Requirements for the Integrity Management of Grade 91 Steel Used Above Currently-Permitted Allowable Stresses

AB–536

Edition 2, Revision 0 - Issued 2022-04-28

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FOREWORD

The Administrator in the pressure equipment discipline has established that ABSA document AB-536: Requirements for the Integrity Management of Grade 91 Steel Used Above Currently-Permitted Allowable Stresses, defines requirements that must be met by owners of equipment which relies on higher allowable design stresses for Grade 91 creep-strength-enhanced ferritic steels than those that are permitted by the current in-force edition of the applicable code of construction.

The next edition of the AB-536 is scheduled for 2027.

1.0 INTRODUCTION AND BACKGROUND

A creep-strength-enhanced ferritic steel designated as Grade 91 was introduced in the early 1980s to provide significantly better strength properties at high service temperatures than other materials that were available at the time. In the years since its introduction, it has been determined that its superior strength characteristics are more dependent on careful control of material chemistry and fabrication processes than originally understood. This discovery led to considerable evaluation by ASME code committees which resulted in a reduction in the allowable stresses for use of these steels at high temperatures permitted by Section II-D of the ASME Boiler and Pressure Vessel Code beginning with the 2019 edition.

Although new equipment that is within the scope of an adopted code must be constructed to that code's current requirements, including use of the lower allowable stress levels, the question was raised by equipment owners as to how to justify the continued service of existing equipment which relies on the previous, higher stress levels. An industry task group was formed in January 2018 to address this question, with the goal of setting out guidelines to help ensure the continued safe operation and maintenance of this existing equipment. The task group comprised several representatives of equipment owners that were expected to be affected by this change in Alberta, several representatives of ABSA, and other subject-matter experts.

In February 2019, the task group finalized and adopted a report proposing recommendations to ABSA for the continued management of equipment affected by this change; the report was reviewed and endorsed by the Pressure Equipment Sub-Council of the Safety Codes Council at their meeting in March 2019. This AB-536 requirements document is based on the recommendations made in that report, and is therefore the result of the collaborative effort of industry and ABSA working together to determine a reasonable standard of care for equipment owners faced with the task of continuing to safely use and maintain equipment which makes use of Grade 91 steel at high service temperatures.

2.0 SCOPE AND APPLICABILITY

This document establishes requirements for the management and continued use of existing pressure equipment which relies on the use of Grade 91 steel at a combination of design temperature and allowable stress which was permitted by the equipment's original code of construction, but which is no longer permitted by the 2019 and subsequent editions of the ASME Boiler and Pressure Vessel Code. The code change affects pressure equipment that includes pressure components which are made of SA-182 Gr. F91, SA-213 Gr. T91, SA-234 Gr. WP91, SA-335 Gr. P91, SA-336 Gr. F91, SA-369 Gr. FP91, or SA-387 Gr. 91 and which have design temperatures above 500°C for metric designs, or above 950°F for designs making use of customary units. This document refers to equipment containing such components as *affected equipment* – that is, equipment that has been *affected* by the reduction in allowable stresses.

Pressure equipment which contains Grade 91 material shall be presumed to be affected equipment, and the requirements of this document shall be applied, unless it can be shown that all Grade 91 pressure components have design temperatures[1] at which allowable stresses have not been reduced.

Any analysis that is used to show that equipment is not affected by the reduction in allowable stresses for Grade 91 materials must take into consideration the design temperatures for individual pressure components and the methods of calculation used in the equipment manufacturer's original design calculations, if they are available. If the manufacturer's original code calculations are not available, design temperatures for individual components and nominal stress levels may be determined by a Professional Engineer familiar with heat transfer and with the design of the type of equipment being considered.

Any such determination that equipment which contains Grade 91 material is not affected by the change in allowable stresses shall be documented in a manner that can be examined and verified upon request by an ABSA safety codes officer.

Affected equipment can otherwise be subjected to an alteration to modify the design or to show that it is suited to the new, lower allowable stresses.

