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December 20, 1996
NRC-96-008

Mr. Ashok Thadani
Assistant Director, Nuclear Reactor Regulation
United States Nuclear Regulatory Commission
Washington, DC 02555-0002

Subject: NRC Generic Letter 96-06

Dear Mr. Thadani:

Thank you for your letter of December 4, 1996. It was very clear and addressed each issue I raised in a clear and professional manner. I feel it is the best and most direct answer to any issue I have ever raised with the NRC. In my opinion, the Staff's response to the specific technical issues is commendable because it directly addresses the issues raised.

I spent much time in writing my letter of November 8, 1996. Your well-thought-out reply shows that on most of my concerns, we are in substantial agreement. The attachment to this letter provides the details for this conclusion.

I believe that the need for Generic Letter public review, comment, and backfit analysis depends on whether or not nuclear plants are operating contrary to the requirements of the Code. If the Code was violated, there may be an issue of regulatory noncompliance, as stated in the Generic Letter. I infer from the statements in the fourth paragraph of your letter that if the Code requirements were met during the design of the plant, there would be no issue of regulatory noncompliance that could justify your use of the compliance exception to the backfit rule, and the Generic Letter would have to be corrected or withdrawn. However, if the Code was not met when the plants were designed and constructed, I'll agree that there is an issue of noncompliance. It should be obvious that I still believe that there is no issue of noncompliance with Code requirements. While I strongly believe that these issues do not constitute contradictions or violations using Code design requirements to evaluate field conditions. The key however, is that use of Code rules is purely discretionary, because these issues are not within the scope of the Code. Using the points of agreement that exist between the staff and me, my response outlines what I feel is conclusive evidence that applicable Code requirements were met for all U.S. plants.

I agree with you that my interpretations of the Code are not official ASME Interpretations. This is a fact I make clear to all of my clients and to students who attend my lectures on ASME Code requirements. I have given over a hundred lectures to engineers and others on Code requirements. Some of these lectures were given for ASME, and some were for my clients. Some lectures were for the general public, and quite a few were for NRC Inspectors. Each time I give a lecture, I identify that my opinions on the Code are my own. I have <u>never</u> identified my opinions as official ASME positions, unless I quoted ASME documents. My letter to the NRC Staff provides no Code Interpretations, but relies only on the wording in the Code and the points of agreement between us. Therefore, I do feel it was unfair to you to make the point that my opinions on the Code were not official positions of ASME. I would truly appreciate your correcting the negative implications of that statement.

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In my extensive correspondence with the NRC, I have quoted ASME official positions. NRC and ASME officials have met to discuss some of the issues raised, and I believe that ASME has agreed with the positions that I have taken on the subject of Code requirements and use of engineering judgment. Therefore, I don't believe that I have been in error regarding ASME Code requirements. I would appreciate any comments that you may have on this, if you disagree

Mr. Taylor implied that I was fostering the idea that Owners should bypass Federal regulations. This charge has no basis in fact. I have received no any apology or correction from Mr. Taylor or from the NRC. I would appreciate correction or retraction of this implication.

Again I want to thank you and the Staff for the well-written reply to my letter. It certainly helps to clarify the situation. I hope that my response is as clear to you.

Very truly yours,

Roger F. Reedy

Roger F. Reedy

Copy: Tad Marsh
D. Modeen, NEI
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G. Eisenberg, ASME

Roger F. Reedy Reply to the NRC Staff

General Issues
It is important to recognize the difference between designing for "design" conditions (using allowable stresses from the ASME Code Stress Tables) and evaluating or designing for "service" conditions (using factors or evaluation techniques that provide equivalent allowable stresses or strains that are much higher than the "design" allowable stresses). Most of my previous comments addressed the "design" condition using Code allowable stresses as tabulated in the Stress Tables. This distinction is very important.

Another important issue is the requirements given in the "Code of Record" for all of the U.S. nuclear plants. For U.S. plants, no "Code of Record" is later than the 1983 Edition of Section III, and almost all are earlier than the Winter 1976 Addenda. Therefore, my comments will be based on Code Editions and Addenda used when the U.S. plants were designed. The Staff's comments were so clear, it forced me to do some more research, and I found that the words in the earlier "Codes of Record," used in U.S. plant designs, were more clear than the present Code, and did not always support the NRC's assertions.

Another important point in evaluating Code issues is to be clear on the design function of the piping and the design requirements provided by the Code. The following discussion is based on engineering logic and professional engineering experience. The requirements in the Code for pressure design are for "active pressure," i.e., pressure which, if released by a growing crack or defect, would cause a sudden eruption and could cause harm to personnel. This is logical, because the Code is intended to protect people and equipment.

