

Metallic Material Limits for Wellhead Equipment Used in High Temperature for API 6A and 17D Applications

API TECHNICAL REPORT 6MET
FIRST EDITION, OCTOBER 2010



AMERICAN PETROLEUM INSTITUTE

Metallic Material Limits for Wellhead Equipment Used in High Temperature for API 6A and 17D Applications

Upstream Segment

API TECHNICAL REPORT 6MET
FIRST EDITION, OCTOBER 2010



AMERICAN PETROLEUM INSTITUTE

Special Notes

API publications necessarily address problems of a general nature. With respect to particular circumstances, local, state, and federal laws and regulations should be reviewed.

Neither API nor any of API's employees, subcontractors, consultants, committees, or other assignees make any warranty or representation, either express or implied, with respect to the accuracy, completeness, or usefulness of the information contained herein, or assume any liability or responsibility for any use, or the results of such use, of any information or process disclosed in this publication. Neither API nor any of API's employees, subcontractors, consultants, or other assignees represent that use of this publication would not infringe upon privately owned rights.

API publications may be used by anyone desiring to do so. Every effort has been made by the Institute to assure the accuracy and reliability of the data contained in them; however, the Institute makes no representation, warranty, or guarantee in connection with this publication and hereby expressly disclaims any liability or responsibility for loss or damage resulting from its use or for the violation of any authorities having jurisdiction with which this publication may conflict.

API publications are published to facilitate the broad availability of proven, sound engineering and operating practices. These publications are not intended to obviate the need for applying sound engineering judgment regarding when and where these publications should be utilized. The formulation and publication of API publications is not intended in any way to inhibit anyone from using any other practices.

Any manufacturer marking equipment or materials in conformance with the marking requirements of an API standard is solely responsible for complying with all the applicable requirements of that standard. API does not represent, warrant, or guarantee that such products do in fact conform to the applicable API standard.

Users of this Technical Report should not rely exclusively on the information contained in this document. Sound business, scientific, engineering, and safety judgment should be used in employing the information contained herein.

All rights reserved. No part of this work may be reproduced, translated, stored in a retrieval system, or transmitted by any means, electronic, mechanical, photocopying, recording, or otherwise, without prior written permission from the publisher. Contact the Publisher, API Publishing Services, 1220 L Street, NW, Washington, DC 20005.

Copyright © 2010 American Petroleum Institute

Foreword

Nothing contained in any API publication is to be construed as granting any right, by implication or otherwise, for the manufacture, sale, or use of any method, apparatus, or product covered by letters patent. Neither should anything contained in the publication be construed as insuring anyone against liability for infringement of letters patent.

This document was produced under API standardization procedures that ensure appropriate notification and participation in the developmental process and is designated as an API standard. Questions concerning the interpretation of the content of this publication or comments and questions concerning the procedures under which this publication was developed should be directed in writing to the Director of Standards, American Petroleum Institute, 1220 L Street, NW, Washington, DC 20005. Requests for permission to reproduce or translate all or any part of the material published herein should also be addressed to the director.

Suggested revisions are invited and should be submitted to the Standards Department, API, 1220 L Street, NW, Washington, DC 20005, standards@api.org.

Contents

Page

Introduction	vi
1 Scope	1
2 Procedure	2
3 Results	2
3.1 Phase I Results	2
3.2 Phase II Results	3
3.3 Phase III Results	3
4 Conclusions	4
5 Recommendations	5
Annex A (informative) AISI 4130 Test Results	10
Annex B (informative) AISI 8630 Test Results	12
Annex C (informative) 2 ¹ / ₄ Cr 1 Mo Test Results	14
Annex D (informative) AISI 4140 Test Results	16
Annex E (informative) 410 Stainless Steel Test Results	18
Annex F (informative) F6NM Test Results	20
Annex G (informative) 25 Chrome Super Duplex Test Results	22
Annex H (informative) ASTM A453 Gr. 660 Test Results	24
Annex I (informative) 718 (per Spec 6A718) Test Results	26
Annex J (informative) 725/625 Plus Test Results	28
Annex K (informative) 925 Test Results	30
Bibliography	32
Figure	
1 AISI 8630 Strength Reduction with Temperature	3
Tables	
1 List of Alloys Included in Phase I Testing	1
2 List of Alloys Included in Phase II Testing	1
3 List of Alloys Included in Phase III Testing	1
4 Recommended Yield Strength Reduction Ratios in Percent by Temperature	4
5 Yield Strength Reduction Factors in Percent by Temperature (from Literature)	4
6 Alloy Composition for AISI 4130	5
7 Alloy Composition for 8630M	5
8 Alloy Composition for 21/4Cr-1Mo (F22)	5
9 Alloy Composition for AISI 4140 Test Material	6
10 Alloy Composition for 410 Stainless Steel	6
11 Alloy Composition for F6NM Stainless Steel	6
12 Alloy Composition for 25Cr Super Duplex	7
13 Alloy Composition for ASTM A453 Gr 660 Precipitation Hardened Austenitic Stainless Steel	7
14 Alloy Composition for Nickel Alloy 718 (per Spec 6A718)	8

