

DEP SPECIFICATION

MATERIALS FOR HIGH-TEMPERATURE CONVERSION PROCESS FURNACE PARTS

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DESIGN AND ENGINEERING PRACTICE



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1. INTRODUCTION

1.1 SCOPE

This DEP specifies requirements and gives recommendations for selection of materials for furnace components which under operating conditions will have a metal temperature above 700°C (1292°F).

- Notes:
1. Some parts associated with the heating section may have actual operating temperatures below 700°C (1292°F), however the requirements of this specification still apply.
 2. For furnace tubes, the metal temperature shall be taken to be the skin temperature.

In addition, guidelines are given to assist in the fabrication, inspection and testing of new furnace parts and the repair welding of used parts.

The DEP is intended for transfer lines, radiant tubes, fittings and assemblies for:

- Steam-naphtha or steam-methane reforming, for the production of synthesis gas or hydrogen;
- Naphtha, gas oil or gas cracking, for the production of ethylene or other lower olefins;
- High temperature (process) steam superheating.

For the selection of materials for furnaces having metal temperatures below 700°C (1292°F), and for the furnace structure, reference shall be made to DEP 31.24.00.30-Gen.

This is a revision of the DEP of the same number dated December 2000; see (1.5) regarding the changes.

1.2 DISTRIBUTION, INTENDED USE AND REGULATORY CONSIDERATIONS

Unless otherwise authorised by Shell GSI, the distribution of this DEP is confined to Shell companies and, where necessary, to Contractors and Manufacturers/Suppliers nominated by them. Any authorised access to DEPs does not for that reason constitute an authorization to any documents, data or information to which the DEPs may refer.

This DEP is intended for use in facilities related to oil and gas production, gas handling, oil refining, chemical processing, gasification, distribution and supply/marketing. This DEP may also be applied in other similar facilities.

When DEPs are applied, a Management of Change (MOC) process shall be implemented; this is of particular importance when existing facilities are to be modified.

If national and/or local regulations exist in which some of the requirements could be more stringent than in this DEP, the Contractor shall determine by careful scrutiny which of the requirements are the more stringent and which combination of requirements will be acceptable with regards to the safety, environmental, economic and legal aspects. In all cases the Contractor shall inform the Principal of any deviation from the requirements of this DEP which is considered to be necessary in order to comply with national and/or local regulations. The Principal may then negotiate with the Authorities concerned, the objective being to obtain agreement to follow this DEP as closely as possible.

1.3 DEFINITIONS

1.3.1 General definitions

The **Contractor** is the party that carries out all or part of the design, engineering, procurement, construction, commissioning or management of a project or operation of a facility. The Principal may undertake all or part of the duties of the Contractor.

The **Manufacturer/Supplier** is the party that manufactures or supplies equipment and services to perform the duties specified by the Contractor.

The **Principal** is the party that initiates the project and ultimately pays for it. The Principal may also include an agent or consultant authorised to act for, and on behalf of, the Principal.

The word **shall** indicates a requirement.

The word **should** indicates a recommendation.

1.3.2 Specific definitions

Term	Definition
DBTT	Ductile-to-brittle transition temperature
EBW	Electron Beam Welding
GTAW	Gas Tungsten Arc Welding
IGSCC	Intergranular Stress Corrosion Cracking
MA	Mechanical Alloying
ODS	Oxide Dispersion Strengthened
PM	Powder Metallurgy
PTA SCC	Polythionic Acid Stress Corrosion Cracking
PWHT	Post Weld Heat Treatment
RE	Reactive Elements (additions) ; In Oxide Dispersion Strengthened alloys generally $ZrO_2-Al_2O_3$ or $Y_2O_3-Al_2O_3$
RSP	Rapidly Solidified Powder
SAW	Submerged Arc Welding
SMAW	Shielded Metal Arc Welding

1.4 CROSS-REFERENCES

Where cross-references to other parts of this DEP are made, the referenced section number is shown in brackets (). Other documents referenced by this DEP are listed in (9).

