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<div style="display: flex; justify-content: space-between;"> <div style="width: 20%;"> <p style="writing-mode: vertical-rl; transform: rotate(180deg);">COPYRIGHT AND CONFIDENTIAL</p> <p style="writing-mode: vertical-rl; transform: rotate(180deg);">The information on this document is the property of BHARAT HEAVY ELECTRICALS LIMITED. It must not be used directly or indirectly in any way detrimental to the interest of the company.</p> </div> <div style="width: 80%; text-align: center;"> <h2><u>HEAT TREAT PROCESS CONTROL</u></h2> <h3>1. <u>SCOPE</u></h3> <p>1.1. This process specification outlines the general requirements for heat treating operations performed on BHEL parts.</p> <p>1.2. This specification requires that BHEL Materials Engineering approve all internal and external heat treat operations. This includes subtypes as defined in GT10620.</p> <h3>2. <u>APPLICABLE DOCUMENTS</u></h3> <p>2.1. AMS 2750 shall form a part of this specification unless otherwise specified herein. The latest revisions shall apply. Deviations must be approved by BHEL Materials Engineering:</p> <div style="margin-left: 40px;"> <p>2.1.1. <u>AMS Specifications</u></p> <table border="0"> <tr> <td style="padding-right: 20px;">AMS-H-6875</td> <td>Heat Treatment of Steel Raw Materials</td> </tr> <tr> <td>AMS 2770</td> <td>Heat Treatment of Wrought Aluminum Alloy Parts</td> </tr> <tr> <td>AMS 2750</td> <td>Pyrometry</td> </tr> <tr> <td>AMS 2759</td> <td>Heat Treatment of Steel Parts, General Requirements</td> </tr> </table> <p>2.1.2. <u>ASTM Specifications</u></p> <table border="0"> <tr> <td style="padding-right: 20px;">ASTM E10</td> <td>Standard Test Methods for Brinell Hardness of Metallic Materials</td> </tr> <tr> <td>ASTM E18</td> <td>Standard Test Methods for Rockwell Hardness of Metallic Materials</td> </tr> </table> <p>2.1.3. <u>ISO Specifications</u></p> <table border="0"> <tr> <td style="padding-right: 20px;">ISO 17025</td> <td>General Requirements for the Competence of Testing and Calibration Laboratories</td> </tr> </table> </div> </div> </div>						AMS-H-6875	Heat Treatment of Steel Raw Materials	AMS 2770	Heat Treatment of Wrought Aluminum Alloy Parts	AMS 2750	Pyrometry	AMS 2759	Heat Treatment of Steel Parts, General Requirements	ASTM E10	Standard Test Methods for Brinell Hardness of Metallic Materials	ASTM E18	Standard Test Methods for Rockwell Hardness of Metallic Materials	ISO 17025	General Requirements for the Competence of Testing and Calibration Laboratories
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COPYRIGHT AND CONFIDENTIAL The information on this document is the property of BHARAT HEAVY ELECTRICALS LIMITED. It must not be used directly or indirectly in any way detrimental to the interest of the company.		<h3>3. DEFINITIONS</h3> <p>3.1. <u>Working Zone</u> - Area of volume of a piece of thermal processing equipment, which may contain parts during thermal treatment.</p> <p>3.2. <u>Control Zone</u> - Portion of the working zone, which has a separate sensor used to control its temperature.</p> <p>3.3. <u>Control/Working Thermocouple</u> - The thermocouple that is used to control the thermal processing equipment.</p> <p>3.4. <u>Primary Test Instrument</u> - An instrument with its calibration directly traceable to a NIST (or equivalent) calibrated instrument.</p> <p>3.5. <u>Secondary Test Instrument</u> - An instrument with its calibration directly traceable to a primary standard or reference standard.</p> <p>3.6. <u>Field Test Instrument</u> - An instrument that is portable and is traceable to a secondary instrument or better.</p> <p>3.7. <u>Correction Factor</u> - The number in degrees, based on the last calibration that must be added or subtracted from the temperature reading of a thermocouple or an instrument to obtain a true temperature.</p> <p>3.8. <u>Lead Wire</u> - The wire that runs between the thermocouple and instrumentation.</p> <p>3.9. <u>Stress Relieving</u> - Thermal treatment used to decrease stresses that remain locked in a material due to manufacturing. For non-austenitic steels, the material shall be heated and held below the lower critical (Ac1) temperature. The cooling rate should be slow and uniform so as not to introduce new stresses in to the material.</p> <p>3.10. <u>Baking</u> - Thermal treatment used to diffuse gas out of a metal. Typically used to remove hydrogen.</p> <p>3.11. <u>Annealing (ferrous alloys)</u> - Thermal treatment used to reduce residual stresses, decrease hardness, and increase the ductility of a metal after cold working. The material shall be heated and held above the upper critical (Ac3) temperature for proeutectoid steels and above the lower critical (A1) for hypereutectoid steels. The cooling is rate should be very slow.</p> <p>3.12. <u>Normalizing (ferrous alloys)</u> - Thermal treatment to provide uniformity of grain size and composition. The material shall be heated and held to approximately 100°F above the upper critical (Ac3 or Acm) temperature. This is followed by air cooling, which should achieve a pearlitic or ferritic microstructure. Normalizing differs from annealing in that the material is heated to a higher temperature and cooled in air.</p>	
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- 3.13. Austenitize (ferrous alloys) - Thermal treatment to transform the materials microstructure to austenite. The material shall be heated to above the upper critical (A_{c3}) temperature and held for the necessary time. This treatment can be used for either processing prior to quenching or homogenizing.
- 3.14. Solutioning - Thermal treatment used for the purpose of dissolving precipitates. The material shall be heated to an appropriate temperature and held for the time necessary to dissolve the precipitates.
- 3.15. Aging - Precipitation from a solid solution of one or more compounds whose solubility decreases with decreasing temperature.
- 3.16. Tempering (ferrous alloys) - Thermal treatment used to decrease hardness and increase toughness. The material is heated and held to below the lower critical (A_1) temperature. The temperature range of 500-700°F is sometimes avoided to reduce the chance for temper embrittlement.

