

MATERIAL AND EQUIPMENT STANDARD
FOR
REFORMER FURNACES INCLUDING
TUBE AND OUTLET MANIFOLDS

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0. INTRODUCTION

Steam-methane reformer furnaces are mainly used for production of hydrogen gas. This process is accomplished by reforming mixtures of C1 to C4 hydrocarbon gases plus steam at high temperatures and in the presence of catalyst.

This Standard specification which covers material and equipment standard for reformer furnaces is prepared in three parts as follows:

Part I: Covers the minimum materials and equipment requirements for reformer furnaces.

Part II: Contains material requirements for centrifugally cast reformer furnace tubes.

Part III: Gives material requirements for outlet manifold of reformer furnaces.

PART I
MATERIALS AND EQUIPMENT STANDARD
FOR
REFORMER FURNACES

1. SCOPE

1.1 This part of standard covers additional requirements for material, design, fabrication, inspection and testing of reformer furnaces.

1.2 For general requirements for furnaces reference is made to the IPS-G-ME-200 "Standard for Fired Heaters".

1.3 In case of conflict between this Standard and IPS-G-ME-200, the requirements of this Standard specification shall govern.

2. REFERENCES

Throughout this Standard the following Standards and codes are referred to. The editions of these standards and codes that are in effect at the time of publication of this Standard shall, to the extent specified herein, form a part of this Standard. The applicability of changes in standards and codes that occur after the date of this Standard shall be mutually agreed upon by the Company and the Vendor:

IPS (IRANIAN PETROLEUM STANDARDS)

G-ME-200	"Material and Engineering Standard for Fired Heaters"
M-TP-710	"Material Standard for Thermal Insulation"

3. UNITS

This Standard is based on International System of Units (SI) except where otherwise is specified.

4. DESIGN

4.1 Design pressure shall be as specified on the steam-hydrocarbon reformer furnace specification sheet, prepared by the Company.

4.2 Design temperature for calculating the tube wall thickness shall be 28°C above the maximum calculated tube wall temperature at any point in the furnace. The calculated tube wall temperature at any point in the furnace shall not exceed 955°C. Back-up calculations to substantiate the calculated tube wall temperatures shall be submitted to the Company for review and approval.

4.3 The furnace shall consist of a radiant (reformer) section and convection section. The radiant section shall be a vertical tube type. The tubes shall be fired on both sides with fuel gas burners. The furnace shall be designed to operate on natural draft.

4.4 The process gas flow shall be downward in the radiant section with the tubes supported at the bottom near the outlet. Flue gas flow shall be upward with the outlet from the radiant section located at the top of the radiant chamber.

4.5 Convection section tubes shall be designed according to the tube metal temperature based on the most severe operating conditions.

4.6 The convection section shall consist of horizontal tubes used to perform the services called for on the furnace specification sheet.

4.7 Radiant flux shall be based on the effective fired length of the tube which is packed with catalyst.

4.8 Radiant tubes shall be arranged in single row with a minimum ratio of center-to-center tube spacing to outside diameter of 1.4 at maximum allowable heat flux of 52058 W/m² (16500 Btu/hr-ft²) of inside tube surface; or doubled row with a minimum ratio of center-to-center tube spacing to outside diameter of 2.5 at maximum allowable heat flux of 47325 W/m² (15000 Btu/hr-ft²) of inside tube surface.

4.9 Furnace arrangement shall be such that the outlet process gas temperature from the radiant tubes shall not vary more than 28°C from the hottest to the coldest tube.

4.10 Convection steam coils shall be designed in accordance with the ASME power boiler code based on the design pressure specified in the furnace specification sheet and the following design temperatures:

- a) For bottommost coil tubes exposed to flue gases leaving radiant section-calculated tube metal temperature plus 56°C.
- b) For other convection coil tubes-calculated tube metal temperature plus 28°C.

5. TUBES

5.1 Unless specified otherwise radiant catalyst tubes shall have a maximum inside diameter of 127 mm (5 in) and effective tube length for radiation section shall be 11940 mm minimum.

5.2 For design, material, fabrication and inspection of centrifugally cast reformer furnace (Radiation section) tubes reference is made to part 2 of this Standard.

5.3 Radiant tubes shall be furnished completely shop fabricated in one piece and shall be provided with a flanged top and bottom closure to facilitate easy catalyst charge and removal.

The design shall be such as to provide sufficient cooling between the hot portion of the radiant tube and the closures. On the top section at the exposed positions of tubes, lagging is necessary to reduce thermal gradient to an acceptable level. Pigtail connections shall not be made to either top or bottom flanges.

5.4 Convection section tubes shall conform to the following specifications:

TUBE METAL DESIGN TEMP. °C	MATERIAL	ASTM NUMBER *
400	Carbon steel	A-106 GR B
427	Low alloy steel	A-209 T1 or A-335 P1
593	Low alloy steel	A-213 T 11 or A-335 P 11
704	Austenitic stainless steel	A-213 TP 304 or 316 A-312 TP 304 or 316 A-376 TP 304 or 316

* Equivalent materials may be suggested for approval.

5.5 If extended surface tubes for convection coils are used, the bottom two tube rows shall be bare tubes. Coils shall be arranged so that extended surface tubes do not see flame. Fin tip temperature shall not exceed values given in the following table:

FIN TIP TEMPERATURE °C	FIN MATERIAL
Below 427	Carbon and low chrome steels
428 to 593	11-13% Cr
594 to 760	18% Cr - 8% Ni
761 to 982	25% Cr - 20% Ni

Continuously welded 1.27 mm minimum thick solid or serrated fins shall be used. First finned tube row shall have no more than 3 fins/inch with successive rows having no more than 5 fins/inch.

6. PIPING TERMINALS AND MANIFOLDS

6.1 High temperature outlet manifold shall be in accordance with part III of this Standard.

6.2 Outlet manifold shall be provided under the radiant cell. Where there are two cells, each manifold shall be joined at the center by a tee in an H-shaped configuration. The outlet shall face downward and connect directly to an incoloy alloy 800 H (or other specified material) transition piece furnished by the company which shall be mounted directly on top of the waste heat boiler. The waste heat boiler shall be anchored at its horizontal centerline.

6.3 Manifolds shall be provided at the inlet and outlet of all convection section coils and the inlet of the radiant section. These manifolds shall terminate in a single flanged connection. In addition, the heater vendor shall furnish the crossover piping between the steam preheat coil and the radiant section inlet manifold.

6.4 The radiant inlet manifold shall be provided with a single welded inlet connection at the center. Connectors between the inlet manifold and the radiant tubes, the manifold and the crossover piping between the steam preheat coil and the inlet manifold shall be so designed as to accommodate the vertical expansion of the radiant tubes as well as the expansion of the manifold and crossover. The use of flexible hoses as connectors is not permitted.

6.5 The inlet and outlet manifolds of the convection section coils shall be designed and fabricated in accordance with the ASME power boiler code section I.

6.6 A mixing connection shall be provided at the outlet of the steam preheat coil or in the crossover piping to provide for the introduction of the feed gas stream. The system shall be so designed as to provide uniform mixing of the feed gas and steam by the time the mixture is introduced to the radiant tubes. All steam leaving the steam preheat coil shall be mixed with all the process feed gas before dividing into two streams for the two separate radiant cell manifolds.

7. TUBE SUPPORTS AND GUIDES

7.1 Tubes in the radiant section shall be vertical and each tube shall be individually supported in a manner to permit expansion without imposing excessive stresses on any part of the furnace, both when new (cold) and after exposure to the design operating conditions. Each tube shall be individually connected to the inlet and outlet manifolds. These connections shall not impose excessive stresses on any part of the furnace while in operation or at any temperature between ambient and operating temperature during heating and cooling of the furnace.

7.2 End support tube sheets, unless made of alloy steel, shall be insulated on the hot side with high temperature castable refractory and shall be of suitable material for the maximum operating temperature.

