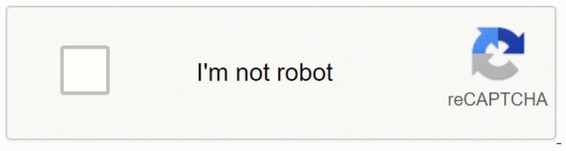

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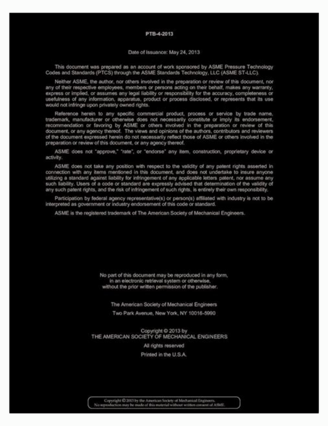

Modernization of Pressure Vessel Design Codes

ASME Section VIII, Division 2, 2007 Edition & Fitness-For-Service Codes, API 579-1/ ASME FFS-1, 2007 Edition with Applications

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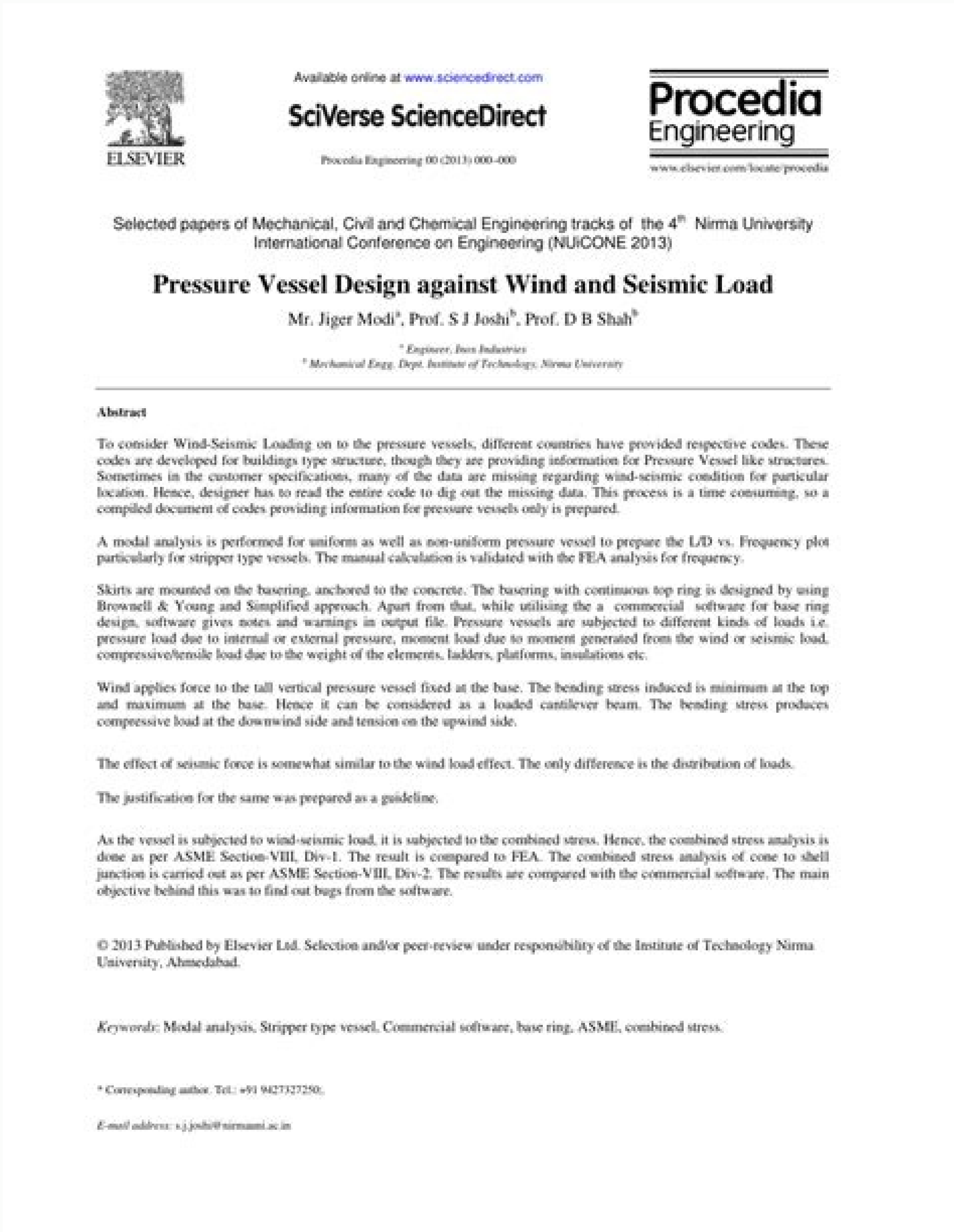