4. ENGINEERING REQUIREMENTS

4.1. Heat Treating Source

- 4.1.1. All processes must conform to BHEL specifications.
- 4.1.2. AMS 2750 may be used as an acceptable alternative to this specification with BHEL Materials Engineering approval.
- 4.1.3. All heat treat vendors shall be approved in writing by BHEL Materials Engineering.
- 4.1.4. Any deviations to approved process procedures require approval from BHEL Materials Engineering and BHEL GT Engineering.
- 4.1.5. Calibration frequencies are based on calendar date. Deviations from that date are permissible per Table 1, which is based on AMS 2750

Calibration/Test Interval	Extension Allowed Beyond Due Date (Days)
Weekly	1
Biweekly	2
Monthly	3
Quarterly	4
Semiannually	6
Annually	12


TABLE 1 – Extension allowed beyond due date for calibration and testing intervals

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<div>COPYRIGHT AND CONFIDENTIAL</div> <div>The information on this document is the property of BHARAT HEAVY ELECTRICALS LIMITED. It must not be used directly or indirectly in any way detrimental to the interest of the company.</div>			4.1.6. Furnace temperature charts, either paper or electronic, and data recorders shall at minimum contain the following information for each load and be retained for at least 10 years:			
			<ul style="list-style-type: none">• Unique load number• Shop order number of purchase order number• Number of parts with drawing number and/or unique part identification number• Time parts are loaded• Time specified heat treatment begins• Time specified heat treatment ends• Cooling rates when specified• Furnace identification• Date• Material specifications and heat treat process			
			4.1.7. Vendors shall retain the following records for 5 years:			
			<ul style="list-style-type: none">• <u>Uniformity surveys</u>: Surveys kept electronically must have the ability to be printed or transmitted to BHEL with a resolution fine enough to discern time and temperatures.• System accuracy tests			
			4.1.8. After final vendor operations, parts shall be tested in accordance to the BHEL specifications and/or drawings.			
			4.1.9. When mechanical testing is required to validate heat treatment, the testing lab needs to meet ISO 17025 if required by BHEL Materials Engineering.			
			4.1.10. Vendor shall notify BHEL of parts not meeting specifications and/or drawing requirements.			
			4.2. <u>Equipment Control</u>			
			4.2.1. Any test failures or out of tolerance sensors shall be cause for evaluation of its potential effects. Corrective actions shall be put into place to prevent further failures.			
			4.2.2. <u>Temperature Uniformity Surveys (TUS)</u>			
			4.2.2.1. Uniformity surveys shall be used to determine the maximum temperature differential within the working zones of all furnaces and baths. This will determine the furnace class of a particular piece of thermal processing equipment. The furnace classes are per Table 2, which is based on AMS 2750.			
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Furnace Class	Temperature Uniformity Range (°F)	Temperature Uniformity Range (°C)
1	± 5	± 3
2	± 10	± 6
3	± 15	± 8
4	± 20	± 10
5	± 25	± 14
6	± 50	± 28