If there is significant pressure in the line, and temperature is increased, causing fluid expansion, and there are no voids to account for the expansion, the "active pressure" is increased, and failure of the pipe could cause a sudden eruption. If, however, there is no "active pressure," an increase in temperature, causing expansion of the fluid, cannot cause a sudden eruption. The technical reason for this is that only a small release of fluid (a spoonful or a small cup) is required to relieve all of the pressure. However, no personnel or equipment can be harmed by the release of this very small amount of fluid, even if someone or something were at the release point. The only damage is the crack in the pipe, which, for containment penetration piping, is either inside or outside of the containment. Containment pressure boundary function is not lost.

Another point is that a vent would be required at each high point in a pipe section to release air pockets to provide an isolated section of piping with no expansion space. If air pockets exist, the thermal expansion issue is a nonissue. Because there are no provisions made to release air in isolated sections of piping, there will be air pockets. Thus, there will be little or no increase in pressure due to expansion of the contained fluid.

The purpose of piping is to transport fluid from one point to another. This is usually accomplished with a pump to create active pressure in the piping. When piping is in a standby condition, pressurized but not flowing (because the valve is closed), or when the fluid is flowing, the system is "in service." If a section of pipe is isolated by two valves, the system cannot operate, therefore the system is not in service, in the sense that it cannot transport fluid while isolated. This is why I said that isolated piping systems were not in service.

With that as background, the following comments provide specific responses to the Staff's comments.

You stated,

> With regard to the first item in your letter of November 8, 1996, you claim the following statement in the generic letter is false: "Piping design codes as far back as U.S.A. Standard (USAS) B31.1 (1967) have explicitly recognized the need to consider the effects of heating of fluid that is trapped in an isolated section of piping." You also claim the following statement made in the backfit discussion is false: "Licensees are also required either by commitment to USAS B31.1 or the American Society of Mechanical Engineers (ASME) Code for piping design or by virtue of 10 CFR 50.55a, which endorses various editions of the ASME Boiler and Pressure Vessel Code, to comply with design criteria which specify that piping systems which have the potential to experience pressurization due to trapped fluid expansion shall either be designed to withstand the increased pressure or shall have provisions for relieving excess pressure." As an enclosure to your letter, you provided a page from the 1995 Edition of Section III to the ASME Boiler and Pressure Vessel Code that deals with design criteria for Class 2 piping. Section NC-3621.2 contains the following statement regarding fluid expansion effects. "When the expansion of a fluid may increase the pressure, the piping system shall be designed to withstand the increased pressure or provision shall be made to relieve the excess pressure." The staff believes that the statements in the generic letter regarding ASME Code requirements are consistent with this quote from the ASME Code. In your letter, you provide three arguments related to nuances of the language used in the generic letter as compared to the ASME Code language to support your claim that the statements in the generic letter are false. You have singled out the phrases "isolated section of piping" and "trapped fluid" from the generic letter to support your argument. In the context of the generic letter, these phrases are only meant to refer to sections of piping in which the fluid is not free to expand when heated. The staff has reviewed your arguments and does not agree with your conclusions, as discussed below.

I agree that thermal effects must be considered in piping design. This is required by NC-3111 of Section III. Further, I believe that NC-3621.2 refers to "ambient conditions," which are certainly not due to LOCA or MSLB. If pressure relief were to be provided, what would be the set pressure for release — Design Pressure, two times the Design Pressure, or more? The Code allows the pressure during an accident condition to exceed two times the Design Pressure. This fact is identified in NC-3611.2 in the Winter 1976 Code; even higher pressures are allowed in the Winter 1981 Addenda. Both of these Codes have been accepted by NRC regulations. I understand that the Staff is saying that the evaluation required should be a service condition for LOCA or MSLB, which means that Service Level D is appropriate, and that Appendix F can be used for this evaluation. This makes perfect sense, and I agree with your position on this issue. My comments were based on the statement in the Generic Letter that stated, "This phenomenon is typically a design consideration." Obviously the Code considers Service Level D to be appropriate for evaluating accident conditions, and the stress limits for the "design condition" may be exceeded. Therefore, I believe we are in agreement on this point.

> Your first argument is that the generic letter only addresses accident conditions and that the ASME Code requirements related to potential overpressure as a result of the fluid expansion cited above do not apply to accident conditions. Unfortunately, you have misinterpreted the generic letter. The requested action for this issue as specified in the generic letter is not limited to accident conditions. In fact, one of the example events cited in the generic letter occurred during normal plant operations (EN 30833). However, the staff does believe that the major concern involves accident scenarios such as loss-of-coolant accident (LOCA) and main steam line break (MSLB). Your argument that the ASME Code doesn't require consideration of this potential overpressure for accident conditions is based on the words contained in the USAS B31.1 Power Piping Code. In the section of USAS B31.1 that specifies design conditions, the requirements for overpressure as a result of fluid expansion effects are under the heading of "Ambient Influences." The term "ambient influences" relates to the surrounding atmosphere. The NRC staff is not aware of any definition that states that ambient influences do not apply to the surrounding atmosphere during

> accident scenarios. The ASME Code quotation cited in the previous paragraph comes under the heading "Design and Service Loadings." As you are aware, service loadings include loads resulting from accident conditions that are evaluated for compliance with ASME Code Level C and D Service Limits. The ASME Code paragraph quoted does not state that the concern is limited only to normal operating conditions. The staff does not find anything in the ASME Code language that supports your argument.