7.3 Intermediate tube supports exposed to radiant heat or flue gases temperature above 650°C (1200°F) shall be made of 50/50 Cr/Ni alloy.

7.4 All supports shall be connected to the structural steel frame work of the heater.

8. REFRACTORIES AND INSULATIONS

8.1 A complete refractory setting shall be provided so that maximum shell casing temperature shall not exceed 93°C when the surrounding air temperature is 16°C.

Refractory shall consist of an inner lining of insulating firebrick and an outer layer of block insulation. As an alternate to the block insulation, insulating castable refractory may be installed between the insulating firebrick and the outer wall.

The floor shall have a top covering of hard firebrick over the insulating firebrick.

8.2 End tubesheets shall be insulated with castable insulating concrete.

8.3 Roof refractory shall be suspended from the structural steel by means of heat resisting alloy hangers.

8.4 Wall refractory shall be tied to the outer steel wall for partial support by 18/8 stainless steel tie backs.

The flue duct shall be lined with insulating castable refractory securely held in place by wire mesh tied to the outer steel shell.

8.5 The roof and floor refractory shall be designed for easy removal of tube assemblies. Furnace shall be suitably sealed against air infiltration, particularly at points where tubes enter and leave firebox. Tube seals shall be designed to allow for tube expansion.

8.6 Refractory materials shall be in accordance with Iranian Petroleum Standard IPS-M-TP-710 "Material Standard for Thermal Insulations".

8.7 Vendor shall consider use of ceramic fiber insulation and proposals shall be submitted for approval of the Company.

9. STRUCTURES AND APPURTENANCES

9.1 The top of the furnace shall be covered with removable covers to permit pulling tubes and for loading catalyst. The top ends of the tubes, end flanges, inlet manifold and radiant tube inlet connectors shall be under this roof.

9.2 Permanent operating platforms shall be provided at all locations where required for normal access to operate control, that is at burners, damper controls, etc. In addition, an operating and maintenance platform shall be provided giving access to the flanges at tops of the tubes.

Permanent stairways at one end of the furnace and emergency ladders with safety cages at the other end of the furnace shall be provided for access to each platform.

9.3 All ladders over three meters high shall be equipped with safety cages. The spacing between ladder rungs shall be 0.3 meter.

9.4 Center column footings shall be spaced to accommodate the waste heat boiler between center columns.

10. STACK

10.1 Design shall be based on natural draft required for operation at 120 percent of furnace design capacity with 25 percent excess air.

11. BURNERS

11.1 Burners shall be arranged at several (minimum of two) elevations on both sides of the radiant cells to provide stage firing control and to provide the most uniform tube skin temperature possible.

11.2 Burners of proper capacity shall be used at each elevation to provide uniform heat distribution along the length of the furnace.

11.3 Heater shall be equipped with fuel gas burners. The properties of the fuel gas will be specified by the Company.

11.4 Fuel manifolding shall be provided and shall have single connection to the fuel header. The manifolding shall be provided with suitable means of adjusting either individual burners or rows of burners to obtain uniform heat distribution.

12. STEAM GENERATION SYSTEM

12.1 The steam generating system shall be a single drum forced circulation type. Boiler drum and all pressure parts shall be in accordance with ASME power boiler code. Support for the boiler drum shall be furnished as a part of the furnace structural steel. Drum will be furnished by the Company.

12.2 Furnace supplier shall furnish piping between steam generating coil and steam drum. Circulating pumps and piping between drum and pumps and between pumps and furnace will be furnished by the Company.

13. INSTRUMENT AND AUXILIARY CONNECTIONS

13.1 Peepholes shall be provided to permit maximum visibility of radiant tubes to allow optical pyrometer measurements on both sides of all tubes.

13.2 Pipe coupling connections for flue gas thermocouples, draft gages, flue gas sampling, etc. shall be supplied by furnace supplier where required. Thermocouple connections shall be DN 40 (1½ in) and all other connections shall be DN 25 (1 in). No. of points and positions of draft gage connections will be specified by the Company.

13.3 Thermowells shall be provided in each sub-manifold or in the outlet of each twentieth tube, whichever provides the greater number of thermowells. These thermowells shall be fabricated from incoloy 800H bar stock or other specified material and shall be air purged.

13.4 A flanged thermowell connection and stainless steel thermowell shall be provided in the outlet manifold of each convection section coil.

14. SHOP FABRICATION AND FIELD ERECTION

14.1 Fabrication of radiation section outlet manifold shall be in accordance with part three of this Standard specification.

14.2 Convection section boiler feed water and steam coil fabrication shall be in accordance with the applicable provisions of the ANSI B 31.3 for piping, Chapter V.

15. INSPECTION AND TESTING

15.1 Steam coils, headers and crossovers shall be radiographed in accordance with the requirements of the ASME power boiler code Section I. Radiography of headers and crossovers not covered by the ASME power boiler code shall be in accordance with ANSI B 31.3.

15.2 All welds of inlet and outlet pigtails shall be 100% radiographed.

15.3 Root pass of butt welds joining austenitic stainless steels and final pass of attachment welds joining austenitic stainless steels shall be dye penetrant examined.

15.4 Welded pressure parts covered by the ASME power boiler code shall be hydrostatically tested in accordance with the code.

15.5 Welded pressure parts not covered by the ASME power boiler code shall be hydrostatically tested to a minimum pressure equal to one and half times the coil design pressure, multiplied by the ratio of the allowable stress at 38°C (100°F) to the allowable stress at the design tube metal temperature.

15.6 The maximum test pressure shall be limited to the extent that the weakest component shall not be stressed beyond 90 percent of the materials yield strength at ambient temperature.

15.7 Hydrostatic test pressure shall be maintained for a minimum period of one hour to test for leaks.

15.8 If hydrostatic testing of pressure parts is not considered practical by agreement between the Company and the Vendor, then pneumatic testing shall be substituted, using a nonflammable gas. The pneumatic test pressure shall be 645 Kpa (90 psig) or 15 percent of the maximum allowable design pressure, whichever is less.

The pneumatic test pressure shall be maintained for a length of time sufficient to examine for leaks, but in no case for less than 15 minutes.

15.9 Water used for hydrostatic testing shall be potable. For austenitic materials, the chloride content of the test water shall not exceed 150 parts per million.

15.10 Except when the test fluid is the process fluid, the test fluid shall be removed from all heater components upon completion of hydrostatic testing.

16. GUARANTEES

16.1 Suppliers shall guarantee that the goods furnished will be free from any inherent defects in workmanship and material and that they will give proper and continuous service under the operating and design conditions specified, for a period of one year reckoned from the day on which the equipment is commissioned, but not more than 36 months from the delivery date.

16.2 In the event of failure covered by suppliers guarantee, after the furnace has been commissioned, the Company shall notify the supplier thereof as soon as possible. Supplier will have the following choices:

- a) Effecting the repair at the site where the equipment is located.
- b) Authorizing the Company to repair.

PART II
MATERIAL STANDARD FOR
CENTRIFUGALLY CAST REFORMER
FURNACE TUBES

1. SCOPE

1.1 Part 2 of this Standard specification covers the minimum requirements for material, thickness design, fabrication, welding and inspection of centrifugally cast high alloy tubes for reformer furnaces.

1.2 In case of conflict between this specification and the pertinent drawings, the latter requirements shall take precedence.

2. REFERENCES

Throughout this Standard the following standards and codes are referred to. The editions of these standards and codes that are in effect at the time of publication of this standard shall, to the extent specified herein, form a part of this Standard. The applicability of changes in standards and codes that occur after the date of this Standard shall be mutually agreed upon by the Company and the Vendor.

