Age-hardened Nickel-based Alloys for Oil and Gas Drilling and Production Equipment

API STANDARD 6ACRA
SECOND EDITION, JANUARY 2025



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. The use of API publications is voluntary. In some cases, third parties or authorities having jurisdiction may choose to incorporate API standards by reference and may mandate compliance.

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 ensure 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 used. 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.

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, 200 Massachusetts Avenue, NW, Suite 1100, Washington, DC 20001-5571.

Copyright © 2024 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.

The verbal forms used to express the provisions in this document are as follows.

Shall: As used in a standard, “shall” denotes a minimum requirement to conform to the standard.

Should: As used in a standard, “should” denotes a recommendation or that which is advised but not required to conform to the standard.

May: As used in a standard, “may” denotes a course of action permissible within the limits of a standard.

Can: As used in a standard, “can” denotes a statement of possibility or capability.

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, 200 Massachusetts Avenue, NW, Suite 1100, Washington, DC 20001. Requests for permission to reproduce or translate all or any part of the material published herein should also be addressed to the director.

Generally, API standards are reviewed and revised, reaffirmed, or withdrawn at least every five years. A one-time extension of up to two years may be added to this review cycle. Status of the publication can be ascertained from the API Standards Department, telephone (202) 682-8000. A catalog of API publications and materials is published annually by API, 200 Massachusetts Avenue, NW, Suite 1100, Washington, DC 20001.

Suggested revisions are invited and should be submitted to the Standards Department, API, 200 Massachusetts Avenue, NW, Suite 1100, Washington, DC 20001, standards@api.org.

Contents

Page

1 Scope 1
1.1 Purpose 1
1.2 Applicability 1

2 Normative References 1

3 Terms, Definitions, and Abbreviations 2
3.1 Terms and Definitions 2
3.2 Abbreviations 3

4 Requirements for Age-hardened Nickel-based Alloys 4
4.1 Process Control Requirements 4
4.2 Testing Requirements 8

5 Certification 18

6 Marking 19

7 Addition of New Alloys and/or New Material Designations 19

Annex A (informative) Reference Microstructures 20

Annex B (normative) Addition of, or Modification to, Alloys and Material Designations in This Standard 41

Annex C (informative) Industry Empirical Data on Hardness Conversion for Age Hardened Nickel-based Alloys . 44

Bibliography 46

Figures

A.1 Acceptable Microstructure for UNS N07718; Original Magnification: 100X for Upper Photomicrograph (A); 500X for Lower Photomicrograph (B) 21
A.2 Acceptable Microstructure for UNS N07718; Original Magnification: 100X for Upper Photomicrograph (A); 500X for Lower Photomicrograph (B) 22
A.3 Acceptable Microstructure for UNS N07718 Showing Isolated Grain Boundary Precipitates; Original Magnification: 100X for Upper Photomicrograph (A); 500X for Lower Photomicrograph (B) 23
A.4 Acceptable Microstructure for UNS N07718 Showing Isolated Acicular Grain Boundary Precipitates; Original Magnification: 100X for Upper Photomicrograph (A); 500X for Lower Photomicrograph (B) 24
A.5 Unacceptable Microstructure for UNS N07718 Showing Acicular Grain Boundary Precipitates; Original Magnification: 100X for Upper Photomicrograph (A); 500X for Lower Photomicrograph (B) 25
A.6 Unacceptable Microstructure for UNS N07718 Showing Acicular Grain Boundary Precipitates; Original Magnification: 100X for Upper Photomicrograph (A); 500X for Lower Photomicrograph (B) 26
A.7 Unacceptable Microstructure for UNS N07718 Showing Acicular Grain Boundary Precipitates; Original Magnification: 100X for Upper Photomicrograph (A); 500X for Lower Photomicrograph (B) 27
A.8 Unacceptable Microstructure for UNS N07718 Showing Acicular Grain Boundary Precipitates; Original Magnification: 100X for Upper Photomicrograph (A); 500X for Lower Photomicrograph (B) 28
A.9 Unacceptable Microstructure for UNS N07718 Showing Grain Boundary Precipitates; Original Magnification: 500X for Photomicrograph 29