1.5 SUMMARY OF MAIN CHANGES

This DEP is a revision of the DEP of the same number dated December 2000. The following are the main, non-editorial changes.

Old section	New section	Change
2.1	2.1	Added: Resistance to reheat cracking and stress relaxation cracking
2.1	2.1	Modified: Resistance to thermal cycling, Low Cycle Fatigue (LCF) and thermal shock
2.3	2.3	Added notes 1 to 5 a note to Table 1 Modified text in column specifications/remarks of Table 1 for alloys HK 40; HK 40HiSi; 24Cr-24Ni-Nb; HP 40 Added alloys 35Cr-45Ni-Nb; 25Cr-45Ni-Nb; 27Cr-47Ni-Nb; 27Cr-47Ni-Nb-W Replacing Type of steel with Type of alloy (first column of Table 1)

Old section	New section	Change
2.4	2.4	Corrective on the Table 2.4: Hot collector ASTM B 366 WPNIC 10 or WPNIC 11 (instead of WPNIC 12 in the previous version) Added alloy 35Cr-45Ni-Nb Added note 6
2.5	2.5	Added note 7
	3	New section degradation mechanisms
3	4	Additional material selection requirements
3.1	4.1	Splitted (4.1) in two sub-sections 4.1.1 – General and 4.1.2 Limitation of alloying element for reheat cracking and stress relaxation cracking
4	5	Inspection and testing
5	6	Welding of tubes
	6.3	Added Prevention of reheat cracking and stress relaxation cracking of alloy 800HT
	6.4	Added Prevention of reheat cracking and stress relaxation cracking of alloys 321H and 347H
	6.5	Added Prevention of reheat cracking and stress relaxation cracking of alloys HK 40, HP 40, HP-Nb and HP-Nb modified
6	7	Developments in furnace technology
6.2	7.2	Splitted the section into Internally-coated tubes (7.2) and overlay-welded and bi-metallic tubes (7.3)
6.2	7.3	New section: Overlay-welded and bi-metallic tubes.
	7.4	New section: FeCrAl-alloys

1.6 COMMENTS ON THIS DEP

Comments on this DEP may be sent to the Administrator at standards@shell.com, using the DEP Feedback Form. The DEP Feedback Form can be found on the main page of "DEPs on the Web", available through the Global Technical Standards web portal <http://www.shell.com/standards> and on the main page of the DEPs DVD-ROM.

1.7 DUAL UNITS

This DEP contains both the International System (SI) units, as well as the corresponding US Customary (USC) units, which are given following the SI units in brackets. When agreed by the Principal, the indicated USC values/units may be used.

2. SELECTION OF MATERIALS

2.1 GENERAL

The high temperature furnace parts covered by this DEP shall be made of wrought or cast heat-resisting iron-chromium-nickel alloys.

Selection of the most appropriate heat-resistant alloy for a given application requires evaluation of the potential degradation of that material due to service exposure to the process environment in addition to selection based on the optimum mechanical properties at high temperatures.

The following criteria shall be evaluated when materials are selected:

1. Stress-rupture and creep strength;
2. Resistance to reheat cracking and stress relaxation cracking;
3. Resistance to thermal cycling, low cycle fatigue (LCF) and thermal shock;
4. Resistance to internal carburisation and metal dusting;
5. Resistance to external oxidation;
6. Embrittlement behaviour;
7. Fabrication requirements;
8. Availability and cost.

A number of "families" of heat-resistant alloys have been identified in the industry. In this DEP, the selection of materials is based on these industry groupings. Alternative (proprietary) materials may also be considered where it is known, either during design or as a result of lessons learned during operation, that the particular furnace components require additional resistance to certain operational conditions.

The selection of proprietary materials shall be based on a detailed review of the proprietary materials' high temperature properties, including creep rupture values, testing requirements, see (4), and records of successful application and shall be approved by the Principal.

2.2 SELECTION GUIDELINES

The tables in (2.4) to (2.7) indicate the recommended materials of construction for the different types of furnaces and furnace components covered by this DEP.