3.0 DEFINITIONS

ABSA Safety Codes Officer (SCO) – means a safety codes officer, designated under the Act, in the pressure equipment discipline. [PESR 1(1)(ee)]

Affected Equipment – any pressure equipment which makes use of an allowable stress for a Grade 91 steel pressure component, which is permitted by the code edition to which it was constructed, but which is higher than the allowable stress permitted by the current in-force edition

Alteration – means any change to an item of pressure equipment as described in the original manufacturer's data report that requires a change of design calculations or otherwise affects the pressure-containing capability of the item of pressure equipment. [PESR 1(1)(d)]

Non-physical changes such as a change in the maximum allowable working pressure or design temperature of a boiler or pressure vessel pressure retaining item are considered alterations, as are reductions, such as reduction in minimum temperature.

[1] The design temperature for an individual pressure component may be higher than the service temperature marked on the equipment or Manufacturer's Data Report, or the temperature of the adjacent fluid. As discussed in paragraph PG-27.4.2 of ASME Section I and in subparagraph UG-20(a) of ASME Section VIII-1, individual components are required to have design temperatures selected based on the highest mean metal temperatures they are expected to be subjected to in operation. A component which is involved in heat transfer, in particular, can be expected to require a design temperature higher than the temperature of the fluid being heated.

Competent Engineer – a professional engineer, as defined by the Pressure Equipment Safety Regulation, who has knowledge and experience with Grade 91 steel in creep service acceptable to the Owner

Design Temperature – the maximum mean metal temperature through the thickness of a pressure component, as determined by the equipment designer, that it is expected to be subject to under operating conditions

Grade 91 Steel – a creep-strength-enhanced ferritic steel alloy identified in various ASME and ASTM material specifications as grade C12A, F91, P91, T91, or WP91, which has a specified chemical composition and which when properly processed, exhibits enhanced creep strength at high temperatures, making it useful for high-temperature, high-stress applications

Owner – includes a lessee, a person in charge, a person who has care and control and a person who holds out that the person has the powers and authority of ownership or who for the time being exercises the powers and authority of ownership. [SCA 1(1)(v)]

Owner's Inspector – the person responsible to the Owner for ensuring the requirements for inspection, examination, testing, and certification of the pressure piping are met.

Owner-User – an owner that has provided an Integrity Management System in accordance with the Pressure Equipment Safety Regulation and has been issued a quality management system Certificate of Authorization Permit under PESR Section 11(3).

Registered Design – means a design as defined in the Safety Codes Act and registered in accordance with the PESR Section 14.

Note: For existing pressure equipment, this includes its original registered design and any registered modification, repair, or alteration designs made to it.

Repair – work necessary to restore an item of pressure equipment to a safe and satisfactory operating condition, provided that there is no deviation from the original registered design.

Note: "Original design" includes previously registered design alterations.

4.0 REFERENCE PUBLICATIONS AND FURTHER READING

Editions and publication dates listed for the following documents are current at the time of publication of this document, and are for reference only. These documents may be amended from time to time; please refer to the latest applicable edition of the referred documents, except in cases where a specific edition is explicitly referred to in later sections of this document.

AB-512: Owner-User Pressure Equipment Integrity Management Requirements, Alberta Boilers Safety Association; Edition 2, Revision 0; Issued 2015-06-25

AB-513: Pressure Equipment Repair and Alteration Requirements, Alberta Boilers Safety Association; Edition 3, Revision 2; Issued 2018-06-28

AB-535: Requirements for Alteration Design Registration Based on Fitness for Service, Alberta Boilers Safety Association; Edition 1, Revision 0; Issued 2018-06-27

ASME B31.1: Power Piping, The American Society of Mechanical Engineers; 2018 Edition

ASME B31.3: Process Piping, The American Society of Mechanical Engineers; 2016 Edition

"Case 2864: 9Cr-1Mo-V Material", Page 1 (2864), ASME Boiler and Pressure Vessel Code / Code Cases: Boilers and Pressure Vessels, Supplement 3, The American Society of Mechanical Engineers; 2019 Edition

ASME Boiler and Pressure Vessel Code / Section I: Rules of Construction for Power Boilers, The American Society of Mechanical Engineers; 2019 Edition

ASME Boiler and Pressure Vessel Code / Section II: Materials / Part D: Properties (Customary) *(and)* …Part D: Properties (Metric), The American Society of Mechanical Engineers; 2019 Edition