ANSI (AMERICAN NATIONAL STANDARD INSTITUTE)

- | | |
|--------|-------------------------------------|
| B 16.5 | "Pipe Flanges and Flanged Fittings" |
| B 46.1 | "Surface Texture" |

ASTM (AMERICAN SOCIETY FOR TESTING AND MATERIALS)

- | | |
|-------|---|
| A-370 | "Test Methods and Definitions for Mechanical Testing of Steel Products" |
| A-608 | "Specification for Centrifugally Cast Iron-Chromium Nickel High-Alloy Tubing for Pressure Application at High Temperatures" |
| E-165 | "Practice for Liquid Penetrant Inspection Method" |

3. UNITS

This Standard is based on International System of Units (SI) except where otherwise is specified.

4. MATERIAL

4.1 Material of reformer furnace tubes shall be centrifugally cast tubes, the type of which will be specified in the purchase order or specification sheet. Some common types of centrifugally cast reformer furnace tubes are given in Appendix A of this Standard. The appendix is given as a guide and does not cover all materials of construction.

4.2 Materials for reformer furnace tube appurtenances such as couplings, flanges, etc. shall be in accordance with the specified materials in the relative drawings.

4.3 Tubes shall be centrifugally cast in permanent metal molds and shall conform to the requirements of relative tube material standard (ASTM).

4.4 The steel for tube casting shall be made by electric furnace or induction furnace process.

4.5 Tubes shall be clean, smooth and free from injurious defects. The outside surface of tubes shall be as cast.

4.6 Chemical composition and mechanical properties of materials shall conform to the specified standard (ASTM) except that the lead content of the material shall not exceed 0.01%.

5. DESIGN

5.1 Design Data

5.1.1 Design temperature

Design temperature for calculating tube wall thickness required shall be 28°C above the maximum mid tube wall temperature. The maximum mid tube wall temperature is the least favourable result of the maximum operating fluid temperature in a certain tube section and the highest heat flux (corrected for tube arrangement) local to that section.

5.1.2 Design pressure

Design pressure for calculating tube wall thickness shall be taken as the maximum operating inlet pressure.

5.2 Thickness Calculation

5.2.1 The wall thickness of the tubes shall be calculated using the creep rupture design formula of the API standard RP-530.

5.2.2 The final thickness shall be established according to 5.2.1 and shall be the most restrictive of the following:

5.2.2.1 Thickness based on allowable stress equal to the rupture stress for 100,000 hours life plus material added for corrosion allowance when specified.

5.2.2.2 Minimum wall of 6 mm plus material added for corrosion allowance when specified.

6. FABRICATION

6.1 Casting

6.1.1 The unsound depth allowance for the outside surface of tubes in the as-cast condition is 0.8 mm and for the inside surface in the bored condition is zero.

6.1.2 Tubes casting surfaces shall be free from injurious defects. Repair of injurious defects by welding is not permitted.

6.2 Cleaning

6.2.1 Before assembling

6.2.1.1 Outside surface of tubes shall be cleaned by sand blasting (blast cleaning).

6.2.2 After assembling

6.2.2.1 The outside of completed tube assemblies shall be cleaned to ensure removal of liquid penetrant developer and any other foreign materials.

6.2.2.2 The inside of completed tube assemblies shall be cleaned by high pressure water or air to ensure removal of test water and other contaminants.

6.2.2.3 After cleaning, all surfaces of completed tube assemblies shall be dried by air.

6.3 Machining

6.3.1 The tube O.D shall be machined for a minimum distance of 13 mm back from the weld bevels, then tapered 1:4 to the as cast surface.

6.3.2 The inside surface of the tubes shall be machined to the specified I.D. Machining shall remove the inner layer which contains porosities. Roughness of the I.D surface shall not exceed 3.2 μ m, Ra per ANSI B 46.1.

6.3.3 Ends of tubes shall be machined to match the machined ends of mating tubes or fittings within 1 mm on inside diameter.

6.3.4 The tolerance on the inside diameter shall not exceed -1 to +0 mm.

6.3.5 The method used for machining the tube bores shall be of the pull bar boring type.

6.4 Welding

6.4.1 All welding operators and welding procedures shall be qualified to ASME Code Section IX.

6.4.2 Complete welding details and procedures shall be submitted for purchaser's approval before starting fabrication. These details shall include weld preparation, electrode data (deposited chemical and physical properties).

6.4.3 Welds shall be made by the GTAW (TIG), or GMAW (MIG) processes, or by combinations of these methods, subject to the following limitations.

6.4.3.1 All root passes shall be made by an inert gas welding process and the underside of the weld shall be protected from oxidation by inert gas purging.

6.4.3.2 Backup rings shall not be used.

6.4.4 Manual metal arc welding methods may be used subject to written approval of the Company and when it can be established that the tensile strength of the weld will be equal to that of inert gas welding.

6.4.5 Complete penetration of the root pass is required and the interior shall be reasonably even and flush. No excess penetration greater than 1 mm is acceptable.

6.4.6 The outside of the completed weld shall have a minimum reinforcement of 1 mm and a maximum of 3 mm. In the case of metal arc welding with coated electrodes the weld area shall be grit-blasted to remove all traces of welding slag.

6.4.7 No full straight length of tube shall be made up of tube pieces shorter than 1 meter and not more than one such piece shall be used in any single tube assembly. The number of pieces used in fabrication of straight of one tube shall not exceed three.

7. INSPECTION AND TEST

The following inspection and tests shall be carried out. However the purchaser reserves the right to ask for additional inspection and tests should his nominated inspector believe that the quality intended by this standard specification is not obtained.

7.1 Inspection of Cast Tube Segments

7.1.1 One ladle analysis is required from each heat. The chemical analysis shall conform the specified material standard and additional requirements thereto.

7.1.2 Visual inspection on outer surface of each tube after blast cleaning shall be carried out. The surface shall be free from injurious defects such as linear discontinuities or other imperfections that encroach on the minimum sound wall of the tube.

7.1.3 Each tube segment shall be dimensionally examined on the O.D. and bowing. O.D. of tube shall be as specified in the relative drawing and maximum bowing of 1 mm is acceptable.

7.1.4 Each tube section shall be air tested in accordance with ASTM A-608 except that the test pressure shall be held for at least 3 minutes or a time sufficient to permit the inspector to examine the tube section.

7.1.5 Tensile test at room temperature shall be made for each heat of material. Test specimen shall be made per ASTM A-370 Fig. 5 and from pouring ends. The tensile properties shall be per the material standard.

7.1.6 From one tube of each of the first ten heats a ring of 30 mm length shall be cut from cold ends. If more heats are required a ring shall be cut from one tube of every following fifth heat. The cross sections of the rings shall be macro-etched and examined for consistency of the grain structure and for presence of inclusions and porosities. The grain structure shall be columnar to the maximum extent possible.

7.1.7 Repairs to individual tube sections shall be in accordance with ASTM A-608.

7.2 Inspection of Machined Tube Sections

7.2.1 Edge preparation and accessible inside surface shall be visually inspected and shall be free from surface irregularities and defects. The inside surface roughness shall conform to the limitation described in Para. 6.3.2 of Part II of this Standard specification.

7.2.2 Inside diameter of each tube shall be measured and shall conform to the relative tube drawing. Excentricity of maximum 1.0 mm is acceptable.

7.2.3 Machined beveled and interior machined surfaces for a distance of at least twice the inside diameter shall be liquid penetrant examined. Examination method shall be per ASTM E-165 and acceptance shall be per ASME Code Section VIII Appendix 8.

7.3 Inspection of Appurtenances From Subvendor

7.3.1 Mill certificates of all appurtenances shall be reviewed and shall conform to the applicable standards.

7.3.2 Appurtenances shall be visually and dimensionally inspected and shall conform to the relative drawings.

7.3.3 Flange tolerances shall conform to ANSI B 16.5.

7.3.4 The following portions shall be liquid penetrant examined, per ASTM E-165.

7.3.4.1 Finished inside surface of couplings.

7.3.4.2 All questional portions by visual inspection .

7.3.4.3 Edges and portions to be welded.

7.3.4.4 Beveled and inner surface of flanges.

7.3.4.5 All accessible surface of sockets (for high alloy materials).

7.3.4.6 All welded portions acceptance shall be per ASME Code Section VIII Appendix 8.

7.4 Inspection of Welds

7.4.1 All welds shall be visually examined and the dimensions measured.

7.4.2 All root and final pass of welds shall be liquid penetrant examined per ASTM E-165 Acceptance shall be per ASME Code Section VIII Division 1 Appendix 8.