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Pressure Vessel Design against Wind and Seismic Load

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Abstract

To consider Wind-Seismic Loading on to the pressure vessels, different countries have provided respective codes. These codes are developed for buildings type structure, though they are providing information for Pressure Vessel like structures. Sometimes in the customer specifications, many of the data are missing regarding wind-seismic condition for particular location. Hence, designer has to read the entire code to dig out the missing data. This process is a time consuming, so a compiled document of codes providing information for pressure vessels only is prepared.

A modal analysis is performed for uniform as well as non-uniform pressure vessel to prepare the L/D vs. Frequency plot particularly for stripper type vessels. The manual calculation is validated with the FEA analysis for frequency.

Skirts are mounted on the basering, anchored to the concrete. The basering with continuous top ring is designed by using Brownell & Young and Simplified approach. Apart from that, while utilising the a commercial software for base ring design, software gives notes and warnings in output file. Pressure vessels are subjected to different kinds of loads i.e. pressure load due to internal or external pressure, moment load due to moment generated from the wind or seismic load, compressive/tensile load due to the weight of the elements, ladders, platforms, insulations etc.

Wind applies force to the tall vertical pressure vessel fixed at the base. The bending stress induced is minimum at the top and maximum at the base. Hence it can be considered as a loaded cantilever beam. The bending stress produces compressive load at the downwind side and tension on the upwind side.

The effect of seismic force is somewhat similar to the wind load effect. The only difference is the distribution of loads.

The justification for the same was prepared as a guideline.

As the vessel is subjected to wind-seismic load, it is subjected to the combined stress. Hence, the combined stress analysis is done as per ASME Section-VIII, Div-1. The result is compared to FEA. The combined stress analysis of cone to shell junction is carried out as per ASME Section-VIII, Div-2. The results are compared with the commercial software. The main objective behind this was to find out bugs from the software.

Keywords: Modal analysis, Stripper type vessel, Commercial software, base ring, ASME, combined stress.

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ASME Section I & Section VIII - Fundamentals