The Duquesne incident (EN 30833) occurred with pressure not exceeding the design pressure. Obviously Code allowable stresses were not exceeded. The butterfly valve didn't open, but that is an operability issue, not a Code issue. Everything that occurred at Beaver Valley was within the original design pressure.

I have found definitions of *ambient* in dictionaries, which definitions imply that ambient conditions include normal exposures of the surrounding environment. Nothing in these definitions supports the idea that accident conditions within the containment vessel are implied by *ambient*. To research the issue further, I found many Code Interpretations containing the term *ambient*. (See Attachment A) If these are read in context, the term *ambient* can be understood. It is obvious that *ambient* includes normal design or operating conditions and does not include accident conditions. However, I believe that we are in agreement that accident conditions should be evaluated using Level C and Level D Service Limits. Our agreement on that point is significant.

> Your second argument is that the ASME Code does not have any requirements for an isolated section of piping. You attached a copy of ASME Code Interpretation III-1-95-19 to support your claim. The question posed in the interpretation reads: "A portion of a piping system consisting of piping and isolation valves is out of service and performs no safety function. Does Section III require the isolated system to be protected from overpressure during these conditions?" The staff did not refer to "out of service" piping systems that perform no safety function in the generic letter. Piping systems that become isolated during normal or accident conditions are not considered "out of service" but merely in a standby situation. Many of these systems form containment barriers, and some systems may have to be actuated during the course of the accident. Clearly, they are performing a safety function. The staff does not consider this ASME Code interpretation relevant to the issue addressed by the generic letter.

Although I do not agree that a portion of a piping system that is isolated inside and outside containment is "in service," the issue is no longer important, because we agree that Level C or Level D Service Limits apply. The ASME Interpretation on the isolated section of piping is no longer important to illustrate this point.

> Your third argument hinges on the fact that there is no mention of "trapped fluid" in the Codes except in relation to the internal cavity of a valve. However, Section NC-3612.4(a)(3)(e) of the ASME Code contains the following statement: "Adequate consideration shall be given to the control of fluid pressure caused by heating of the fluid trapped between two valves." The statement is contained on the ASME Code page just previous to the one you enclosed with your letter. The concern addressed by the ASME Code relates to the heating of a lower temperature section of the piping by a higher temperature section. However, it appears to demonstrate that the ASME Code is concerned with the heating of "trapped fluid" between valves. It also appears to contradict your assertion that the ASME Code considers a piping section shut off between two valves out of service.

Your fourth paragraph is interesting for several reasons. The first reason is that NC-3612.4(a)(3)(e) was not part of the Code of Record for most U.S. nuclear plants, because these provisions were not added until the Winter 1976 Addenda. Further, the paragraph addresses two active lines designed for different pressures, joined by an interconnecting valve. This condition addresses "active pressure" and "design conditions," not "static pressure" in an isolated line subject to accident conditions. There is a huge difference in the two situations, because NC-3612.4 addresses "design conditions." I believe that we have agreed that we are concerned with Service Level C and D Service Loadings. The reason for concern for trapped fluid, which was added in the Winter 1976 Addenda, is pressure locking of the valve, causing failure of the disk or the bonnet retaining mechanism or inability to open the valve. It has nothing to do with loss of pressure integrity of the piping system.

> In the second item in your letter, you argued that there is no real reason to be concerned with the increase in pressure of a fluid in a portion of piping between isolation valves. You argue that the piping will probably not fail because of leakage through the valves or if valve leakage does not occur, at worst, the pipe would merely crack and the fluid "dribble" out. The staff does not agree that cracking the pipe to relieve the overpressure is an acceptable consequence, and we cannot assume the valves will always leak. In addition, the requirement cited from Section NC-3612.4(a)(3)(e) does not appear to support your position.

Your fifth paragraph discusses a "faulted" condition, not a "design" condition. The reference to NC-3612.4(a)(3)(e) applies to "design" conditions, not "faulted" conditions. With regard to the "leak" and the "dribble", valve manufacturers have told me that they know of no case in which valves would not leak past the disk when subjected to pressures great enough to crack or fracture the connected pipe. Also, they have assured me that it would be next to impossible to eliminate the air pockets in the isolated line. With air pockets in the line, there is enough volume to accommodate the expansion of the fluid. There appears to be no recorded case of failure of piping in any industrial service that reflects the postulated condition raised in Generic Letter 96-06. Whether or not the "dribble out" theory is accepted, the point is that the pipe can't break until someone invents tighter valves than have ever been placed in service. Again, however, the importance of this theory is minimized because we agree that Level C and D Service Limits apply for the conditions stated in the Generic Letter.