7.4.3 All pressure containing welds including attachment welds of couplings shall be radiography examined per the following:

7.4.3.1 Completely radiograph the first 25 welds and thereafter every 6th weld.

7.4.3.2 Radiography shall be per ASME boiler and pressure vessel code section V article 2 and section VIII para. UW-51.

7.4.3.3 All radiographs shall meet the acceptance requirements of ASME Code Section VIII para. UW-51 except that elongated slag inclusions are not acceptable. In addition:

- a) No burn-through or root undercut is permissible.
- b) The density (blackness) of any "suck-up" or "suck-back" in the radiographic image shall not be darker than the adjacent base metal and the weld reinforcement at the area in question shall not exceed 1.5 mm.

7.5 Inspection of Completed Tube Assembly

7.5.1 Completed tube assembly shall be dimensionally inspected and shall conform to the relative tube drawings. The following requirements shall be fulfilled:

7.5.1.1 The tubes shall be reasonably straight with a maximum deviation of 6 mm either side of a line normal to the flanges when measuring along the tube.

7.5.1.2 Inside diameter of tubes shall be checked using a going through plug gage. The length of the plug gage shall be 305 mm and its diameter shall be 2 mm smaller than the nominal I.D of the tubes.

7.5.2 Each completed tube assembly including any flanges, fittings, couplings, etc. shall be hydrostatically tested in accordance with the following requirements:

7.5.2.1 Maximum chloride content of the water used as test media shall be 150 ppm.

7.5.2.2 Test pressure shall be as specified in the tube drawings.

7.5.2.3 Test pressure shall be held for at least 15 minutes or a time sufficient to permit the inspector to examine tube length assembly.

7.5.3 Repairs to a completed tube assembly are permitted subject to approval of the Company or its nominated inspector.

7.5.4 All repair welds shall be completely radiographed.

7.5.5 Repairs made after pneumatic or hydrostatic tests require testing.

8. SUPPLEMENTARY REQUIREMENTS

8.1 Drawings and Documentation

8.1.1 Shop fabrication drawings shall be sent for purchasers approval prior to start of fabrication.

8.1.2 The following documents shall be submitted to the Purchaser:

8.1.2.1 As built drawings.

8.1.2.2 Assembled list (stating fabrication No., serial No. of each tube section, radiographic film No., random examined welds and welder's No., of each weld joint).

8.1.2.3 Material certificates stating chemical (ladle) analysis and tensile properties.

8.1.2.4 Macro-etch test results.

8.1.2.5 Dimensional check results.

8.1.2.6 Radiographic examination results.

8.1.2.7 Liquid penetrant examination.

8.2 Packing

8.2.1 Machined surfaces and flange surfaces shall be suitably protected from damage during transportation.

8.2.2 Open ends of tubes shall be plugged or capped to prevent entrance of foreign materials.

APPENDICES

APPENDIX A

**CHEMICAL COMPOSITION AND MECHANICAL PROPERTIES OF
ASTM A-608 GR HK40**

MATERIALS		
Chemical composition (wt, %)	C	0.35/0.45
	Si	1.5 max.
	Mn	1.5 max.
	Cr	23/27
	Ni	19/22
	Co	—
	Nb	—
	W	—
	Mo	0.5 max.
*Room temperature tensile properties (as cast, T.W.T 1 inch)	T.S. (Ksi)	78
	0.2% P.S. (Ksi)	40
	E. (%)	20
	R.A. (%)	20
* High temperature tensile properties (as cast, T.W.T 1 inch)	Test temp. (°F)	1652
	T.S. (Ksi)	22
	0.2% P.S. (Ksi)	13
	E. (%)	40
	R.A. (%)	35

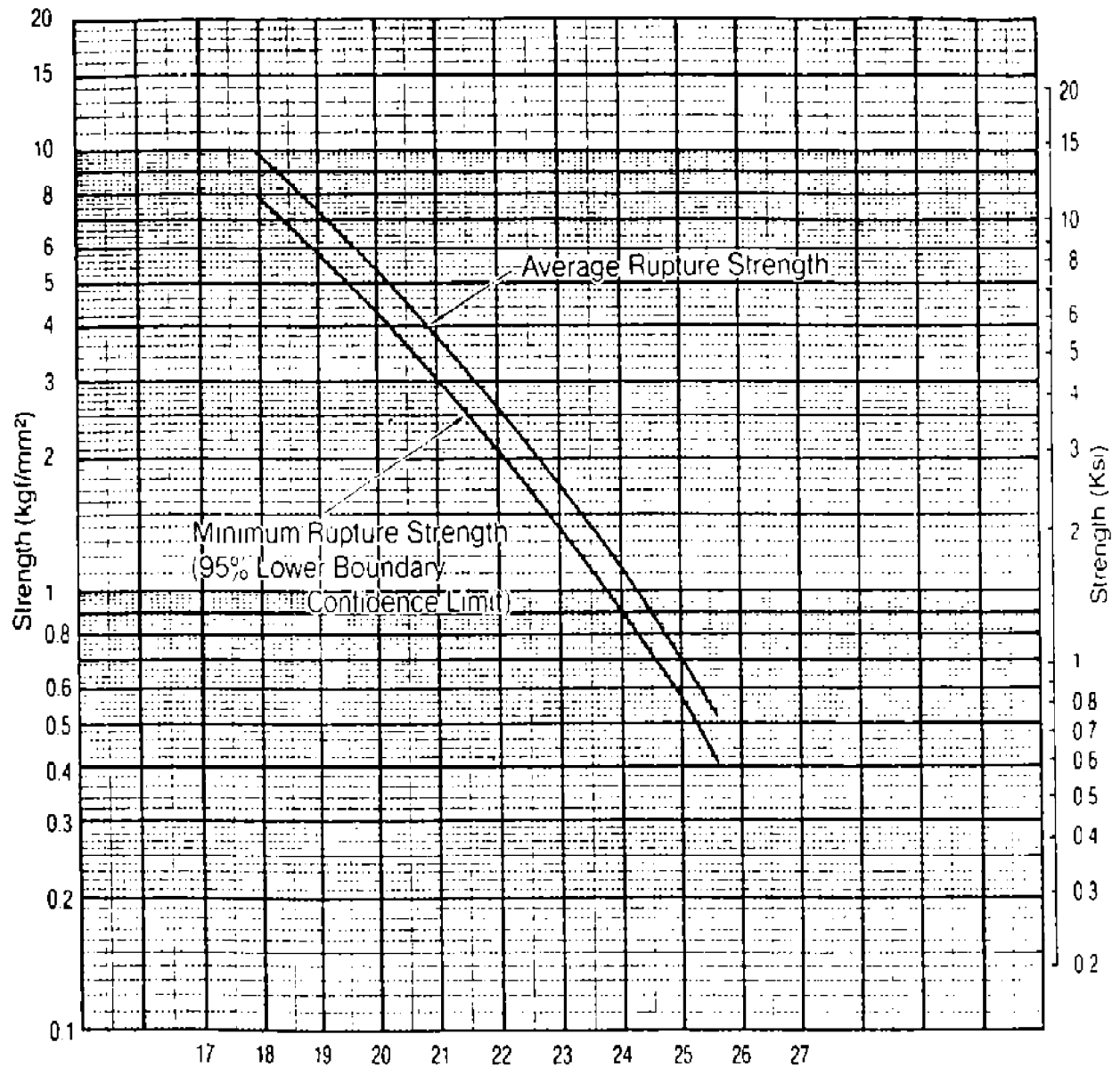
**MECHANICAL PROPERTIES OF
ASTM A-608 GR HK40**