ASME Boiler and Pressure Vessel Code / Section V: Nondestructive Examination, The American Society of Mechanical Engineers; 2019 Edition

ASME Boiler and Pressure Vessel Code / Section IX: Welding, Brazing, and Fusing Qualifications, The American Society of Mechanical Engineers; 2019 Edition

API 579-1 / ASME FFS-1: Fitness-for-Service, The American Society of Mechanical Engineers / American Petroleum Institute; 2016 Edition

Best Practice Guideline for Well-Engineered Weld Repair of Grade 91 Steel (EPRI Product ID 3002003833), Electric Power Research Institute; December 2014

Guidelines and Specifications for High-Reliability Fossil Power Plants, 2nd Edition (EPRI Product ID 3002006390), Electric Power Research Institute; June 2015

Integrated Life Management of Grade 91 Steel Components: A Summary of Research Supporting the Electric Power Research Institute's Well-Engineered Approach (EPRI Product ID 3002012262), Electric Power Research Institute; May 2018

NB-23: The National Board Inspection Code, The National Board of Boiler and Pressure Vessel Inspectors; 2017 Edition

Safety Codes Act / Pressure Equipment Safety Regulation (Alberta Regulation 49/2006), Province of Alberta; With Amendments up to and Including Alberta Regulation 195/2015

A Proposal for the Management of Grade 91 Materials in Existing Pressure Equipment for Continued Use at the Allowable Stress Levels Permitted by the Original Construction Codes, Notwithstanding the Reduction of Allowable Stresses Expected to Be Published in ASME Section II-D, 2019 Edition, The Grade 91 Material Joint Industry and ABSA Task Group; February 25, 2019

5.0 REQUIREMENTS FOR THE CONTINUED USE OF AFFECTED EQUIPMENT

Pressure equipment which is required to continue to operate with reliance on allowable stresses for Grade 91 materials which were permitted by its original code of construction, but which are higher than those permitted by the current edition of the code of construction, shall meet all of the requirements herein:

An engineering assessment shall be conducted in accordance with Section 5.1, *Engineering Assessment Requirements*, in which a competent engineer representing the owner's interests undertakes an analysis of the equipment and determines required supplementary periodic inspections and maintenance, required changes to the owner's integrity management system, and any other actions necessary to ensure the equipment's continued integrity and safe operation. Components smaller than NPS 4 may be excluded from only the engineering assessment, at the discretion of the competent engineer[2], but all other requirements of this document still apply.

The owner's integrity management system shall be revised as recommended by the engineering assessment and as necessary to meet the requirements of Section 5.2, *Integrity Management System Requirements*.

Any required repairs to affected equipment shall meet the requirements of Section 5.3, *Requirements for Repairs*, and any associated physical work shall meet the requirements of Section 5.6, *Requirements for Fabrication Practices*.

Any required alterations to affected equipment shall meet the requirements of Section 5.4, *Requirements for Alterations*, and any associated physical work shall meet the requirements of Section 5.6, *Requirements for Fabrication Practices*.

[2] Some examples of cases that may warrant specific consideration, even for components smaller than NPS 4, are cases where excessive damage is noted in adjacent components, or where a special risk exists due to proximity to personnel.

Any use of fitness-for-service principles to justify continued service of affected equipment shall meet the requirements of Section 5.5, *Requirements for Fitness-for-Service Assessments*.

5.1 Engineering Assessment Requirements

A competent engineer shall conduct an engineering assessment of any affected pressure equipment on behalf of the owner, in order to determine what special risks associated with Grade 91 components pertain to the subject equipment. The assessment shall consider all information considered relevant by the competent engineer, including the following, if available or readily obtainable:

Historical Information:

- Service history (time at temperature), including details of operating changes and excursions
- Original design calculations and/or specifications
- Construction, fabrication, and/or as-built drawings
- Other fabrication records, such as manufacturer's data reports and partial data reports
- Mill test reports for Grade 91 and adjacent welded materials
- Stress analyses of components as required to determine expected types of damage, and as required to recommend appropriate inspection methods, locations, and intervals
- Documentation, literature, or other evidence pertaining to the material used at the time of construction or during subsequent repairs or alterations, which may suggest deviations in chemistry, volumetric deficiencies, deficits in material processing or heat treatment, etc.
- Historical records from previous condition assessments, inspections, and of other observations, such as those described below