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… Interpretation 15-1147 Question (3) reads as follows: In those cases when: 1) a cladding is constructed by welding together multiple cladding plates before the final bonding to the base material; 2) it is assumed that the cladding material contributes to the wall strength; 3) the clad plate material fulfills the specifications in UCL-11(a); is it the intent of Section VIII, Division 1, UCL-11 to require that the welding performed before final bonding is performed by a manufacturer holding a Certificate of Authorization? Reply (3): Yes it is, as per the provisions in UG-120(c). UG-120(c) states what follows: (UG-120 Data Reports) (c) Partial Data Reports. Concentrating on 3 key aspects; Allowable Stress Additional Material Properties Safety Factor Screenshots are from CEI's DesignCalcs, pressure vessel design software. When used, Form U-2 or Form shall be attached to the associated Form U-1 or Form U-1A issued by the Manufacturer of the vessel that is to be marked with the Certification Mark. He plans to get the welding performed by an external supplier. ASME Standards Section VIII, Division 2 ASME BPV Section VIII, Division 2, uses a much smaller safety factor on tensile strength than Division 1 does. At 250 degrees S = min(0.9*0.85*139 or 0.85*502/3.5) = 106.34 MPa, which is very close to the listed allowable of 107 MPa. At 375 degrees S = min(0.9*0.85*125 or 0.85*495/3.5) = 95.63 MPa, which is very close to the listed allowable of 95.7 MPa. Additional Material Properties Yield Strength The Yield Strength primarily comes from the Y tables in Section II, Part D. (4) Nonmandatory Appendix W provides a guidance in preparing Partial Data Reports. 2) All welding shall be carried out according to the Welding Procedure Specifications that the Manufacturer issued in accordance with the requirements of Section IX. It is here highlighted since revealing the rationale of the approach used by the Code. Here it is stated that … in lieu of the requirement in UG-11(d)(4)(-a), the Certificate Holder is allowed to subcontract to an individual or organization not holding an ASME Certificate standard pressure parts that shall be fabricated following a standard other than an ASME product standard, provided that all the following conditions are fulfilled … Based on the above, the conclusion is that the main aspect to be considered is whether or not credit is given to the cladding thickness for strength purpose. DesignCalcs provides this with custom materials and manual entry options. At each of these increments, the allowable is determined based on the ultimate tensile stress, the yield stress, and the creep data. The Manufacturer holding the ASME Certificate of Authorization shall be responsible of the welding, shall issue the Data Report and affix the Certification Mark. If neither option works, the MoE values will be zero. The yield allowable criteria is the same and the bolting allowables are still from Table 3 (for design by rule). … To be noted that this interpretation deals with the cladding used for strength purposes! Paragraph UW-26 "General" of section "Fabrication" of Part UW states what follows: (a) The following paragraphs provide rules that specifically apply to pressure vessels and vessel parts that are constructed by welding. These rules shall be used in conjunction with the general fabrication requirements of Subsection A and the fabrication requirements of Subsection C, regarding the class of materials used for construction. If neither option works, the ultimate strength values will be listed as zero for all temperatures. Form U-2A may be used provided it is suitable to record all the applicable information; otherwise Form U-2 shall be used. … 1) The Manufacturer shall retain the responsibility of the whole Code construction. It is important to remember that not all jurisdictions will accept code cases; they may also be harder to get accepted by the customer requesting the bid. More information about custom materials may be found in our help files. They shall be, then, forwarded, in duplicate, to the Manufacturer of the completed vessel [see U-2(b)]. Having a weight of zero is not a conservative assumption most of the time. … (d) Provided that the following conditions are fulfilled, a Manufacture holding a Certificate of Authorization, for the construction