> You also discuss the case of a piping run that penetrates the containment shell and has inside and outside containment isolation valves. You argue that if the valves do not leak, the piping can only crack at a point either inside or outside the containment in the segment confined between the two isolation valves, thereby maintaining containment isolation. Although this scenario is possible, the staff believes it would be difficult to demonstrate conclusively that only one side of the pipe would crack in an overpressure event. If a crack occurs on both sides of the penetration, containment integrity would be lost. The staff does not accept your argument as an adequate basis for ignoring this issue.

Your sixth paragraph is very important. We know as professional engineers that because of the "banding" effect on the isolated pipe, that a failure crack cannot propagate from inside containment to outside containment, because of the strain constraint caused by the "band" created by the containment shell, liner or flued head, as the case may be. This means that two independent failures would have to occur at exactly the same time, because when one crack occurs, the pressure is immediately relieved. If the NRC Staff is saying that two independent failures must be considered to occur simultaneously, this is a brand new concept. I know of no regulatory requirement that says two simultaneous failures must be postulated to occur in a single segment of piping. A requirement to assess the potential for multiple simultaneous failures in an isolated pipe section, from one limited source of pressure seems unrealistic and unwarranted. It appears you are trying to establish a new regulatory criteria.

As you may be aware, the staff evaluated the specific issue of inside and outside containment isolation valves in Generic Safety Issue (GSI) 150, entitled "Overpressurization of Containment Penetrations." The resolution of GSI-150 was based on probability arguments, In its evaluation, the staff assumed a uniform strain in the piping segment. On the basis of the computed uniform strain, a relatively low failure probability was estimated. In your letter, you have pointed out that the pipe cannot expand at the containment penetration. Therefore, the local strains near the penetrations may be much higher than those assumed in the staff's previous assessment. The staff is currently reassessing the technical evaluation in GSI-150.

This paragraph is interesting but it's relevance to issues raised in my letter is unclear. Where the containment shell, liner or flued head constrains the penetration, the local strains must be lower. Some local bending will occur, but this <u>does not</u> produce higher strains. I do not understand why you would reassess your technical evaluation in GSI-150. Your statement does not make sense to me.

In the third item of your letter, you express the concern that thermal relief valves regularly leak in operation. You also claim that because of the possibility of a stuck-open relief valve, compliance with the generic letter can have a direct adverse effect on safety. The generic letter does not require installation of thermal relief valves. The generic letter requests that licensees evaluate the potential for overpressurization of the piping and take appropriate corrective actions. It is up to licensees to determine whether thermal relief valves are necessary to prevent overpressurization of the piping. The staff does not consider the potential for leakage or the potential for a stuck-open relief valve an adequate basis for allowing the pipe to fail due to overpressure. Further, the generic letter states that consideration must be given to the effects of stuck-open relief valves.

It is clear that the solution to the problem is not installation of thermal relief valves. Industry experience shows that they are not effective and cause more problems than solutions. Owners should realize that installation of relief valves is not <u>never</u> needed to address the issues in Generic Letter 96-06.

In the fourth item of your letter, you referred to the staff's actions in issuing the generic letter without public review and backfit analysis. I discussed the staff's position on this topic in my letter transmitting this enclosure to you.

The staff issued the generic letter without public comment because it considered the issues urgent. The urgency existed because two licensees had considered the technical issues addressed in the generic letter to be significant enough safety concerns to warrant a shutdown of their facilities, The staff followed its procedure as specified in NRC Inspection Manual Chapter 0720 for issuing a generic letter which allows the staff to issue a Category 1 generic letter without Federal Register notification when urgent circumstances exist.

The staff issued the generic letter without a full backfit analysis because it considered the issues to be compliance backfits under the provisions of Section 50.109 of Title 10 of the Code of Federal Regulations (10 CFR 50.109). Under the provisions of 10 CFR 50.109(a)(4)(i), a backfit analysis by the staff is not required if a plant modification is necessary to bring a facility into conformance with its license or the rules or orders of the Commission, or into conformance with written commitments by the licensee. Your charge that the statements in the generic letter are false is based on the assertion that the piping codes that licensees committed to in the design of their facilities did not require consideration of the issues addressed by the generic letter. These issues involve the potential for overpressure of isolated sections of piping as a result of the heating of the trapped fluid, and the potential for water hammer because of the flashing of water in the containment fan coolers during postulated accident conditions. The staff addresses your specific concerns in the enclosure.

> As discussed in the enclosure, the staff believes its statements in GL 96-06 are not contradicted by the piping codes. The staff continues to conclude that the issues identified in the generic letter should have been addressed in the original plant design and, therefore, have been properly designated as compliance backfit issues in accordance with the Commission's regulations.

With regard to your comments regarding public review of the Generic Letter and backfit analysis, I have the following comments:

(1) I understand that public review is not necessary when urgent circumstances exist. However, the Generic Letter has not demonstrated that urgent circumstances exist. The circumstances are no different than they were twenty years ago, and we know that Code requirements were met when the plants were designed and constructed. Even though the plant took an extremely conservative approach, and shut down to asses this issue, no evidence was or is available to support existence of my safety concern.