Contents

Page

A.10 Acceptable Microstructure for UNS N06625; Original Magnification: 100X for Upper Photomicrograph (A); 500X for Lower Photomicrograph (B) 30
A.11 Acceptable Microstructure for UNS N06625; Original Magnification: 100X for Upper Photomicrograph (A); 500X for Lower Photomicrograph (B) 31
A.12 Unacceptable Microstructure for UNS N06625 Showing Acicular Grain Boundary Precipitates; Original Magnification: 100X for Upper Photomicrograph (A); 500X for Lower Photomicrograph (B) 32
A.13 Acceptable Microstructure for UNS N07716, UNS N07725, UNS N09925, UNS N09935, UNS N09945, UNS N09946 and UNS N09955; Original Magnification: 100X for Upper Photomicrograph (A); 500X for Lower Photomicrograph (B) 33
A.14 Acceptable Microstructure for UNS N07716, UNS N07725, UNS N09925, UNS N09935, UNS N09945, UNS N09946 and UNS N09955 Showing Isolated Grain Boundary Precipitation; Original Magnification: 100X for Upper Photomicrograph (A); 500X for Lower Photomicrograph (B) 34
A.15 Acceptable Microstructure for UNS N07716, UNS N07725, UNS N09925, UNS N09935, UNS N09945, UNS N09946 and UNS N09955 Showing Partial Coverage of Grain Boundaries with Second Phase Particles; Original Magnification: 100X for Upper Photomicrograph (A); 500X for Lower Photomicrograph (B) 35
A.16 Acceptable Microstructure for UNS N07716, UNS N07725, UNS N09925, UNS N09935, UNS N09945, UNS N09946 and UNS N09955 Showing Partial Coverage of Grain Boundaries with Second Phase Particles; Original Magnification: 100X for Upper Photomicrograph (A); 500X for Lower Photomicrograph (B) 36
A.17 Unacceptable Microstructure for UNS N07716, UNS N07725, UNS N09925, UNS N09935, UNS N09945, UNS N09946 and UNS N09955 Showing Full Coverage of Grain Boundaries with Second Phase Particles; Original Magnification: 100X for Upper Photomicrograph (A); 500X for Lower Photomicrograph (B) 37
A.18 Unacceptable Microstructure for UNS N07716, UNS N07725, UNS N09925, UNS N09935, UNS N09945, UNS N09946 and UNS N09955 Showing Acicular Grain Boundary Precipitates; Original Magnification: 100X for Upper Photomicrograph (A); 500X for Lower Photomicrograph (B) 38
A.19 Unacceptable Microstructure for UNS N07716, UNS N07725, UNS N09925, UNS N09935, UNS N09945, UNS N09946 and UNS N09955 Due to Acicular Precipitates; Original Magnification: 100X for Upper Photomicrograph (A); 500X for Lower Photomicrograph (B) 39
A.20 Unacceptable Microstructure for UNS N07716, UNS N07725, UNS N09925, UNS N09935, UNS N09945, UNS N09946 and UNS N09955 Showing Grain Boundary Precipitates; Original Magnification: 500X for Photomicrograph 40
C.1 Rockwell C-scale (HRC) Hardness Values Versus Mean Brinell (HBW) Hardness Values for Age Hardened Nickel-based Alloys, including Empirically Derived Regression Equation 45

Tables

1 Chemical Composition (weight %) 5
2 Acceptable Melt Practices 6
3 Heat Treatment Procedures 7
4 Etchants Used for Macroetch Examination 9
5 Etchants Used for Microstructure Examination 10
6 Tensile Requirements 12
7 Charpy V-notch Impact Toughness Requirements (10 mm × 10 mm) 15
8 Hardness Requirements 18
C.1 Tabulated Hardness Conversions for Age Hardened Nickel-based Alloys Based on Empirically Derived Regression Equation 44

Introduction

This standard for Age-Hardened Nickel-Based Alloys was formulated by the API Committee on Standardization of Oilfield Equipment and Materials (CSOEM), Subcommittee on Valves and Wellhead Equipment (SC6), Materials Task Group. It is based on the conclusions of a task group evaluation of requirements needed for Age-Hardened Nickel-Based Alloys to supplement the existing requirements of API Specification 6A, Specification for Wellhead and Tree Equipment.

NOTE Age-hardened and precipitation-hardened terms are interchangeably used in international standards

Age-hardened Nickel-based Alloys for Oil and Gas Drilling and Production Equipment

1 Scope

1.1 Purpose

This document provides material requirements, including acceptable microstructures, for age-hardened nickel-based alloys used in the manufacture of solid or hollow wrought raw materials for API 6A equipment, and other equipment where specified by the applicable Standard or Specification.

The process controls and tests requirements contained in this standard assist in achieving adequate performance in a variety of environments. These requirements have been applied since 2004 for UNS N07718 120K via API 6A718 (which was superseded by this Standard).

WARNING—Failures attributed to hydrogen-induced stress cracking (HISC) have been reported in production equipment and early in the life of subsea equipment made from age-hardened nickel-based alloys. Some age-hardened nickel-based alloys that meet the requirements of ANSI/NACE MR0175/ISO 15156 and API 6ACRA may be susceptible to HISC. Sources of hydrogen charging include but are not limited to galvanic coupling to a more active material, direct exposure to seawater with cathodic protection (CP), and decomposition of brines. The industry is evaluating alternate test methods and/or acceptance criteria to identify material with susceptibility to HISC.

1.2 Applicability

This standard is intended to apply to raw materials used in the manufacture of pressure-containing and pressure-controlling components as defined in API 6A. Requirements of this standard may be applied by voluntary conformance by a manufacturer, normative reference in API 6A or other product specification(s), or by contractual agreement.

Thermal post-processing of API 6ACRA material designations, after the applicable final aging heat treatment specified in this standard, is outside the scope of this standard.

NOTE Examples of thermal post-processing are thermochemical surface treatments (e.g. chemical vapor deposition) and/or thermal diffusion treatments (e.g. boronizing, nitriding, nitrocarburizing), welding, and brazing.

2 Normative References

The following referenced documents are indispensable for the application of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

API Specification 6A, *Specification for Wellhead and Tree Equipment*

ASTM A370,[1] *Test Methods and Definitions for Mechanical Testing of Steel Products*

ASTM A604, *Standard Practice for Macroetch Testing of Consumable Electrode Remelted Steel Bars and Billets*

ASTM B880, *Standard Specification for General Requirements for Chemical Check Analysis Limits for Nickel, Nickel Alloys and Cobalt Alloys*

ASTM E8, *Standard Test Methods for Tension Testing of Metallic Materials*

[1] ASTM International, 100 Barr Harbor Drive, West Conshohocken, Pennsylvania 19428-2959. www.astm.org.