of pressure vessels and their parts, may engage external welders, by contract or service agreements, to be employed at the shop location (shown on the Certificate of Authorization) and at the field sites (if allowed by the Certificate). This can be seen by several of the notes in the stress tables. For yield strength, the safety factor in most cases is a ⅔ multiplier, with the joint efficiency factor of 0.85 applied in the same case as for tensile; in some cases a higher value of 90% yield may be used instead of the ⅔ value. Topics: Blog Pressure Vessel Design ASME standards for materials are a critical requirement for calculating a design's safety factor. 4) The Manufacturer's Quality Control System shall have as a minimum: - a requirement regarding the complete and exclusive administrative and technical supervision authority on all welders by the Manufacturer; - the evidence that the Manufacturer has the authority to assign and remove welders at his discretion, without involvement of any other organization; - a requirement for assignment of welder identification symbols; - the evidence that the program has been accepted by the Manufacturer's Authorized Inspection Agency which provides the inspection service. Those calculations include calculating a sliding saddle slot length and the differential thermal expansion in a fixed tube exchanger. Manufacturers with multiple locations, each with its own Certificate of Authorization, are allowed to transfer pressure vessel parts from one of their locations to another without Partial Data Reports, provided the Quality Control System describes the method of identification, transfer, and receipt of the parts. Allowable Stress ASME Standards Section VIII, Division 1 The allowable stresses are determined by safety factor criteria listed in the appendices in the back of the Section II, D. These criteria include matching on aspects such as min yield strength, spec, and nominal composition. Allowable Stress Example 1: SA-516 Gr 70 Customary for SC8D1 Allowable stress (S, psi) in 2013 is on page 22, line 6Yield strength (Sy, psi) in 2013 is on page 578, line 30Ultimate tensile strength (Su, psi) in 2013 is on page 488, line 8. Note G6 in Table 5A indicates an 85% multiplier like we see for Division 1 allowables, even though the Appendix itself does not spell it out. Learn more about using DesignCalcs to reduce design errors and save time on your next design. The normal approach, stated by UG-26Linings, is to not consider the linings (resistant to corrosion and abrasion), attached or not to the vessel wall, as contributing to the wall strength, unless it is permitted by the provisions of Part UCL and Nonmandatory Appendix F. … (b) Each Manufacturer is responsible for the quality of the welding done by his organization. The Appendix 3 provides the definitions of clad vessel and lined vessel: a) Clad vessel: with this statement it is intended a vessel that, in addition to the base material, is provided with another material that is resistant to corrosion; this second material can be attached to the base one by or integral bonding or weld metal overlay technique. At 250 degrees S = min(2/3*34200 or 70000/3.5) = 20000 psi At 650 degrees S = min(2/3*28200 or 70000/3.5) = 18800 psi At 1000 degrees S is governed by creep data and is 2500 psi; this is less than 2/3*22600 and 69100/3.5 Allowable Stress Example 2: SA-249 TP316, High (90% yield basis) Metric for SC8D1 Allowable stress (S, MPa) in 2013 is on page 78, line 9Yield strength (Sy, MPa) in 2013 is on page 638, line 17Ultimate tensile strength (Su, MPa) in 2013 is on page 512, line 17. Skip to Main Content Skip Nav Destination You do not currently have access to this chapter. 3) All welders employed have been qualified by the Manufacturer in accordance with the requirements of Section IX. (2) In case the parts Manufacturer has performed a design activity on the part furnished he shall record the activity performed and its extension (if partial or total) under "Remarks", clearly describing the portion of design activity performed. … (c) No welding activity shall be started before having qualified the welding procedures to be used. Related Article: 2020 Pressure Vessel & Heat Exchanger Design Guidelines and Resources Additional Properties Example 1: This material will back solve for ultimate strength, if necessary, and will