(2) It is my understanding that plant license conditions, rules and orders of the Commission, and written commitments by the licensee all refer to ASME Code requirements. However, because the Code excludes consideration of thermal effects for Level C and D Service conditions, the increased pressure due to LOCA or MLSB does not violate Code requirements. In addition. the Staff agrees that water hammer is required to be considered only when it is an anticipated load. The referenced water hammer was obviously not anticipated during design and construction, so to require utilities to evaluate the condition is not a Code issue, and may be a backfit.

(3) Based on the attached evaluation of the Staff's reply, I believe the Code was not violated because of the exclusion of the thermal effects from evaluation of Level C and D Service Conditions.

I agree that it may be appropriate to evaluate the conditions identified in the Generic Letter. However, such evaluation could easily be done on a generic basis using Appendix F of the Code with very conservative assumptions. This approach would eliminate the confusion that currently exists in the industry because different utilities are taking different approaches to evaluating the situation. Use of a consistent approach will significantly reduce unnecessary Owner costs.

> In the fifth item in your letter, you include a number of unrelated statements. You state that two-phase flow is not an ASME Code issue. The staff has not made any claim that two-phase flow is an ASME Code issue. Your assertion that pressure in a system higher than design pressure is not a safety concern is ambiguous. In the ASME Code, "design pressure" is a term associated with Level A Service Limits. For Level C and D Service Limits (typically used for accident conditions such as LOCA and MSLB), the design pressure can be exceeded as long as the Level C and D Service Limits are met. The staff does not agree with the assertion that an evaluation that shows that the Level C and D Service Limits may be exceeded for a postulated service load is not a safety concern. You cite ASME Code Interpretation III-1-92-45 as clarification of the issue. This interpretation contains several carefully worded questions. No claim is made in the response to the questions posed in the interpretation that loading a piping component beyond the ASME Code criteria is not a safety concern. (In your discussion of this item, you also make reference to systems "out of service." This aspect was already addressed in our response to Item one, above).

The tenth paragraph essentially identifies another point of agreement. You identify that design pressures can be exceeded for Service Levels C and D. Therefore, Interpretation III-1-92-45 is no longer needed to address Generic Letter 96-06. However, I will address this Interpretation as an adjunct point later.

> In the sixth item of your letter, you assert that the ASME Code does not require piping to be designed for water-hammer conditions. You base this argument on the contention that water hammer is an accident condition and, therefore, the loads need not be checked for compliance with ASME Code allowable stresses. The ASME Code page attached to your letter contains the requirements for design and service loadings. For example, in Section NC-3622.1, "Impact forces caused by either external or internal loads shall be considered on the piping design." In fact, water-hammer loads resulting from two-phase flow conditions are specifically identified in Section NC-3622.5 of the 1995 Edition of the ASME Code. Also, paragraph 101.5.1 from the page from B31.1-1995 enclosed with your letter addresses this issue. It contains the following statement: "One form of internal impact force is due to propagation of pressure waves produced by sudden changes in fluid momentum." Pressure wave propagation produced by sudden changes in fluid momentum is a water hammer. The staff believes that the ASME Code does require evaluation of water-hammer events when they are expected to occur. The staff also believes that the words in the ASME Code contradict your assertion that the ASME Code does not requi[illegible]ing to be designed for expected water-hammer loads.

I am in agreement with most of these statements. The Code states that impact forces caused by either internal or external forces must be considered. This does not mean that specific loads must be quantified. Such loads may be enveloped by the identified pressure used for design (design pressure) if such loads are anticipated, or such loads may be identified separately using appropriate Service Levels. However, if such loads are <u>not anticipated</u> at the time the Design Specification and Design Report are written, no aspect of the Code is violated. In other words, the Code does not require every piping system to be designed for water hammer. If such a load is anticipated, the Design Specification must identify it and the appropriate Service Level for it.

If the water hammer is not identified in the Design Specification, and someone later decides that such a load could be postulated to occur, no Code requirement has been violated, and there is absolutely no issue of Code compliance. In this case, the issue is one of operability, and the Interpretation discussed in the last paragraph may be appropriate, because there is no issue of Code compliance. This happens in use of pressure retaining equipment all the time, when pressure loads greater than the design loads are experienced. I have checked with many Code experts and regulatory experts who agree with me that such an occurrence is <u>not</u> a Code compliance issue. In effect, this is exactly what the referenced Interpretation says. You may want the issue evaluated, but such evaluations are <u>not</u> Code compliance issues. I agree with you that when water hammer loads are anticipated and identified in the Design Specification, the designer must show compliance with the appropriate Service Levels. In practical terms, the water hammer loads postulated in the Generic Letter were never anticipated and were not identified in the Design Specifications. Therefore the postulated water hammer loads are <u>not</u> Code compliance issues, because no one postulated them at the time the plants were designed and constructed. If an operability evaluation is required by the NRC, the requirement must come from some NRC rule or regulation other than by reference to the ASME Code, because the Code does not address either functionality or operability.