TABLE 2 – Furnace classes

- 4.2.2.2. Uniformity surveys shall be conducted in accordance with the following requirements unless otherwise approved by BHEL Materials Engineering. Note: Temperature tolerance ranges are based on being above and below the furnace set point. If a survey is taken at a set point of 1000°F with a tolerance of ±10°F, then max temperature range is 990°F to 1010°F.
- 4.2.2.2.1. New furnaces or baths shall be surveyed for temperature uniformity before heat treating BHEL parts.
- 4.2.2.2.2. The selected temperatures used for uniformity surveys shall be at the low and high side of normal operating temperature ranges of the furnace (two surveys). The temperatures at which two adjacent surveys are run shall not exceed 600°F (335°C) apart.
- 4.2.2.2.3. Uniformity surveys shall be conducted with a maximum planned furnace load of production or scrapped parts, unless otherwise approved by BHEL Materials Engineering via local ISO procedure.
- 4.2.2.2.4. The type and size of furnace will determine the type, number, and location of the thermocouples. Typically, a minimum of nine (5 for furnaces of less than 3 cubic feet capacity) thermocouples will be used during the uniformity survey. The uniformity survey plan and local ISO procedure shall be submitted to BHEL Materials Engineering for approval. This plan should include the size of furnace work zone, shape of the furnace (rectangular or cylindrical or etc.), and the number and location of the thermocouples.

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4.2.2.2.5. Surveys shall take place using normal operating conditions. For example, if fans are used during production they shall also be used during the survey. For vacuum furnaces the lowest vacuum level used during production shall be used during the survey.

4.2.2.2.6. After all thermocouples stabilize, data collection shall continue for a minimum of 30 minutes. At no point during this time shall any of the thermocouples drift above or below the required range.

4.2.2.2.7. Uniformity surveys shall be conducted every 6 months, unless otherwise approved by BHEL Materials Engineering. Uniformity survey frequency on a new furnace shall be per AMS 2750, unless otherwise approved by BHEL Materials Engineering.

4.2.2.2.7.1. Uniformity surveys of furnaces that are only used for stress relieving, annealing, and baking are required annually.

4.2.2.2.7.2. Uniformity surveys of furnaces that are only used for normalizing are required annually, but only when not used as part of the final heat treatment (ex. when conducted prior to a quench and temper).

4.2.3. Test Instrument Calibration Requirements

4.2.3.1. Instrument calibration intervals shall be per AMS 2750.

4.2.3.2. Primary and/or secondary standard instruments shall remain in the laboratory area for calibration of field test instrument.

4.2.4. Temperature Controlling Instruments


4.2.4.1. Controlling instruments and recorders shall be calibrated once every three months by a comparison test using a millivolt potentiometer calibrated to a secondary standard. A sticker showing the date of the last calibration and when the next calibration is due shall be affixed to the instruments.


4.2.5. Furnace Instrumentation Requirements


4.2.5.1. Each piece of thermal processing equipment shall have the instrumentation type identified (A, B, C, or D). The requirements for each instrumentation type are detailed in AMS 2750. Examples of Instrumentation Types A and D are shown in Appendix A.