Present Observations:

- Boiler support displacement measurements, measured in the hot and cold conditions, and any evidence of malfunctioning supports
- Piping system displacement measurements, measured in the hot and cold conditions
- Local component geometry, including thickness transitions
- Evidence of significant vibrations
- Evidence of geometry changes
- Hardness test results, or other evidence of improper heat treatment
- Positive material identification (PMI) test results
- Volumetric examination records (ultrasonic and/or radiographic)
- Surface examination records (magnetic particle or liquid penetrant)
- Other evidence of material defects or deficiencies
- Evidence of dissimilar metal welds
- Evidence of previous weld repairs

- Interfaces between hard and soft materials in Grade 91 cast and forged components, as may be caused by weld repairs

The engineering assessment shall prescribe an inspection / monitoring plan for the subject equipment, consisting of:

- A list of examinations, inspections, and in-service monitoring tasks that need to be undertaken on a periodic basis to ensure the continued safe operation of the equipment
- Explicit acceptance criteria for each prescribed inspection item
- Maximum inspection intervals for each prescribed item
- A procedure for deferral of prescribed items, if permitted
- Criteria under which the engineering assessment is to be revised or reaffirmed by a competent engineer

The engineering assessment shall be stamped by the competent engineer, and shall be kept in a manner that allows it to be examined and verified upon request by an ABSA safety codes officer.

5.2 Integrity Management System Requirements

Owners of affected equipment shall maintain an owner-user pressure equipment integrity management system that meets the requirements of AB-512 and is acceptable to the Administrator.

In addition to the requirements of AB-512, owners of affected pressure equipment shall incorporate the following into their integrity management systems:

- The inspection / monitoring plan and any other requirements prescribed by the engineering assessment
- All applicable recommendations of ASME B31.1, Non-Mandatory Appendix V, “Recommended Practice for Operation, Maintenance, and Modification of Power Piping Systems”[3]
- The mandatory use[3] of ASME B31.1, paragraph 141.4, “Failure Analysis”, when a formal failure analysis is required
- The mandatory use[3] of ASME Section I, Nonmandatory Appendix C, “Local Heating of Welds in Cylindrical Components of P-No. 15E Materials When Using Electric Resistance Heating”

[3] These requirements are applicable to pressure components made to any of the construction codes.

- Requirements for repairs and alterations to affected pressure equipment, as required to meet the applicable requirements of AB-513[4], and the additional requirements of this document and the engineering assessment
- Requirements for fitness-for-service alterations of affected pressure equipment, as required to meet the applicable requirements of AB-513[4], AB-535, this document, and the engineering assessment

5.3 Requirements for Repairs

All repairs of affected equipment shall be conducted in accordance with a written procedure which addresses the entire extent of required repairs, as determined by the evaluation described in Section 5.3.1 below.

5.3.1 Condition of the Item to Be Repaired

As required by AB-513, the condition of all components of the equipment shall be evaluated prior to undertaking any repairs in order to determine the complete required extent of repairs. Consideration shall be given to the components to be repaired, and to adjacent components.

In the case of affected equipment, this evaluation shall be carried out and documented by a competent person with experience and qualifications with Grade 91 materials satisfactory to the owner.

5.3.2 Requirement for Failure Analysis

In addition to the determination of root cause required by Section 8.1 of AB-513, a complete failure analysis shall be performed prior to undertaking repairs to affected equipment. Such an analysis may need to be accompanied by appropriate testing to determine or confirm the root cause or to facilitate future integrity management activities. This failure analysis may be omitted for repairs to pressure components which are smaller than NPS 4.

The repair that is undertaken shall mitigate the root cause and prevent future recurrence, or if future damage is expected as a result of normal operation, the inspection / monitoring plan shall provide for its monitoring and management.

[4] In the case of a discrepancy between this document and AB-513, the requirements of this document are intended to prevail for affected equipment. It should be noted that most of the requirements of AB-513 are applicable, except the exemption for registration of certain types of alteration procedures provided in AB-513 Section 8.6.1, and the requirement that allowable stresses of the current code edition be used for alterations given in AB-513 section 8.6.