Hv (AS CAST CONDITION)		180
* Room temperature tensile properties after 10 ³ hrs. aging	Aging temp. (°F)	1652
	T.S. (Ksi)	81
	0.2% P.S. (Ksi)	48
	E. (%)	4
	R.A. (%)	4
Mean rupture strength in 10 ⁴ hrs. (psi)		Temperature: 1652°F
		3270
Limiting creep strength 1% 10000 hrs.		4410

APPENDIX A

CREEP RUPTURE STRENGTH CURVES

FOR ASTM A-608 Gr HK 40



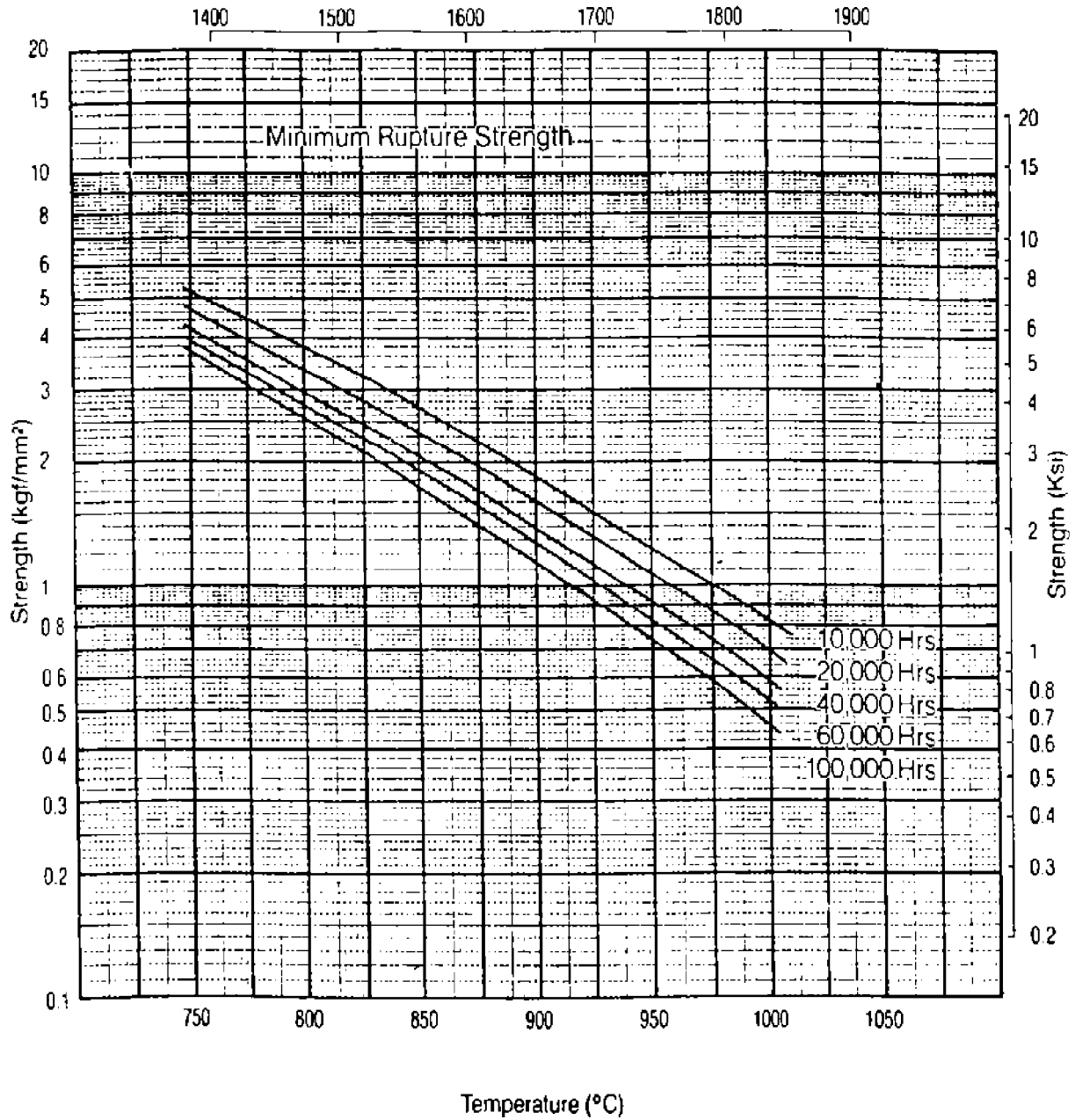
$$P = T \cdot (15 + \log tr) \cdot 10^{-3}$$

[T (°K), tr (Hrs.)]

APPENDIX A

TEMPERATURE (°F)

FOR ASTM A-608 Gr HK 40



APPENDIX A

GENERAL PROPERTIES OF IN-519

CHEMICAL COMPOSITION

	COMPOSITION RANGE	NOMINAL VALUE
C (%)	0.25 \approx 0.35	0.30
Si (%)	< 1.5	-
Mn (%)	< 1.5	-
P (%)	< 0.03	-
S (%)	< 0.30	-
Cr (%)	23 \approx 26	24.0
Ni (%)	23 \approx 26	24.0
Nb (%)	1.0 \approx 2.0	1.5
Fe (%)	BALANCE	BALANCE

PHYSICAL PROPERTIES

DENSITY (g/cm ³), (lb/in ³)	7.91 (0.286)
YOUNG'S MODULUS (kg/mm ²)	17,100 20°C
(ksi)	(24,300) (68°F)
	15,900 200°C
	(22,600) (392°F)
	14,400 400°C
	(20,500) (752°F)
	13,000 600°C
	(18,500) (1,112°F)