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<div><div>4.2.5.1.1. Each control zone shall have at minimum (Instrumentation Type D):<ul style="list-style-type: none">At least one controlling instrument which displays and controls temperature.Temperature recording from the control thermocouple.Over temperature protection. The control thermocouple cannot also be used as the over temperature thermocouple.</div><div><div>4.2.6. Thermocouples</div><div><div>4.2.6.1. Thermocouples shall have a certificate of compliance that identifies the source of the calibration data, nominal test temperature, actual test temperature, calibration technique, and correction factor for each calibration temperature traceable to NIST (or equivalent). Non-calibrated thermocouples shall be checked before first use and subsequent recalibrations shall meet the requirements in AMS 2750.</div><div>4.2.6.2. Thermocouples shall be calibrated using the same temperature range in which they will be used.</div><div>4.2.6.3. The only acceptable connections for thermocouples to extension/lead wires are the use of connectors, plugs, jacks, and terminal strips of a type compatible with the thermocouple wire used. Joining wires by twisting, crimping, welding, etc. is not acceptable.</div><div>4.2.6.4. A replacement schedule is required for controlling, monitoring, and recording thermocouples.</div></div><div><div>4.3. Quenching</div><div><div>4.3.1. Quenching rate control tests</div><div><div>4.3.1.1. When required by BHEL Materials Engineering, either a Comparative Cooling Curve Evaluation or Mechanical Property Tests shall be used to test effectiveness of quenching.</div></div><div>4.3.2. Quenching Parameters</div><div><div>4.3.2.1. Allows for complete immersion of part(s).</div><div>4.3.2.2. Media shall have a temperature sensor.</div><div>4.3.2.3. Media temperature shall be kept in the specified range both before and during quenching.</div></div></div></div></div></div>				
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COPYRIGHT AND CONFIDENTIAL The information on this document is the property of BHARAT HEAVY ELECTRICALS LIMITED. It must not be used directly or indirectly in any way detrimental to the interest of the company.	<p>4.3.2.4. Media shall be checked periodically for contamination based on local ISO procedures.</p> <p>4.3.2.4.1. For oil quenching, water content must be either manually checked monthly or continuously monitored by an automated system.</p> <p>4.3.2.5. If liquid quench media is being used, the flow rate shall be periodically measured. The method and frequency shall be detailed in the local ISO procedures. This requirement can be waived with BHEL Materials Engineering approval.</p> <p>4.3.2.6. If polymer or other additives are being used to modify the quench cooling rate, a target additive concentration range must be specified. Concentration should be checked once per shift unless otherwise approved by BHEL Materials Engineering. Results of the checks shall be recorded.</p> <p>4.3.2.7. If the quench media is filtered, a procedure or system should be in place for checking the cleanliness of the filters and installing new filters when required.</p> <p>4.4. <u>Atmospheric Controls (if applicable)</u></p> <p>4.4.1. <u>Endothermic and or Exothermic</u></p> <p>4.4.1.1. Dew point or O₂ concentration for both furnace and generator shall be continuously monitored.</p> <p>4.4.1.2. A waiver may be granted by BHEL Materials Engineering for the frequency of checking dew point and gas analysis. The vendor shall notify BHEL Materials Engineering in writing with the following information prior to granting any waivers:</p> <ul style="list-style-type: none">• Type of heat treat cycle (hardening annealing, and etc.• Machined condition of parts.• Part material. <p>4.4.2. <u>Dry Hydrogen</u></p> <p>4.4.2.1. Dew point level and temperatures shall be recorded for each heat treat cycle.</p> <p>4.4.3. <u>Vacuum</u></p> <p>4.4.3.1. Vacuum levels and temperatures shall be recorded for each heat treat cycle.</p>	
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<div><div><div>COPYRIGHT AND CONFIDENTIAL</div><div>The information on this document is the property of BHARAT HEAVY ELECTRICALS LIMITED. It must not be used directly or indirectly in any way detrimental to the interest of the company.</div></div><div><p>4.4.3.2. Vacuum furnaces shall be checked for leak-up rate at ambient temperature on a weekly basis. The empty chamber shall be pumped down to less than 0.5 microns, and then isolated from the pumping system for at least one hour. The pressure rise (leak rate) shall not exceed 25 microns per hour. Alternatively a ½ hour isolation time may be used with a maximum leak rate of 20 microns per hour.</p><p>4.4.4. <u>Carburizing</u></p><p>4.4.4.1. The furnace shall be equipped with instrumentation that continuously monitors, controls, and records the carbon potential of the furnace. It is also recommended that a secondary system also be used to verify the carbon potential within the furnace at regular intervals such as a dew point analyzer, three-gas (CO, H₂, CO₂) analyzer, or shim stock analysis. Results of these secondary tests should be recorded. This requirement shall also apply for other heat treat processes involving atmosphere carbon control such as carbonitriding and neutral hardening.</p><p>4.4.4.2. Nitrogen-natural gas atmospheres may not be used for carburizing or neutral hardening operations.</p><p>5. <u>OPERATIONAL REQUIREMENTS</u></p><p>5.1. <u>Part Racking/Loading</u></p><p>5.1.1. Parts shall be racked/loaded to ensure proper heating and cooling.</p><p>5.1.2. Racks/supporting fixtures shall be designed to prevent distortion of the parts.</p><p>5.1.3. Racking/loading details shall be submitted to BHEL Materials Engineering for approval.</p><p>5.1.4. Rack/supporting fixture materials shall be selected to prevent reactions with parts particularly for high temperature solution heat treatments.</p><p>5.1.5. For heat treat temperatures exceeding 2000°F, it may be necessary to ensure that the parts are not in contact with each other.</p><p>5.1.6. Rack/supporting fixtures shall be properly cleaned to remove all surface contaminants which may be detrimental to the material being heat treated or furnace components.</p></div></div>				
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5.2. Furnace Maintenance