get its MoE values from external pressure chart CS-3 as needed. (3) In case the welding is not performed by the vessel manufacturer, it shall be supplied with a Partial Data Report. Section "List of Changes in Record Number Order" of [1.], page lvii, shows the Record Number 12-421 which the following change is associated to. Section II, D tables 1A, 1B, and 3 provide allowable stress data for use in Section 1 (Power Boilers), Section III (Nuclear), Section VIII, Division 1 (Pressure Vessels), and Section XII (Transport Tanks). Article (f) of paragraph UCL-11 “Integral and Weld Metal Overlay Clad Material” provides the requirements in case the cladding is included in the design calculations, i.e. it is considered to contribute to the wall strength, as permitted in UCL-23(c). The designer still needs more flexibility. In addition, if the product form is welded tube or pipe, a joint efficiency factor of 0.85 is typically applied. Sometimes, however, a match using these criteria cannot be made. These Partial Data Reports are subject to authority of the final Inspector who will witness the application of a Certification Mark to the vessel [see UG-90(c)]. If a Y table match cannot be made and the external pressure chart method cannot be used, the yield will be listed as zero for all temperatures. When credit is not given to the cladding thickness, then the cladding joints may be made by a manufacturer not holding a Certificate of Authorization, provided that the requirements of UW-26(d) are met. The Mean Coefficient of Thermal Expansion data comes from SC II, Part D TE tables column B. Ultimate Strength The Ultimate Strength comes from the U tables in Section II, Part D. Alternatively, welds may be ultrasonically examined for their full length as required by UW-53. However, when a clear match cannot be made, a backup method is employed. As declared by Record Number 12-421, UCL-11(f) has been added to state that, when cladding material is used in design calculations, then the cladding joints are to be made by a Manufacturer holding a Certificate of Authorization. In these cases, DesignCalcs will follow the steps provided in ASME Section VIII, Division 1, UG-28(c)(2) Step 3, using the material’s listed external pressure chart. The safety factor is 2.4 instead of 3.5 for non-bolting (see Mandatory Appendix 10 in SC II, Part D). UG-26 Linings – This paragraph states that corrosion or abrasion resistant linings, which may be or not attached to the vessel wall, have not to be considered as contributing to the strength of the wall, except as permitted in Part UCL and Nonmandatory Appendix F. Other Values The density and Poisson’s Ratio values come directly from Table PRD in SC II, Part D. If instead the designer wishes to use their own values for the 4:1 safety factor, or they wish to use a different safety factor on yield or whatever the criteria may be, the designer may either manually input the values in the component form for each instance or they can create a custom material. This same approach can be used for materials that are not yet in Section II, Part D, but are included in a materials code case like Code Cases 2402-1 and 2403. All materials that are in the shipping data for DesignCalcs have both. Safety Factor Previous years of ASME Standards BPV Section VIII, Division 1, used a safety factor of 4 on tensile strength instead of 3.5. Until recently, this safety factor of 4 was still in place for the design of certain DOT vessels. The parts Manufacturer shall furnish a copy of the Partial Data Report to the user or his designated agent. Paragraph UCL-55 “General” in section “Marking and Reports” provides the requirements that the manufacturer shall meet to affix the ASME Mark and issue the Data Report. It refers to the general paragraphs UG-115 through UG-120, with the following supplementary requirements: (a) In the Data Report, the specification and type of lining material is to be included; (b) In the Data Report, the applicable paragraph in UCL-23 used to design the shell and the heads are to be included. The lowest of the three governs. The safety factor on yield strength for bolting material is a ⅔ multiplier or a ¼ multiplier. In such a case: (1) The welding is to be performed by a Manufacturer holding a Certificate of Authorization. For the most part, this is determined by four things: the tensile strength, the yield strength, the time dependent properties at higher temperatures (creep), and the product form (bolting, plate, etc). Material lines listed for use in Section VIII, Division 1; the lines that are good for Section VIII, Division 1 are explicitly marked. At 150 degrees S = min(0.9*0.85*161 or 0.85*516/3.5) = 123.17 MPa, which is higher than the listed allowable of 117 MPa. The allowable at this temperature exceeds the listed SF requirements. Based on them, the Manufacturer performing the cladding joints shall be certified by the Manufacturer holding the ASME Certificate of Authorization, following the procedures of its Quality Control Manual and its welding procedures, in accordance with Section IX of the BPVC. Table 1A covers ferrous materials, table 1B covers non-ferrous materials, and table 3 covers bolting material. The discussion of creep and time dependent properties is going to be left out of this article; however, if you are looking in SC II, D, and you see an allowable stress that is italicized, that is a value that is governed by creep.For tensile strength, the code requires a safety factor of 3.5 for non-bolting and 4 or 5 for bolting. Section II, Part D, of the ASME BPV code. This discrepancy can be handled in DesignCalcs in one of several ways.The user may set a vessel safety factor of 4 instead of 3.5. In this case the allowable stress will be calculated using 4 instead of 3.5 in equations shown in the examples above; as a safety measure, we do not allow the calculated allowable stress to be more than the allowable stress form the ASME codebook. A