APPENDIX A

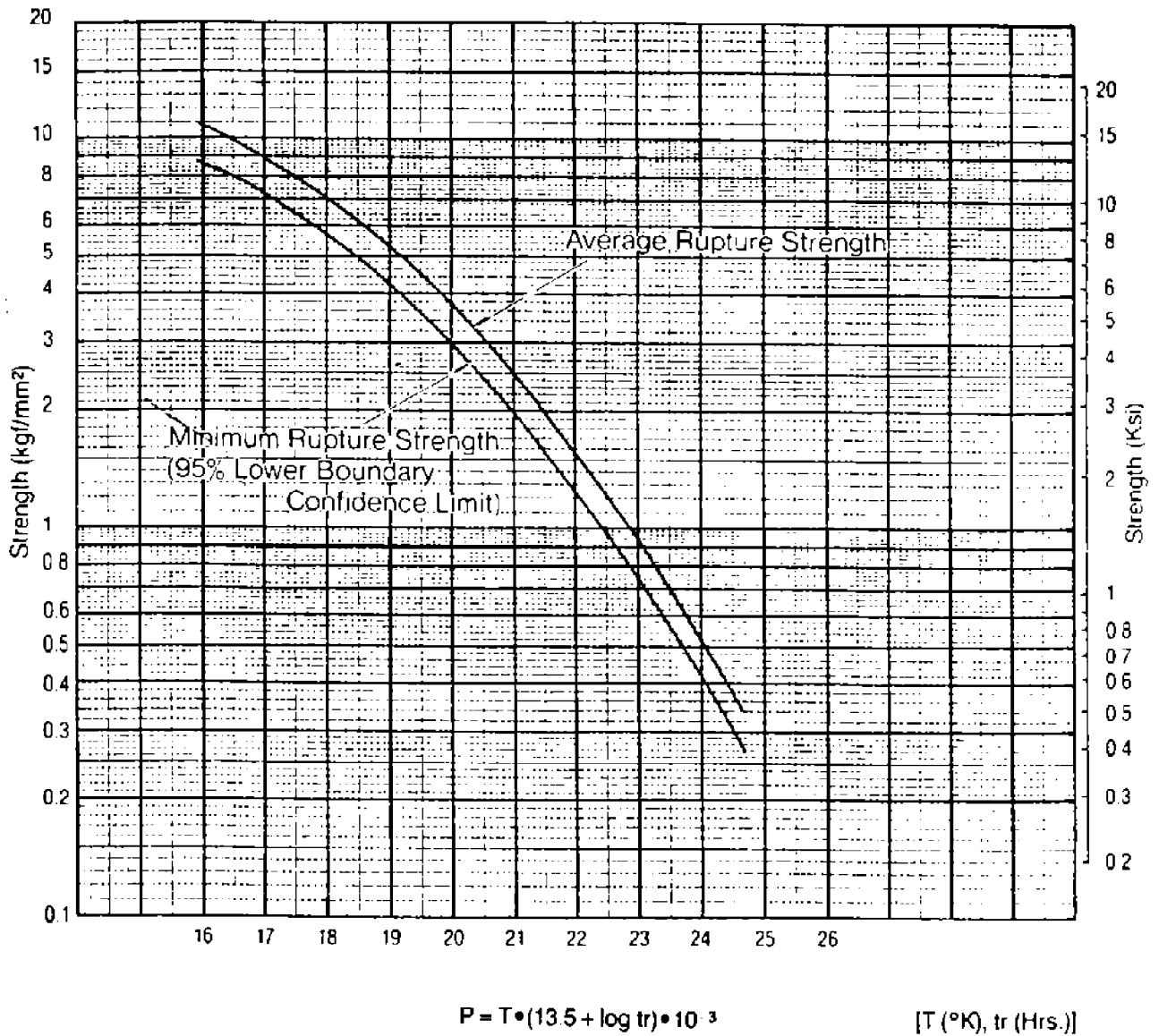
TENSILE PROPERTIES OF IN-519

ROOM TEMPERATURE TENSILE PROPERTIES AFTER AGING

AGING CONDITION		TENSILE STRENGTH $\frac{\text{kg}}{\text{mm}^2}$ (Ksi)	0.2% PROOF STRESS $\frac{\text{kg}}{\text{mm}^2}$ (Ksi)	ELONGATION (%)	REDUCTION OF AREA (%)
As cast		64.3 (91.4)	29.2 (41.5)	15.1	15.8
Temp.	Aging time				
871°C (1,600°F)	1 hr.	66.5 (96.0)	33.8 (48.1)	15.1	14.4
	10 hr.	65.7 (94.8)	32.1 (45.6)	14.3	13.9
	100 hr.	66.5 (94.6)	30.9 (43.9)	16.4	15.5
	1,000 hr.	63.0 (89.6)	29.5 (41.9)	12.9	12.5
982°C (1,800°F)	1 hr.	61.2 (87.0)	30.5 (43.4)	11.6	13.6
	10 hr.	60.9 (86.6)	29.1 (41.4)	11.5	13.3
	100 hr.	61.9 (88.0)	28.7 (40.8)	12.7	13.1
	1,000 hr.	63.4 (90.2)	28.0 (39.8)	14.9	19.2
1,093°C (2,000°F)	1 hr.	61.3 (87.2)	27.8 (39.5)	18.4	19.3
	10 hr.	56.9 (80.9)	26.8 (38.1)	16.8	17.6
	100 hr.	54.9 (78.1)	26.3 (37.4)	13.6	13.3
	1,000 hr.	50.7 (72.1)	23.1 (32.8)	13.1	8.2

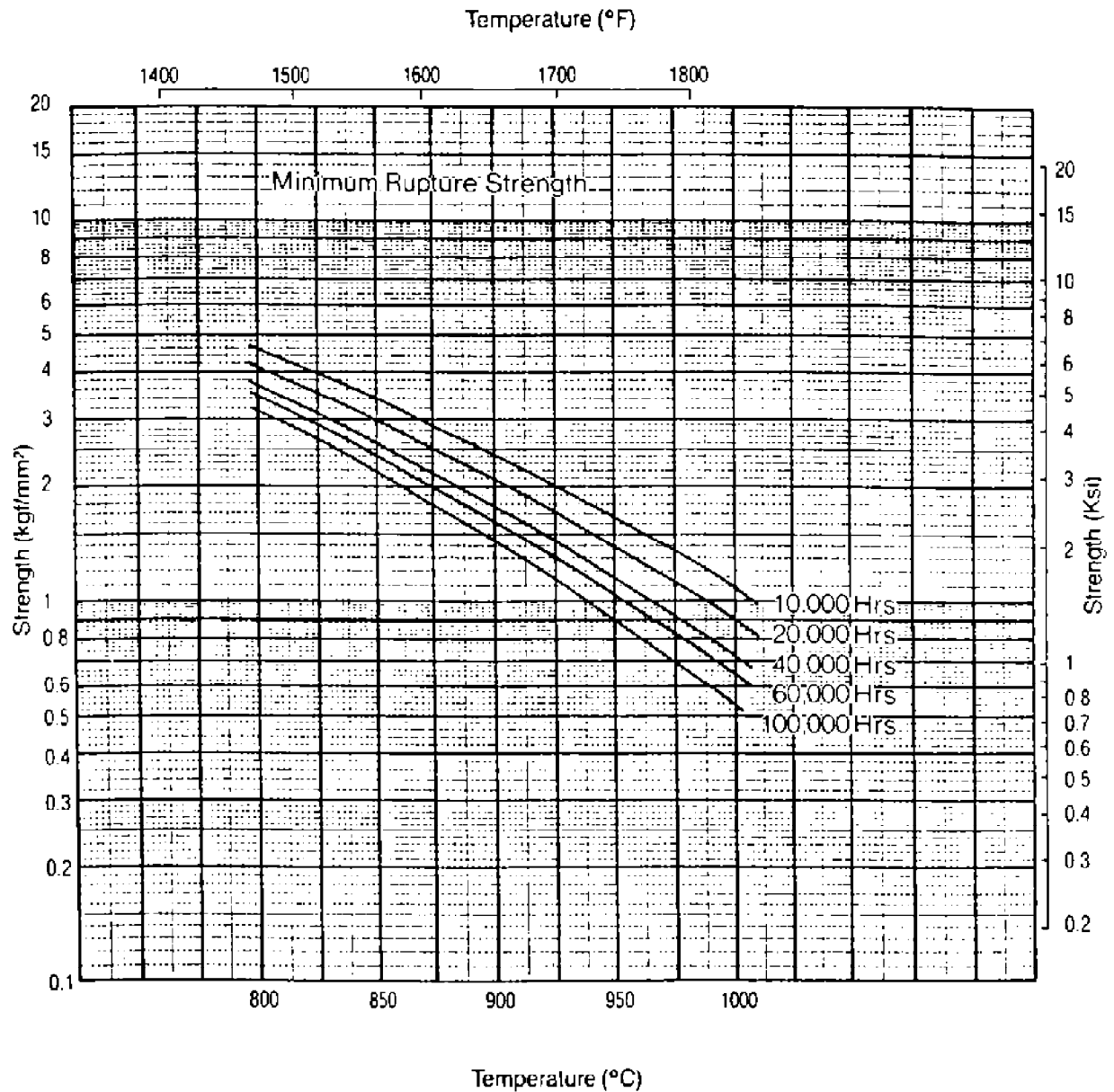
APPENDIX A

CREEP RUPTURE STRENGTH CURVES FOR IN-519



APPENDIX A

IN-519



APPENDIX A

CHEMICAL COMPOSITION (%) OF MODIFIED HP

(ASTM A-608)

C	0.40 \approx 0.50
Si	2.0 max.
Mn	0.5 max.
Cr	24 \approx 28
Ni	34 \approx 37
Nb	0.6 \approx 1.5

