N.B. If pre-stress relief hardness is in excess of 300 BHN, the cooling rate from hold to 1100 degrees should be 150 degrees maximum per hour per inch. Then from 1100 to 600 degrees at 400 degrees maximum per hour per inch.

If a lower final weld hardness is required, the pre-stress relief hardness requirements should be reduced accordingly.



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Material:                    9% Chromium 1% Molybdenum

P-Number:                    5

Applications: Excellent creep, stress corrosion and oxidation resistance. High chromium gives corrosion resistant service to 1200 degrees. Used in refineries for very sour crudes and applications where highly corrosive materials do not require stainless steel.

Transformation Temperature:

1490 Degrees

Recommended Preheat Temperature:

500 Degrees Minimum

Recommended Post Weld heat Treatment:

Rise ambient to 600 deg F at a moderate but unrestricted rate.  
600 to 1400 deg F at 400 deg F max (divided by material thickness).  
Hold at 1400 deg F for 2 hrs min + 1 hr /each additional inch of thickness.  
Cool to 600 deg F at 400 deg F max (divided by material thickness).  
600 deg F to ambient in still air/under insulation.

Recommended Final Brinell Hardness Number: 241 BHN Maximum



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N.B. If pre-stress relief hardness is in excess of 300 BHN, the cooling rate from hold to 1100 degrees should be 150 degrees maximum per hour per inch. Then from 1100 to 600 degrees at 400 degrees maximum per hour per inch.

If a lower final weld hardness is required, the pre-stress relief hardness requirements should be reduced accordingly.



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7.9    TIME TEMPERATURE CHART

Preheat and Stress Relief Program Control

A-B    Temperature raised to selected preheat temperature

B-C    Weld time at preheat level

C-D    Temperature raised at controlled rate to selected soak temperature

D-E    Soak time a selected time interval

E-F    Temperature lowered at controlled rate



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TITLE: Glossary of Common Terms

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**ANNEALING** - Heating to and holding at a suitable temperature and then cooling at a suitable rate for such purposes as: reducing hardness, improving machinability, facilitating cold working, producing a desired microstructure, or obtaining desired mechanical, physical or other properties.

**BLISTERS** - A raised spot on a metal surface caused by an expansion of gas just below surface during heating.

**BRITTLENESS** - The bending of sheets or plates under a compressive load.

**BUCKLING** - The bending of sheets or plates under a compressive load.

**BUTT WELDING** - Joining two edges or ends by placing one against the other and welding them.

**CARBON STEEL** - Steel that owes its properties chiefly to the presence of carbon with very little amounts of alloying elements; also termed "mild steel".

**COOLANT** - A liquid or gas circulated through the core of a reactor to transport heat of the fission process from the fuel.

**CORE** - The heart of a reactor that contains the nuclear fuel.

**CORROSION** - Chemical, electrochemical and moisture attack on metal by the environment, etc.

**CREEP** - Permanent deformation of metals held for long periods of time at stresses lower than the yield strength.

**CRYSTAL** - A solid in which the atoms or molecules are arranged in a perfect three-dimensional symmetrical pattern.



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**CURIE** - A measure of the rate at which a radioactive material disintegrates. A curie is the radioactivity of one gram of radium and is named after Pierre and Marie Curie, the discoverers of the radioactive elements radium, radon, and polonium. One curie corresponds to 37 billion disintegrations per second.

**DECARBURIZATION** - The loss of carbon from the surface of steel. It is the result of heating in an atmosphere that reacts with the carbon.

**DECAY** - The spontaneous transformation of a radioactive material from one nuclide to another or into a different energy state of the same nuclide.

**DIFFUSION** - A movement of atoms. This movement takes a long time at a low temperature and a much shorter time at a high temperature.

**DOSE** - The amount of ionizing radiation energy absorbed per unit mass.

**DUCTIBILITY** - The property that permits permanent deformation before fracture.

**EDDY CURRENT** - Eddy current testing consists of a source of alternating electrical current of known frequency applied to a test coil assembly and an electronic detecting system to sense and indicate variations in output resulting from changes in the electromagnetic field. These changes in the electromagnetic field are indications of discontinuities in the material. The indications may be verified by the use of calibrated controls or the incorporation of an indicator to monitor the electrical signals.