Contents

Page

15	Alloy Composition for Nickel Alloys 725 and 625 Plus	8
16	Alloy Composition for Nickel Alloy 925	9
A.1	AISI 4130 Test Results	10
A.1	Plot of 4130 Test Results	11
B.1	AISI 8630 Test Results	12
B.1	Plot of 8630 Test Results	13
C.1	21/4 Cr 1 Mo Test Results	14
C.1	Plot of 21/4 Cr 1 Mo Test Results	15
D.1	AISI 4140 Test Results	16
D.1	Plot of AISI 4140 Test Results	17
E.1	AISI 410 Test Results	18
E.1	Plot of AISI 410 Stainless Steel Test Results	19
F.1	F6NM Test Results	20
F.1	Plot of F6NM Test Results	21
G.1	25 Chrome Super Duplex Test Results	22
G.1	Plot of 25 Chrome Super Duplex Test Results	23
H.1	ASTM A453 Gr. 660 Test Results	24
H.1	Plot of ASTM A453 Gr. 660 Test Results	25
I.1	718 (per Spec 6A718) Test Results	26
I.1	Plot of 718 (per Spec 6A718) Test Results	27
J.1	725/625 Plus Test Results	28
J.1	Plot of 725/625 Plus Test Results	29
K.1	925 Test Results	30
K.1	Plot of 925 Test Results	31

Introduction

This API-funded project was conducted by a Task Group charged by the Association of Well Head Equipment Manufacturers (AWHEM). The Task Group examined mechanical properties of metallic materials used for API 6A and API 17D wellhead equipment for service above 250 °F. A total of eleven different alloys meeting API 6A, PSL 3 conditions were supplied "in condition" by a variety of suppliers. Materials in this test program included alloys common to the oil and gas industry. The alloys tested included low alloy steels, martensitic, precipitation hardened and duplex stainless steels, and nickel alloys. Yield strength reduction ratios at temperatures of 300 °F, 350 °F, 400 °F, and 450 °F are reported. As a result of testing, yield strength reduction ratios at 300 °F to 450 °F ranged from 92 % to 87 % for the low alloy steels, 92% to 88% for the martensitic stainless steels 81 % to 73 % for super duplex, 99 % to 89 % for the precipitation hardened stainless steel and 94 % to 89 % for the nickel alloys. The reported results represent an average over the different heats for each type of material. These results are intended to expand the data shown in API 6A, Annex G.

Metallic Material Limits for Wellhead Equipment Used in High Temperature for API 6A and 17D Applications

1 Scope

Testing was performed in three phases, presented herein in chronological order as Phase I, II, and III. Initially, all testing was to be completed in two phases, but testing anomalies in Phase II prompted re-testing of some alloys in Phase III.

Alloy candidates were recommended by AWHEM membership for analysis and confirmed by API's approval of New Work Item No. 2003-100786 in June 2002. Several material suppliers and several AWHEM member companies donated material for testing. Metallurgists on the Task Group screened material certificates to ensure a "normal" chemistry without enhancements for the material candidates listed in Table 1, Table 2, and Table 3.

Alloy chemistries from the material certificates for each of the supplied alloy candidates are provided in Table 6 through Table 16, located at the end of this report for readability.

Table 1—List of Alloys Included in Phase I Testing

Material	Yield Strength Class	Application	Bar Size
AISI 4130	75K	Pressure Containing	5 in. ER
AISI 8630	75K	Pressure Containing	5 in. ER
2 ¹ / ₄ Cr 1 Mo	75K	Pressure Containing	5 in. ER
AISI 4140	75K	Pressure Containing	5 in. ER
AISI 410 SS	75K	Pressure Containing	5 in. ER
F6NM	75K	Pressure Containing	5 in. ER

Table 2—List of Alloys Included in Phase II Testing

Material	Yield Strength Class	Application	Material Size
25 Cr Super Duplex*	110K	Pressure Containing	2.4 in. to 5.5 in. OD
ASTM A453 Gr 660	100K	Pressure Retaining	0.75 in. to 1.5 in. OD
718 (per Spec 6A718)	130K	Pressure Containing	1.25 in. to 8.5 in. OD x 5.5 in.
725/625 Plus	130K	Pressure Containing	0.63 in. to 6.5 in. OD data 9 in. OD test
925	110K	Pressure Containing	1 in. to 6.5 in. OD
* Pitting resistance equivalence number, PREN >40.			

Table 3—List of Alloys Included in Phase III Testing

Material	Yield Strength	Application	Material Size
Nickel Alloy 725/625 Plus	120K	Pressure Containing	1.25 in. to 6.0 in. OD
Nickel Alloy 925	110K	Pressure Containing	1.0 in. to 8.7 in. OD