Where industry standard specifications do not presently exist, generic materials types, as described in (2.3), are listed and often there will be a choice of similar alternatives from different Manufacturers/Suppliers.

For the most critical applications the material selection will be dependent upon a number of factors, e.g., operational coking/de-coking practice and its effect on carburisation, furnace design and potential distortion, etc.

In the case of new furnaces it is recommended that the initial selection of the generic material type is based upon the design requirements and any known operational characteristics of the furnace.

Once the basic generic type of material has been established, a final selection from the available standard and proprietary alloys may be made in consultation with the tube Manufacturers/Suppliers, based on performance and economic considerations.

Although there are variations in alloy composition (mostly minor different additions) from one tube Manufacturer to another within the generic types, it is considered impractical to restrict the Manufacturers to standard compositions.

The Manufacturers' published mechanical properties shall also be used when determining tube dimensions in accordance with the requirements of API STD 530.

When tubes are replaced in existing furnaces, the operational history and the primary factors contributing to the replacement may dictate the material selected.

The micro-alloyed variant of the 25Cr-35Ni-Nb (HP Nb modified) type and its variant provides the best combination of properties and performance.

In all cases the weld mechanical/creep properties shall be demonstrated and agreed with the Principal prior to fabrication

2.3 MATERIALS CHARACTERISTICS

Applicable to (2.4) to (2.6), i.e., excludes cast coil supports in (2.7).

Table 1 Material characteristics

Type of Alloy <i>Note 1</i>	Common Name (UNS#)	Specification ASTM	Characteristics
18Cr-8Ni-Ti (wrought)	321H (UNS S32109)	A 182, A 193, A 312, A 403	Austenitic stainless steels have moderate creep and good corrosion-resistant properties.
18Cr-8Ni-Nb (cast)	347H (UNS J92710)	A 351	A minimum 0.4% C is required to obtain H grade properties.
20Cr-33Ni (cast)	CT15C (UNS N08151)	A 351	The H and HT grades of the wrought alloy have significantly higher creep and rupture strength than Alloy 800 (not used).
20Cr-33Ni (wrought)	Alloy 800H/HT (UNS N08810) (UNS N08811)	B 366, B407, B 408, B 564	Chemical composition restrictions, annealing heat treatment and grain size control result in desired properties.
25Cr-20Ni (centrifugally cast)	HK40 (UNS J94204)	A 608	Historically used in reformer furnaces, should not be used for new design. <i>Note 2</i>
25Cr-20Ni (statically cast)		A 297, A 351	<i>Note 3</i>
25Cr-20Ni-Si	HK40 High Si		<i>Note 4</i>
24Cr-24Ni-Nb	IN 519		<i>Note 5</i>
25Cr-35Ni	HP40 (UNS J95705)		
25Cr-35Ni-Nb	HP Nb modified		Creep strength increased by adding Nb to HP alloy to form NbC. Grain boundary network is finer and very stable at high temperature.
25Cr-35Ni-Nb-Ti	HP Micro alloy		Creep strength increased by adding Nb and Ti to HP alloy Titanium offers resistance to secondary carbide growing.
25Cr-35Ni-Nb-Ti + additions (Zr etc.)			Secondary carbide precipitation in austenite matrix after ageing is less than for HP Nb modified alloy.
25Cr-35Ni-Nb-W	HP W mod		W is added to the HP Nb modified alloy to improve corrosion resistance.
35Cr-45Ni-Nb	Proprietary alloys		These alloys have been developed for ethylene cracking applications.
25Cr-45Ni-Nb			
27Cr-47Ni-Nb			
27Cr-47Ni-W / other metals			

- NOTES:
- 1) The alloys that can be used are not limited to the alloys listed in Tables 1 to 5; the Manufacturers have developed some specific alloys that can be used, if technically or economically justified.
 - 2) Secondary carbide precipitation in austenite matrix
 - 3) Susceptible to aging embrittlement
 - 4) Improved carburization resistance
 - 5) Strengthening by precipitation of primary NbC on grain boundaries