**ELASTIC DEFORMATION** - Temporary changes in dimensions caused by stresses. The material returns to its original size after removal of the stress.

**ENRICHED FUEL** - Nuclear fuel containing more than the natural amount of fissile atoms.



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**EROSION** - The abrasion of a metal by the action of a liquid or gas; usually accelerated by bombarding the metal with solid particles suspended in the gas or liquid. Erosion is also accelerated by corrosion.

**FAST BREEDER REACTOR (FBR)** - A reactor in which fast neutrons sustain the fission chain reaction. The fuel is enriched and "blanket" of fertile material that surrounds the core captures neutrons to become fissile.

**FILLER METAL** - In brazing or welding the added metal, which is melted by the arc, or flame and acting to bind edges or fill empty zones.

**FILLET** - A concave joint between two surfaces.

**FISSION** - The splitting of a heavy nucleus into two parts accompanied by the release of energy and more neutrons. It may occur spontaneously or be induced by the capture of bombarding particles, particularly neutrons.

**GAMMA RAYS** - High energy, highly penetrating, short wavelength electromagnetic radiation emitted by the nuclei of many radioactive atoms during radioactive decay. Dense materials like lead absorb the rays.

**GAS-COOLED REACTOR** - A nuclear reactor, usually graphite moderated, in which a gas such as carbon dioxide is used as the coolant.

**GIRTH WELD** - A complete circumferential butt weld joining pipe or components.

**GRAINS** - Individual crystals in metals.

**HALF LIFE** - The time for half the atoms of a radioactive substance to disintegrate; hence the time to lose half its radioactive strength. Each radionuclide has a unique half-life ranging from millionths of a second to billions of years.



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HEAT-AFFECTED ZONE (HAZ) - That portion of the base material which has not been melted, but whose mechanical properties or microstructure have been altered by the heat of welding, brazing, soldering, or cutting.

IRRADIATED FUEL - Nuclear fuel that has been irradiated in a reactor and hence becomes radioactive.

LIGHT WATER REACTOR (LWR) - A term that covers both boiling water reactors (BWR) and pressurized water reactors (PWR). A reactor that uses enriched fuel with ordinary water as moderator and coolant.

LIQUID PENETRANT (LP) - Liquid penetrant is a non-destructive testing method used for detecting discontinuities, which are open to the surface. These discontinuities may entail cracks, seams, laps, laminations, etc. The method used for LP is as follows: the part or object being tested is wetted with a liquid penetrant. After a suitable dwell time the excess penetrant is wiped off the surface and the part is dried. A developer is then applied which draws the entrapped penetrant out of the discontinuity, straining the developer. The part can then be inspected visually to determine the presence or absence of indications.

MAGNETIC PARTICLE INSPECTION (MP) - There are two types of magnetic particle inspection. Magnetic particle inspection is a non-destructive method to detect surface cracks in ferromagnetic materials. Finely granulated magnetic particles are sprinkled on a surface that is magnetized. The particles are attracted to the areas where there are regions of magnetic non-uniformity. These regions are associated with defects and discontinuities producing indications that can be observed visually. Magnetization of the test piece is accomplished with a portable magnetizing piece of equipment.

MANUAL WELDING - Welding wherein the entire welding operation is performed and controlled by hand.



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MEGAWATTS (MW) - One million watts or one thousand kilowatts; a means of indicating the power rating of equipment, e.g.: an atom of U-235 contains a total of 235 protons and neutrons in its nucleus.

NORMALIZING - A process in which a ferrous metal is heated to a suitable temperature above the transformation range and is subsequently cooled in still air at room temperature.

NUCLEAR FUSION - The formation of a heavier nucleus from two lighter ones with the simultaneous release of large amounts of energy. This is the process of energy production in the sun.