Your reference to the provisions of NC-3622.5 regarding water hammer due to two phase flow was very interesting. This provision was not added as a Code requirement until the 1994 Addenda to Section III. The NRC has not endorsed accepted any Addenda after the 1989 Edition of the Code. Though interesting, these provisions are not applicable to any licensees, except through a backfit.

> In your letter, you stated that you were not aware of any event in which piping broke because of water hammer at a nuclear plant. There have been numerous water-hammer events at nuclear power plants that have resulted in damage to piping and piping supports. These events have been documented in previous staff reports such as NUREG/CR-2059 and NUREG/CR-5220. In a recent event at Oconee Unit 2, a balance-of-plant-system pipe rupture resulting from a water hammer caused several injuries to the plant staff. Also, a feedwater water-hammer event at Indian Point Unit 2 (NUREG/CR-2059) caused a 180-degree crack in the feedwater line. Water-hammer loads have caused piping damage, including actual pressure boundary failures, at nuclear power plants. The staff believes that the preferred solution to potential water-hammer problems is to eliminate the cause. However, if internal impact forces (water hammers) are expected to occur, they should be evaluated in the piping design.

This paragraph identifies failure of some nonnuclear piping. It is likely that these failures were associated with erosion, flow-accelerated corrosion, or other deterioration effects. Balance of plant systems are not inspected to the Section XI requirements. With regard to the feedwater line, you identified that the pipe had a crack, and the pressure boundary remained intact. I agree that the cause of the problem should be eliminated or mitigated. However, this is not a Code compliance issue. Evaluations of such loads after the plant has been designed and constructed is beyond the scope of both the Section III and Section XI Codes. Any decision to use Code guidance in evaluating these loads is surely elective. No Code requirements or regulations force use of Code provisions to evaluate acceptability of these operating issues. Therefore, Code compliance is not the issue.

> In Item seven of your letter, you state, "allowable stresses have no significance with regard to operation of the equipment." Your argument is based on the margins used in design. The staff disagrees with your assertion. If a load creates a high-enough stress, it will fail the component regardless of the original design margins. In addition, the staff believes that the margins you quoted for design are not applicable to higher stress limits used for ASME Code Service Level C and D loadings. The staff does not endorse the sweeping generalization that exceeding ASME Code stress limits poses no safety concern because of the design margins. In your letter, you also state that ASME Code allowable stresses are often exceeded because of settlement of supports or foundations. You further state that this condition creates an overstress that is not an ASME Code compliance issue. In Section NC-3653.2, contrary to your statement, the ASME Code has a specific stress limit for piping stresses that are caused by predicted building settlement.

With regard to evaluation for operation (operability), my statement was that Code allowable stresses had no significance. I felt that this was an obvious fact, because operability is beyond the scope of the Code. Further, as Professional Engineers know from looking at stress-strain curves, that structures fail because of strain, not because of stress. In the elastic range of steel, stress is proportional to and is an indication of strain, but in the plastic range of steel, stress and strain are not directly proportional. In the plastic range, stress has no practical meaning, because the material is beyond its proportional limits. For some stresses, the Code limit is the 3 S_m, which is ultimate tensile strength of the material. Even though the failure strength is the ultimate stress limit, failure will not occur, because failure is based on strain, not stress, and a portion of the stress is secondary, or self-limited, and the strain is therefore limited. If equipment can yield and still operate, Code allowable stresses are meaningless. The important point is to place practical limits on strain in this condition. This is the logic behind my statement about the significance of allowable stresses.

Your comment about building settlement was interesting. This provision is in paragraph NC-3653.2, which deals with thermal effects. NC-3653.2 relates to "<u>predicted</u> building settlement," not <u>actual</u> building settlement, as I related in my previous letter. There is a big difference between these two cases. Furthermore, this provision was added to the Code in the Winter 1981 Addenda. No U.S. plant was designed and constructed to this Addenda. Though interesting, these provision are not applicable to current licensees except through a backfit.

> In the eighth and final item in your letter, you claim that the issues in the generic letter are "imagined issues." The staff considers the technical issues in the generic letter as significant safety concerns and not "imagined issues." Two licensees have shut down their facilities because of concerns about these issues. With regard to your assertions about the cost of the implementation of the generic letter, the staff has not received any information from licensees on this subject.

With regard to my statement of "imagined issues," allow me to provide some clarification. The loads referred to are postulated. That is, they are not loads that were anticipated by anyone prior to this year. This issue raised in Generic Letter 96-06 was "violation of the ASME Code." Because the Code was not violated, imagination is required to reach the conclusion that these issues have anything to do with Code compliance.