5.2.1. Maintenance records shall be kept for each furnace detailing the repairs/modifications/replacements, which were performed. The facilities quality assurance department shall review the furnace maintenance records to determine if the repairs meet the criteria of section 5.2.1.1 and 5.2.1.2.

5.2.1.1. Major modifications to a furnace, which will require a new temperature uniformity survey, shall be identified within internal procedures. An example list of repairs which require new uniformity surveys is given in AMS 2750.

5.2.1.2. The replacement of equipment, instruments, etc. shall have the appropriate retests and results documented in the maintenance logs.

6. QUALITY ASSURANCE PROVISIONS

Heat Treating Process	Maximum Temperature Variation
Normalizing	±25°F (13.9°C)
Solution Treating	±20°F (11.1°C)
Annealing	±25°F (13.9°C)
Hardening	±25°F (13.9°C)
Aging	±20°F (11.1°C)
Tempering	±25°F (13.9°C)
Stress Relieving	±25°F (13.9°C)
Carburizing	±25°F (13.9°C)
Carbonitriding	±25°F (13.9°C)
Nitriding	±25°F (13.9°C)
Salt Baths	±25°F (13.9°C)

TABLE 3

The maximum variation in temperature shall be as stated above unless a different requirement is stated in the materials or process specification.

7. NOTES

None

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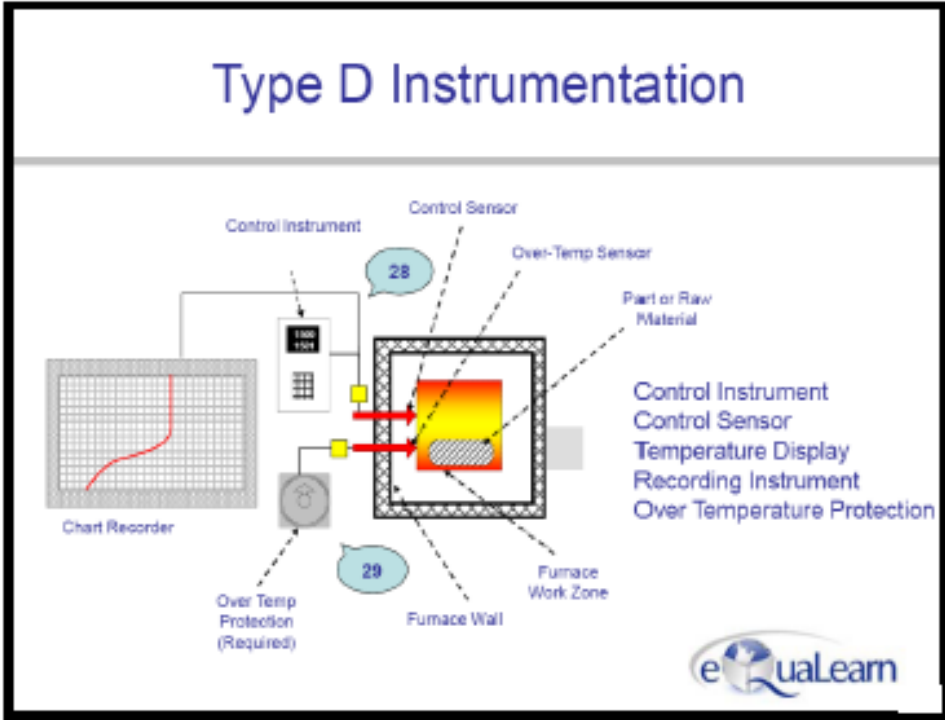