5.3.3 P.Eng. Certification of Repair Procedures

For repairs to pressure components 4 NPS and greater, the repair procedure shall be prepared and stamped by a competent engineer.

5.3.4 Provision for Urgent Repairs

Despite the requirements of Section 5.3.2 above, the owner's integrity management system may provide for specific circumstances under which "urgent" repairs may be made. Such repairs may be carried out before the required failure analysis is completed, only in cases where the failure analysis is expected to take an extensive amount of time to complete and it is not practical to delay the repair. Urgent repairs shall meet all other applicable requirements of this document.

In order to provide for urgent repairs, the owner's integrity management system must establish:

- A requirement that the failure analysis be initiated prior to the start of repair activities
- Requirements for follow-up and completion of the failure analysis within a predetermined timeframe, not to exceed 12 months unless there is specific justification for an extended amount of time
- Requirements for interim monitoring of repaired equipment before the failure analysis is completed
- Requirements for appropriate follow-up and remedial action based on the results of the failure analysis

5.4 Requirements for Alterations

Any alteration of affected equipment shall be carried out in accordance with a written alteration procedure which is stamped by a competent engineer and registered by ABSA Design Survey. The exemption from registration of the alteration procedure given in Section 8.6.1 of AB-513 shall not be applied to alterations of affected equipment.

5.5 Requirements for Fitness-for-Service Assessments

Any use of fitness-for-service methodologies to justify continued service of affected equipment shall meet the requirements of AB-535, as supplemented and modified herein.

The fitness-for-service analysis shall be performed by, and the report stamped by, a competent engineer who represents the owner and who is familiar with the fitness-for-service assessment methodologies being used, and with the properties of Grade 91 steel.

5.5.1 Preliminary Inspection and Examination of Equipment

Affected equipment that is to be subjected to a fitness-for-service analysis shall be inspected, examined, and tested as appropriate to obtain the information necessary to provide for an accurate assessment. When available, actual measured data and inspection results shall be used, such as measured tensile and yield strengths, alloy chemistry, remaining creep life, fracture toughness, crack-tip opening displacement (CTOD) toughness, and other inspection and non-destructive examination results. Where material properties are not obtained by testing and are not given in the code of construction, they shall be obtained from suitable sources acceptable to the owner and to ABSA Design Survey, with bibliographical references given to support the data.

Non-destructive examination shall be conducted to the current edition of the equipment's code of construction, and to ASME Section V, including techniques, extent of coverage, qualification and implementation of procedures, and qualification of personnel. Examination methods that are not described in ASME Section V shall be acceptable to the owner and to ABSA Design Survey, and shall be conducted in accordance with a written and qualified procedure; personnel shall be qualified in accordance with a recognized international standard.

Pertinent information relating to the equipment's design, operating history, and intended future operation shall be considered in the assessment, and details provided in the report.

When examination results will be relied upon for the assessment of crack-like flaws as described in Part 9 of ASME FFS-1, examination procedures shall be compliant with ASME Section V, Article 4, Appendix VIII.

5.5.2 Use of ASME FFS-1 for Analysis

When fitness-for-service assessments make use of the methods of ASME FFS-1, all limitations on the applicability given in each part of that standard shall be considered to be mandatory.

When a stress analysis is carried out in accordance with ASME FFS-1, Part 2, Annex 2D, the allowable stresses used shall be those given in ASME Section IID, 2017 Edition for boilers and pressure vessels, or given in the 2016 edition of the applicable code of construction for piping, prior to their being lowered in subsequent editions of these documents.

When a fitness-for service assessment makes use of ASME FFS-1, Part 6 for assessment of pitting corrosion, a creep assessment in accordance with ASME FFS-1, Part 10, shall also be carried out.

Any fitness-for-service assessment that considers material that is within a distance of $2.5 \cdot (r \cdot t)^{1/2}$ from a weld shall also consider the weld metal, the heat-affected zones, and any base material within that distance, on both sides of the joint. This distance is based on the stress decay length for a cylinder subject to pressure, where 'r' is the inside radius of the cylinder, and 't' is its nominal thickness.