Now I will explain. Please bear in mind, I believe that we are in substantial agreement regarding the Code requirements. With regard to water hammer, it was not anticipated for the situations identified in the Generic Letter. Also it was not identified in any Design Specification. Therefore there is no Code violation.

Next, with regard to thermal effects, these were also not identified in the Design Specifications. Therefore, postulating them now does not show that any Code requirements were violated. That statement may sound weak to some, so I will explain further.

(a) If you read the Summer 1976 Addenda to Section III, slightly modified by the Winter 1976 Addenda, you will find that the Code allows thermal effects to be ignored for Level C and D Service Limits. You have agreed that Level C and D Service Limits are appropriate for the stress caused by thermal expansion of the fluid due to the LOCA and MSLB events.

(b) NC-3611.3(c) states that Equations (10) and (11) are not applicable for these conditions. These evaluations are the ones that incorporate consideration of thermal effects. If you refer to NC-3652.3 of the Winter 1976 Code, you will see that these equations address consideration of thermal effects.

(c) Furthermore, in paragraph NC-3611.2(c)(3), you will find that evaluations may be made using Appendix F of the Code without consideration of all other Design and Service Loadings. Use of Appendix F excludes consideration of thermal stresses.

If you read the Code paragraphs cited (and attached) you'll see no Code Interpretations are required. The thermal effects identified in the Generic Letter are not required to be considered in the Code design for Service Levels C and D, which your letter to me identified as appropriate. When the US Nuclear plants were designed, the Professional Engineers knew that the Code did not require thermal effects to be considered for Service Levels C and D.

Because thermal effects need not be considered, I referred to the Generic Letter 96-06 issue as imaginary. A better explanation would have been that the issues raised in the Generic Letter are outside the scope of Code requirements. However, when I wrote the letter to you, I was not aware that you agreed with me that Service Levels C and D were appropriate, and that loads were only required to be considered in design if they were anticipated. Because we agree on this, I believe we agree that Code compliance is not an issue of Generic Letter 96-06.

The unresolved issue is, what regulations were violated? How is Generic Letter 96-06 an issue of compliance?

ATTACHMENT A
ASME CODE INTERPRETATIONS REGARDING USE OF AMBIENT TEMPERATURE

Interpretation: III-1-83-253
Subject: Section III, Division 1, Table NF-3292.1-1 Allowable Stress Limits for Linear Component Support Welds - All Classes (All Editions)
Date Issued: July 26, 1984
File: NI84-015

Question (1): What is the effective temperature range of the allowable stress limits for shear stress of fillet welds, Table NF-3292.1-1, up to the Summer 1982 Addenda, and Table NF-3324.5(a)-1, Winter 1982 Addenda and later?

Reply (1): The allowable stress limits are effective from ambient temperature to 400 F, inclusive.

Question (2): What stress limits apply to the allowable stresses discussed in Question (1) when the design specification for linear type component supports stipulates Levels A, B, C, and D loading conditions?

Reply (2): In the Winter 1982 Addenda and later, NF-3324.5 states that the stress limits of Table NF-3324.5(a)-1 are multiplied by the appropriate stress limit factor. For shear stress in linear-type support welds, use the stress limit factors Kv in Table NF-3523(b)-1 and Table NF-3623(b)-1. Prior to the Winter 1982 Addenda, the stress limits of Table NF-3292.1-1 could be multiplied by 1.33 for Service Level C and by 1.0 for Service Levels A and B.

Interpretation: VIII-1-92-64
Subject: Section VIII, Division 1 (1989 Edition, 1991 Addenda); UG-20
Date Issued: April 20, 1992
File: BC92-102

Question: Do the requirements of UG-20(f)(3) in Section VIII, Division 1 specify a duration of time at which ambient temperature can be below -20 F and still be classified as "seasonal"?

Reply: No.

Interpretation: VIII-1-86-57
Subject: Section VIII, Division 1, UG-125, UG-129(a), and UG-136(a), Liquid Relief Valves
Date Issued: May 13, 1986
File: BC86-199

Question (2): Does a relief valve for relieving expansion of water caused by ambient temperature changes (ambient temperature less than 140 F) require a lifting device if operating temperature of the vessel exceeds 140 F?

Reply (2): No.

Interpretation: VIII-1-83-307
Subject: Section VIII, Division 1, Table UCS-56, Heat Treatment Requirements
Date Issued: October 1, 1984
File: BC83-636

Question: Table UCS-56 of Section VIII, Division 1, gives postweld heat treatment requirements for carbon and low alloy steels. Do the minimum holding temperatures given in this Table refer to the measured ambient temperature in the furnace, to the measured temperature at the surface of the product, or to the measured temperature at the center of the product?

Reply: The temperatures given in Table UCS-56 refer to the product metal temperature. The temperature is measured at the surface of the product with a sufficient soaking period that allows for full thickness temperature penetration.