3. PHYSICAL PROPERTIES

Density	(g/cm ³) (lb/in ³)	8.05 (0.291)
Melting Point	(°C) (°F)	about 1,355 (2,471)
Hardness	(BHN)	160 \approx 220
Mean Coefficient of Linear Thermal	20 \approx 900°C (68 \approx 1,652°F)	17.2×10^{-6} (9.6×10^{-6})
	20 \approx 1,000°C (68 \approx 1,832°F)	17.5×10^{-6} (9.7×10^{-6})
Expansion (mm/mm/°C) (in/in/°F)	20 \approx 1,100°C (68 \approx 2,012°F)	18.1×10^{-6} (10.1×10^{-6})
Thermal Conductivity		
at 1050°C	Cal/cm ² .s.°C	0.75
at 1992 °F	(Btu. in/ft ² . hr.°F)	(218)

APPENDIX A

MECHANICAL PROPERTIES OF MODIFIED

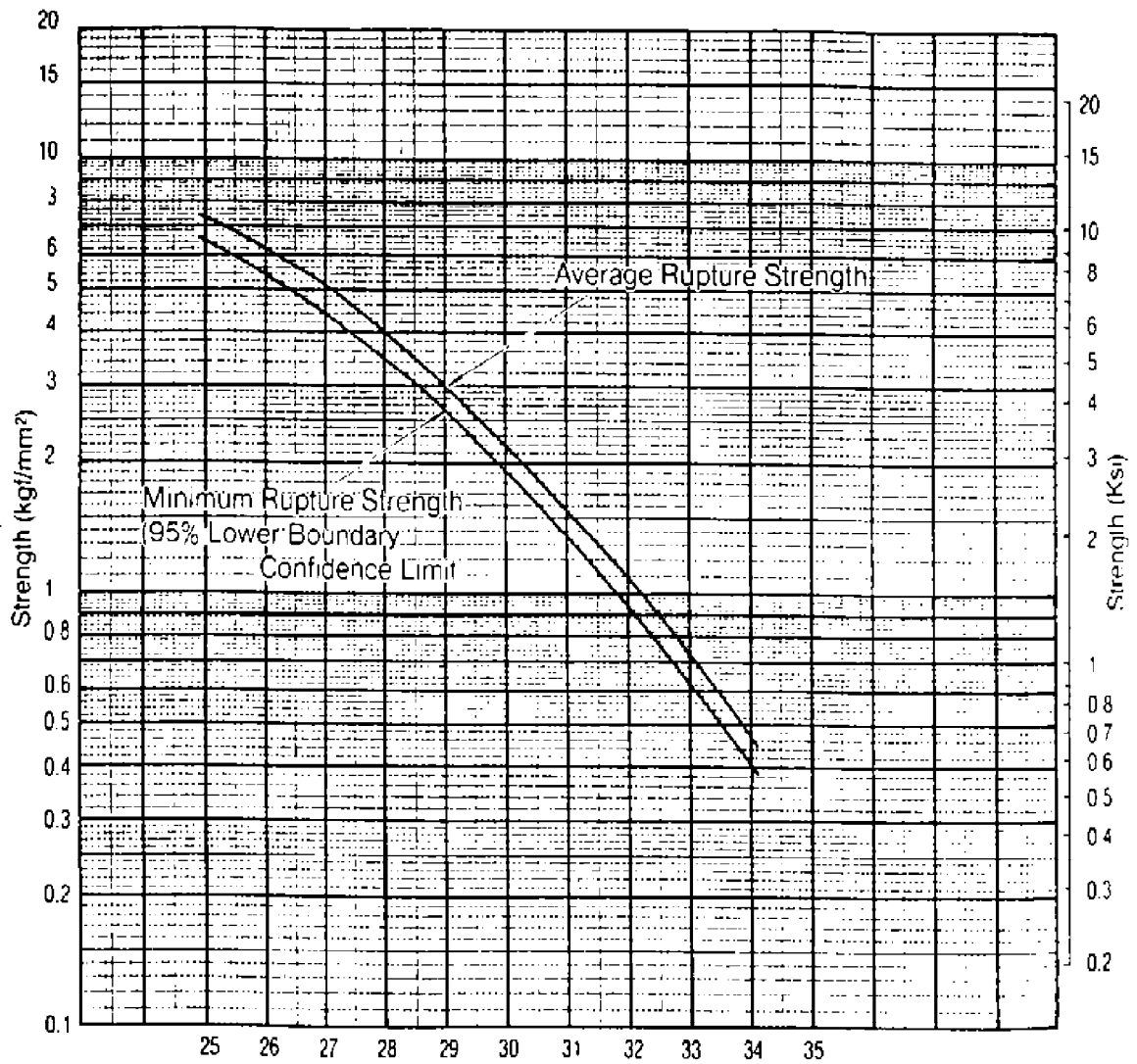
HP (ASTM A-608)

At Room Temperature	(Representative Value)		
Tensile Strength (kg/mm ²) (Ksi)	56 (79.6)		
Yield Strength (kg/mm ²) (Ksi)	27 (38.4)		
Elongation (%)	15		
At Various Temperature	(Representative Value)		
	900°C (1,652°F)	1,000°C (1,832°F)	1,100°C (2,012°F)
Tensile Strength $\frac{\text{(kg/mm}^2\text{)}}{\text{ksi}}$	$\frac{17}{(24.2)}$	$\frac{11}{(15.6)}$	$\frac{6}{(8.5)}$
Elongation (%)	35	48	63
Reduction of Area (%)	45	62	70