PETROLEUM - Crude oil, condensate, natural gasoline, natural gas liquids, liquefied petroleum gas, and liquid petroleum products.

PHASE - A portion of a material in which all the atoms are arranged in the same order.

PLASTIC DEFORMATION - Deformation that is permanent even after the stress is removed.

PRESSURE - Unless otherwise stated, pressure is expressed in pounds per square inch above atmospheric pressure i.e.: gage pressure. (Abbreviation - psig.)

PRESSURE TUBE REACTOR - A reactor in which the fuel is located inside hundreds of tubes designed to withstand the circulation of the high pressure coolant. The tubes are assembled in a calandria containing the moderator at low pressure.

PRESSURIZED WATER REACTOR (PWR) - A nuclear power reactor cooled and moderated by light (ordinary) water and fueled with enriched uranium. Unlike the boiling water reactor, the coolant in the PWR transfers heat (via heat exchangers) to a secondary circuit, generating steam to drive the turbines.

QUENCHING - Rapid cooling of a heated metal.



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**RADIOACTIVITY** - The spontaneous decay of an unstable atomic nucleus into one or more different elements or isotopes. It involves the emission of particles and/or electro-magnetic radiation or spontaneous fission until a stable state is reached.

**RADIOGRAPHY (RT)** - Radiographic testing is a method of examining materials for internal discontinuities by the means of transmitting either X-ray or Gamma Rays through the material to a piece of industrial X-Ray film. The film when exposed to the X-Ray or Gamma Ray transposes the discontinuity from the material to the film. By examining the film in a dark room under special viewers the below surface discontinuities can be visually detected on the film.

**RESIDUAL STRESS** - Refers to the stress existing in a component part free from external loads.

**SCALING** - A surface reaction caused on metals by heating in air.

**SOLUTION HEAT TREATMENT** - Heating an alloy to a suitable temperature, holding at that temperature long enough to allow one or more constituents to enter into solid solution, and then to cooling rapidly enough to hold the constituents in solution.

**SPOT WELDING** - A welding process in which the fusion is limited to a small area.

**STRESS** - Is a force divided by the area over which it is applied.

**STRESS RELIEVING** - Is any means for reducing residual stresses substantially. It is usually achieved by increasing the temperature of a metal to a suitable value, and holding at that temperature for a suitable length of time.

**TEMPERING** - Reheating a hardened metal to a temperature below the transformation range to improve toughness.

**TENSILE STRENGTH** - The maximum stress that a metal subjected to tension can withstand without a predefined amount of deformation.



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**THERMAL STRESS** - Stress in a metal resulting from non-uniform distribution of temperatures.

**THERMOCOUPLE** - A device for measuring temperature, by use of two dissimilar metals in contact, this junction when heated gives rise to measurable voltage that varies with changes in temperature.

**TRANSFORMATION RANGE** - A temperature range in which a phase is initiated and completed.

**TRANSFORMATION TEMPERATURE** - A temperature at which a phase change occurs.

**TRANSITION TEMPERATURE** - The temperature at which a metal changes from yielding in a brittle manner to a ductile manner.

**ULTIMATE TENSILE STRENGTH** - The maximum stress that a brittle metal can withstand without fracture when subjected to tension.

**ULTRASONIC TESTING (UT)** - Ultrasonic testing is a method of examining steel for surface and below surface defects not visible to the naked eye. UT is accomplished by transmitting a high-frequency electrical pulse through a material by means of a transducer. The transducer services two purposes: 1) To transmit the electrical pulse, and; 2) to receive the rebound of the electrical pulse. These electrical pulses are projected on a portable scope, which can be visually monitored.

**WELD** - A localized coalescence of material wherein coalescence is produced either by heating to suitable temperatures, with or without the application of pressure, or by application of pressure alone and with or without the use of filler material.

**WELDER** - One who is capable of performing a manual or semi-automatic welding operation.

**WELDING PROCEDURES** – The detailed methods and practices including joint welding procedures involved in the production of a weldment.



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WELDMENT - An assembly whose component parts are joined by welding.