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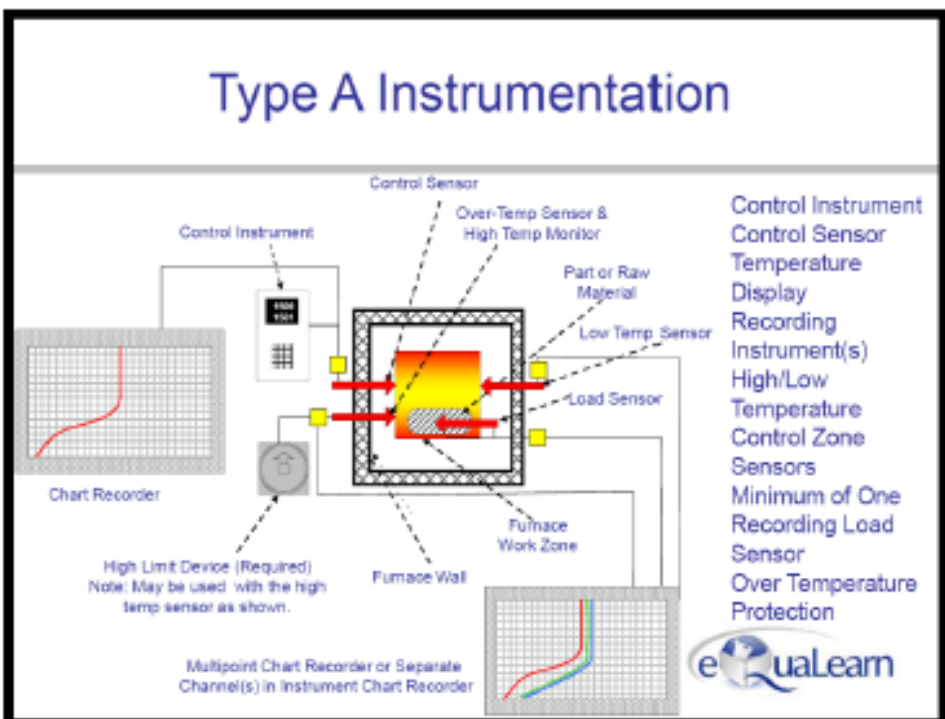
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Appendix A**