5.5.3 Use of Alternative Analysis Methods

Alternative standards may be used in lieu of ASME FFS-1, and are required in cases where the flaws or damage mechanisms being analyzed are not adequately addressed by ASME FFS-1. Any such alternative standard shall employ comparable philosophies and principles, and shall achieve the level of safety intended by ASME FFS-1.

Creep life calculations shall be no less conservative than those provided in ASME FFS-1, Part 10, using either the Omega method or the Larson-Miller method, with parameters selected from Tables 10B.4 or 10B.4M, as appropriate.

The suitability of any alternative fitness-for-service standard is subject to the scrutiny and acceptance of the owner and ABSA Design Survey at the time of registration.

5.6 Requirements for Fabrication Practices

All activities for the repair and alteration of affected equipment shall be undertaken in accordance with a detailed written procedure. Repair procedures for components NPS 4 and greater, and all alteration procedures, shall be prepared and stamped by a competent engineer. In preparing such a procedure, the competent engineer shall take into account the best industry practices for Grade 91 steel construction at the time the work is to be performed, such as those described in EPRI's publication, "Guidelines and Specifications for High-Reliability Fossil Power Plants, 2nd Edition: Best Practice Guideline for Manufacturing and Construction of Grade 91 Steel Components," EPRI Product ID 3002006390.

5.6.1 Replacement Components

The design of repaired or altered components for affected equipment shall be in accordance with the original code of construction, including the use of the originally-permitted allowable stress values, as long as the requirements of this document are met.

Newly purchased materials and replacement components made of Grade 91 steel shall meet the requirements of the original material specification, *and* the more stringent requirements of ASME Code Case 2864. Materials

and components that meet the requirements of the original material specification and which were purchased by the owner prior to January 1, 2020 may be used without consideration of the more stringent requirements of Code Case 2864, subject to an evaluation of any such use to be carried out by a competent engineer.

5.6.2 Welding and Post-Weld Heat Treatment

Welding shall be conducted to the current edition of the code of construction and ASME Section IX. The repair or alteration procedure shall address:

- The weld procedure specification number(s) to be used for the work
- Filler metal chemistry requirements, with particular attention to carbon and nickel contents, and to nitrogen-to-aluminum ratio
- Weld bead size
- Weld metal deposition rate
- Explicit monitoring and control of weld preheat and inter-pass temperatures
- Minimization of interruptions during welding
- Post-weld hydrogen bake
- Limitation of delays prior to post-weld heat treatment

The use of ‘Welding Method 6’, described in section 2.5.3.6 of the National Board Inspection Code (NB-23), Part 3, is permissible, but is subject to any separately published requirements of the Administrator, such as those published in IB18-009.

For welds joining Grade 91 steel with dissimilar metals, the joint design and repair strategy shall be specifically addressed in the repair / alteration procedure.

Heat treatment shall be carried out in accordance with a written procedure that meets the requirements of the weld procedure specification and the current code of construction, and incorporates the best industry practices at the time the work is to be performed. The detailed heat treatment procedure shall address:

- Applicable joint geometry
- Placement of thermocouples
- Specification and placement of insulation blankets
- Maximum temperature ramp rates
- Required holding time and temperature

It is recommended that the heat treatment procedure take into account the hardness of the base materials measured prior to welding, and of the base and weld materials measured after welding and cooling to the point that martensite transformation is complete, as discussed in EPRI document 3002006390.

5.6.3 Examination, Inspection, and Oversight

Non-destructive examination shall be conducted to the current code of construction and to ASME Section V, including choice of techniques, extent of coverage, documentation and qualification of procedures, qualification of personnel, and documentation of results.

Examination and inspection techniques that are not described in ASME Section V shall be acceptable to the owner and to the ABSA safety codes officer, and shall be conducted in accordance with a written and qualified procedure; personnel shall be qualified in accordance with a recognized international standard.

Repair and alteration activities shall be overseen and certified by the owner's Inspector or by an Authorized Inspector, as required or permitted by the owner's pressure equipment integrity management system.

6.0 REVISION LOG

Edition #	Revision #	Date	Description
1	0	2019-07-02	Initial Release
1	1	2021-04-28	Deleted the last paragraph in Section 5 and reaffirmed the rest of the document with no further changes
2	0	2022-04-28	The document reaffirmed with one change that the next edition is scheduled for 2027.