APPENDIX A

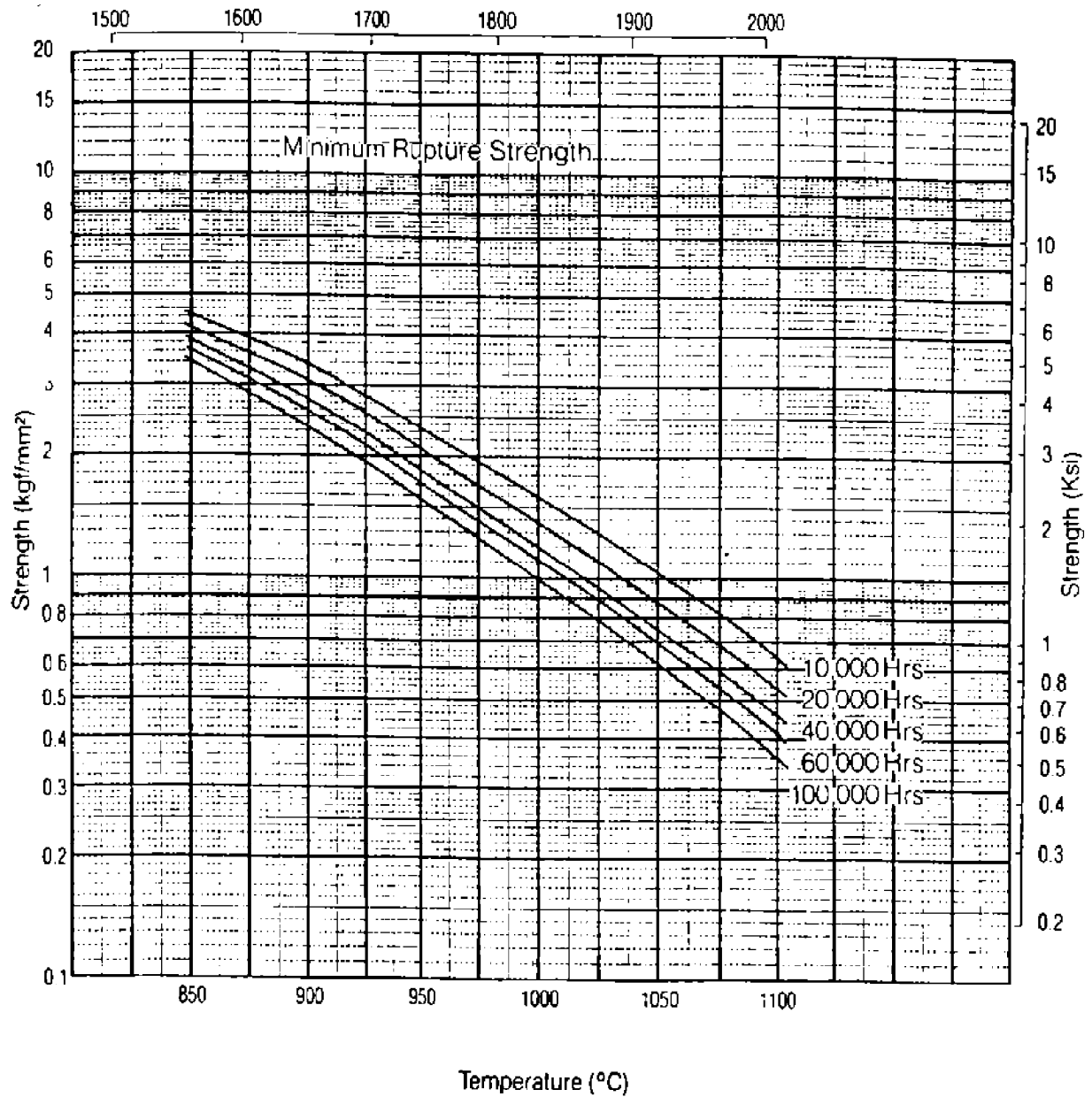
CREEP RUPTURE STRENGTH CURVES FOR

MODIFIED HP (ASTM A-608)



APPENDIX A

MODIFIED HP (ASTM A-608)



PART III

MATERIAL STANDARD FOR OUTLET MANIFOLD FOR REFORMER FURNACES

1. SCOPE

1.1 This part of this Standard specification covers the minimum requirements for the design material, fabrication, inspection and testing of outlet manifolds for steam-hydrocarbon reformer furnaces.

1.2 In case of conflict between this specification and the pertinent drawings, the latter requirements shall govern.

2. REFERENCES

Throughout this standard the following standards and codes are referred to. The editions of these standards and codes that are in effect at the time of publication of this standard shall to the extent specified herein, form a part of this standard. The applicability of changes in standards and codes that occur after the date of this standard shall be mutually agreed upon by the Company and the Vendor.

ASTM (AMERICAN SOCIETY FOR TESTING AND MATERIALS)

B-407	"Specification for Nickel-Iron-Chromium Alloy Seamless Pipe and Tube"
E-165	"Practice for Liquid Penetrant Inspection Method"

3. UNITS

This Standard is based on International System of Units (SI) except where otherwise is specified.

4. MATERIAL

4.1 Outlet manifold materials shall comply with the specifications as given on the relative drawings and requisition.

4.2 Connectors and fittings shall be forged and machined wrought incoloy 800 grade II, solution annealed with an ASTM grain size of five (5) or coarser. Material shall be in accordance with ASME SB-407 latest edition.

4.3 Unless otherwise specified, only seamless pipe and fittings shall be used.

4.4 Guides material shall be wrought incoloy 800.

4.5 Thermowells material shall be as specified in the manifold drawings.

4.6 Chemical composition, physical and mechanical properties of the materials shall conform to their relative material standard. Material certificates shall be sent for Purchaser review and approval.

5. DESIGN

5.1 Design of outlet manifold for hydrogen reformer furnace shall be in accordance with ANSI B 31.3 with exception of allowable stress value, tube wall thickness and hydrostatic test pressure which shall be according to ASME boiler and pressure vessel code Section VIII, Division 1.

5.2 As far as possible, design of outlet manifold for reformer furnace shall be such that welds are avoided at locations where thermal conditions are most severe.

5.3 It shall be the Vendors responsibility to integrate the design of the furnace, radiant tube outlet connectors and manifold to insure that no excessive stresses are imposed on any part of the system while in operation or at any temperature between ambient and operating temperatures during heating and cooling of the furnace.

6. FABRICATION

6.1 Shop fabrication drawings shall be submitted for purchasers approval prior to start of fabrication. Manufacture shall be in conformity with these approved drawings.

6.2 The manifolds shall be shop assembled to the greatest possible degree consistent with shipping limitations.

6.3 Pipes and fittings shall be bevelled for welding using a joint design consistent with the metal thickness and the welding procedure to be utilized in fabrication.

7. WELDING

7.1 Welding shall conform to ASME code Section VIII. Qualifications tests for welding procedures and welders shall comply with the requirements of Section IX of the ASME boiler and pressure vessel code.

7.2 Fabricator shop welding procedures including joint design shall be submitted for approval to the purchaser prior to the start of fabrication.

7.3 Welds should preferably be made by tungsten arc inert gas or metal arc inert gas with manual or automated processes. Metal arc welding with coated electrodes (SMAW) is not allowed for the root runs.

7.4 Filler wires and electrodes shall be selected by the fabricator on the basis of his experience and shall be approved by the Purchaser.

7.5 Complete penetration of the root run is required and the interior shall be reasonably even and flush with no excess penetration greater than 1 mm.

7.6 The outside of the completed weld shall have a minimum reinforcement of 1 mm and a maximum of 3 mm. In the case of metal arc welding with coated electrodes the weld area shall be cleaned to remove all traces of welding slag.

7.7 Permanent backing rings shall not be used.

8. INSPECTION AND TEST

8.1 All material and work including the work of sub-suppliers shall be subject to inspection by the vendor. Purchaser's inspector shall have free access to the plants at all times when the work is performed. Any rejections made by him will be final.

8.2 Mill certificates of all appurtenances from subvendor shall be reviewed and shall conform to the applicable standards.

8.3 Appurtenances shall be visually and dimensionally inspected and shall conform to the relative drawings.

8.4 Flange tolerances shall conform to ANSI B 16.5.

8.5 The following portions shall be liquid penetrant examined per ASTM E-165:

8.5.1 Finished inside surface of couplings.

8.5.2 Edges and bevelled portions to be welded.

8.5.3 Bevelled and inner surface of flanges acceptance shall be per ASME Code Section VIII Appendix 8.

8.6 Completed root pass shall be inspected inside and outside for cracks before continuing. Internal inspection shall be made with borescope and external inspection with dye penetrant. Root passes showing cracks shall be removed completely and rewelded.

8.7 Final weld pass shall be liquid penetrant inspected including the pipe or fitting surface for a minimum of 12 mm on each side of the weld. The weld shall be completely free from flaws and porosity.

8.8 All welds shall be 100% radiographed in accordance with the procedures and interpretation of the ASME boiler and pressure vessel code Section VIII Division 1 part UW. Radiographing shall be carried out using high contrast fine grained films and penetrameters.

8.9 If any weld or any portion of a weld or welds is deemed to be of unsatisfactory standard or quality, repairs or rewelding shall be carried out in accordance with ASME section VIII Division 1 part UW.

8.10 Welds joining structural attachments shall be liquid penetrant inspected. Examination method shall be per ASTM E-165 and acceptance shall be per ASME code Section VIII Appendix 8.

8.11 Completed manifold assembly including any flanges, fittings, coupling, etc. shall be hydrostatically tested in accordance with the following requirements:

8.11.1 Testing procedure shall be submitted to Purchaser for approval prior to testing.

8.11.2 Test media shall be clean water with maximum 25 ppm chloride content.

8.11.3 Test pressure shall be as specified in the manifold drawing.

8.11.4 Test pressure shall be held for at least 15 minutes.

8.11.5 The manifold assembly shall be thoroughly dried after testing.

8.12 Any materials applied for inspection, testing and identification shall be free from metals, metal salts, such as lead, zinc, copper or sulphur compounds with low melting points that could become corrosive at high temperatures or detrimental to welds.

9. DRAWINGS AND DOCUMENTATION

9.1 One reproducible copy of the as built drawings shall be submitted to the purchaser for record.

9.2 Vendor shall supply three copies of material certificates inspection and test certificates and photo micrographs showing grain size of material to the Purchaser.