Type D Instrumentation



Type A Instrumentation

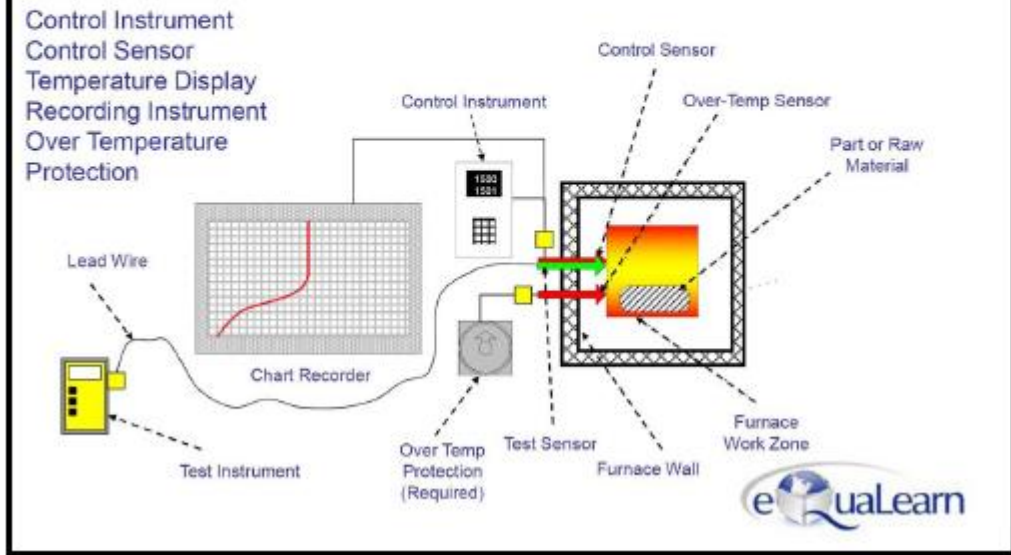


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Appendix B**

Example System Accuracy Test Type D Instrumentation



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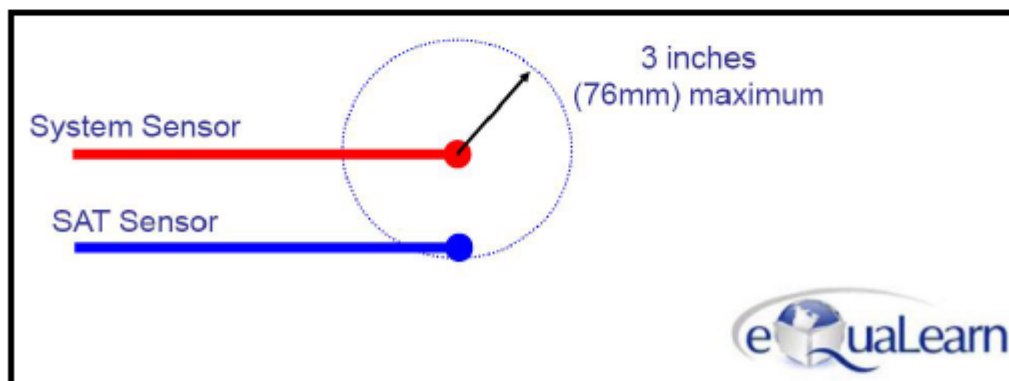
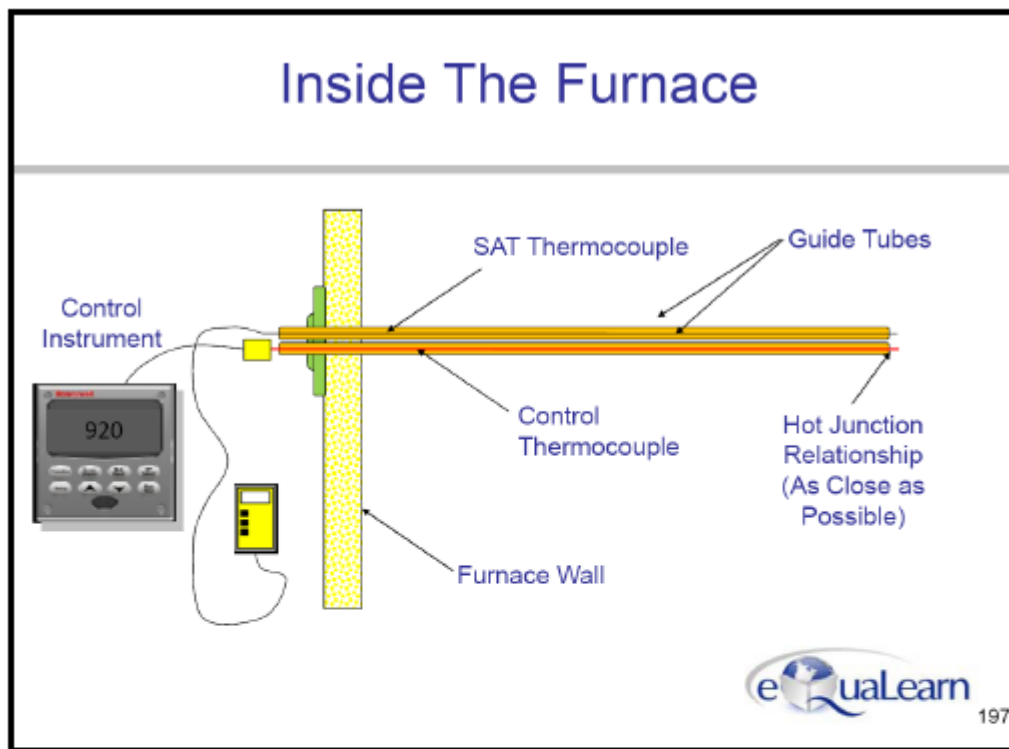
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	00	14.12.1991	FIRST MADE		
	01	22.06.2021	SPEC COMPLETELY REVISED AND RETYPED AS PER OEM SPEC P10A-AG2 REV-'E'	SHRIDHAR	KAMALDEEP
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