number of interpretations have been issued over the years to provide clarifications on cladding and lining (see section ASME VIII-1 interpretations on cladding and lining). See Mandatory Appendices 1 and 2 in ASME BPV Section II, Part D, for more information. In the following, CEI provides an overview of how various material properties impact your pressure vessel design. UCL-11(f) has been added, since interpretations clarify that the Code requires that, when a cladding material is considered as contributing to the strength of the vessel wall, i.e. is used in design calculations, the welding of cladding material shall be made by a Manufacturer who holds a Certificate of Authorization. In this scenario, when the cladding is made by welding multiple plates together prior to attach the resulting cladding plate to the base metal, the Code requires that the plate welding joints are made by a certified Manufacturer, are subject to full RT, are provided with a Partial Data Report and with the Certification Mark. In case of pressure vessel parts which require inspection under Division 1 and are furnished by Manufacturers other than the Manufacturer responsible for the vessel to be marked with the Certification Mark, the Partial Data Report shall be prepared by the Parts Manufacturer and his Inspector based on applicable Form U-2 or Form U-2A and in accordance with the requirements of Division 1. Paragraph UG-11(e) states an approach similar to that indicate by UW-26(d) but not applicable to the cladding. As such, he is required to run tests: 1) regarding the welding procedure to ensure that it fulfills the Code requirements; 2) to ascertain the welders and welding operators a cladding layer ability to apply the procedure properly. If a match from the U-tables cannot be used, DesignCalcs employs a conservative method to find the ultimate strength values; in this case, it is assumed that the tensile strength governs the allowable stress and it is solved for in reverse order. (3) Vessel parts produced the same day may be reported on a single Form U-2 or U-2A provided all of the following are met: - vessel parts are identical; - Manufacturer’s serial numbers must be in uninterrupted sequence; - - The Manufacturer’s Quality Control System includes procedures to control the development, distribution, and retention of the Partial Data Reports. There is not a backup method for this property and it is only used in a few calculations at the moment. (1) Parts of a pressure vessel, supplied as replacement or repair by a parts Manufacturer to the user on an existing Code vessel, shall be accompanied by a Data Report based on Form U-2 or U-2A which is prepared by the parts Manufacturer and his Inspector in accordance with the requirements of Division 1. Welding shall be performed only by welders and welding operators qualified in accordance with Section IX. Shall the external supplier be ASME certified? The ASME VIII-1 Code deals with cladding and linings in the following paragraphs. DesignCalcs will grab the MoE from the external pressure chart when it cannot find a TM table match. The lines allowing 90% of yield will include a G5 material note. An allowable stress is determined at several temperature increments up to the allowed maximum temperature. Among those listed, the following one is specifically dealing with the subject: Interpretation 15-1147 issued on May 14, 2015 regarding UCL-11 – Clad Plate: Interpretation 15-1147 Question (2) reads as follows: ... Question (2): In case: 1) a cladding layer is obtained by welding together multiple cladding plates, prior to the final bonding to the base material, 2) it is assumed that the cladding contributes to vessel wall strength, and 3) the clad plate material meets the UCL-11(a) specifications, is it the intent of Section VIII, Division 1, UCL-11 to permit that welding performed prior to the final bonding is carried out by a manufacturer not holding a Certificate of Authorization?” Reply (2): No it is not the intent, welding shall meet UW-26. Additional Properties Example 2: This material will back solve for ultimate strength, if necessary, and will get its MoE and Yield Strength values from external pressure chart NFA-12 as needed. A Manufacturer, ASME VIII-1 certified, is committed to fabricate a pressure vessel with a corrosion-resistant internal cladding. The external pressure charts (figure form as opposed to table form) include a MoE value at various temperatures. DesignCalcs uses fairly strict criteria when attempting to match an allowable stress line from Tables 1A, 1B, and 3 to a yield line in the Y tables. Similar criteria to finding a yield match are used to find an ultimate strength match for an allowable stress line. The Manufacturer is, in any case, responsible for Code compliance of the vessel or part, so that he shall apply the Certification Mark and provide to properly prepare the Data Report Forms and get them countersigned by the Inspector. Materials allowable for use in various applications are covered by their relevant code. (2) Welds are to be radiographically examined for their full length as required by UW-51. Part UCL provides the additional requirements for pressure vessels constructed by welding that are provided with claddings (integrally bonded or attached by weld metal overlay) or lining (applied by discontinuous welding) which are constructed with corrosion resistant materials. The Modulus of Elasticity (MoE) primarily comes from the TM tables in SC II, Part D, and DesignCalcs will use the criteria in these tables to assign MoE values to the allowable stress lines. b) Lined vessel: with this statement is intended a vessel that is provided with an independent lining, whose material is resistant to corrosion, which is attached not continuously but intermittently to the vessel wall. This Partial Data Report shall be maintained in accordance with clause (a) of UG-120.

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