Interpretation: VIII-81-107
Subject: Section VIII, Division 1, UCS-79(b)
Date Issued: November 25, 1981
File: BC81-447

Question: Under the provisions of UCS-79(b), what constitutes a cold blow, and how is that differentiated from a multiple press?

Reply: A cold blow is the result of an impact, such as a hammer strike, at ambient temperature. This differs from a multiple press, which is a slow deformation without an impact.

Interpretation: VIII-2-83-38
Subject: Section VIII, Division 2, AD-160.2
Date Issued: June 29, 1984
File: BC83-644

Question (3): AD-160.2 also states: "Pressure cycles caused by fluctuations in atmospheric conditions need not be considered." If the pressure variation exceeds 20 percent of the design pressure only when ambient temperature changes cause some of the pressure variation, does this constitute an operation pressure cycle?

Reply (3): No.

Interpretation: IX-92-10
Subject: Section IX, QW-160; Guided-Bend Test Specimens
Date Issued: October 7, 1991
File: BC91-261

Question (1): Does Section IX impose a specific temperature at which the specimen must be during the bend test?

Reply (1): No.

Question (2): May the test temperature of the specimen be any temperature between ambient and the maximum allowable temperature imposed by ASME Section III for that specific material?

Reply (2): No.

Interpretation: IX-78-54
Subject: Section IX, QW-482, QW-483, and QW-484; Section VIII
Date Issued: April 4, 1978
File: BC77-308

Question (5): If no preheat is used to weld because the ambient temperature is above the minimum preheat temperature, what is filled in for QW-406, Preheat Temperature, on QW-483?

Reply (5): The ambient temperature must be recorded.

Interpretation: B31.3-12-06
Subject: ASME B31.3-1990 Edition, Paragraph 319.2.3, Displacement Stress Range
Date Issued: June 7, 1993
File: B31-93-007

Question: In accordance with ASME B31.3-1990 Edition, does paragraph 319.2.3 require that the difference between the minimum and maximum piping temperatures, whether caused by ambient or operating conditions, be considered as one of the range of conditions for calculating the displacement stress range?

Reply: Yes.

Interpretation: B31.3-11-03
Subject: ASME B31.3-1990 Edition, Paras. 306.4.2 and 332.4.2, Heat Treatment for Flared Laps
Date Issued: May 22, 1992
File: B31-91-052

Question: In accordance with ASME B31.3-1990 Edition, paras. 306.4.2 and 332.4.2, does a flared lap on a P-No. 1 material made at ambient temperatures and exhibiting a calculated maximum fiber elongation greater than 50 percent of the specified basic minimum for the grade of steel used, require heat treatment under paragraph 332.4.2(a)?

Reply: Yes, except as excluded by paragraph 332.4.2(a).

Interpretation: B31.3-1-49
Subject: 321; Design of Pipe Supporting Elements
Date Issued: September 8, 1981
File: 1552

Question: Does 321.1.4(d) permit plastic materials approved for pressure piping to be used as pipe support elements in tension at pipe temperatures above ambient?

Reply: Yes, provided the other requirements of 321.1 have been satisfied.

Interpretation: B31.4-4-2
Subject: 419.6.4(b) and 419.6.4(c) and 419.7
Date Issued: May 25, 1978
File: 1216

Question (1): We have designed a manifold arranged piping system carrying various oils at elevated and ambient temperatures. Does the manifold, because of the restraint effect of ambient pipes connected to heated pipes, still fall under the criteria of 419.6.4(c)?

Question (2): For this piping arrangement should we also check the design of the system using the criteria listed under 419.6.4(b)?

Question (3): In order to cover a general situation where above-ground piping is subject to substantial axial restraint without being rigidly anchored, should a paragraph be added to the Code to point the reader in the right direction?

Reply: The equation for S_L in 419.6.4(b) evaluates the upper limit thermal longitudinal stress in a pipe (or any other prismatic body), in which there is absolutely no flexibility and, consequently, all the thermal expansion must be absorbed in compressive strain. Physical arrangements complying with the requirements of "absolutely no flexibility" are: buried pipe or a straight run of above-ground pipe between two anchors. For the latter case, an analysis (computer or otherwise) based on 419.6.4(c) and 419.7 should yield the same results as the equation of 419.6.4(b). If a piping system is properly defined (geometry and restraints), then a flexibility analysis as indicated by 419.6.4(c) and 419.7 will fulfill the requirement of the Code. As implied above, if the system is subject to substantial axial restraints, the value of S_L [from 419.6.4(b)] will represent the upper limit.

Based on the above observations, the answers to your questions are:

Question (1) - Yes;

Question (2) - No.

Regarding question (3), the Committee will consider a possible revision to the Code. You are advised to review future addenda to the Code for any revisions.

Interpretation: PTC 4.1
Subject: Clarification on the Use of "Abbreviated Test Procedures," ASME PTC 4.1, 1964, While Using Steam Coil Air Heaters
Date Issued: March 1980 MECHANICAL ENGINEERING
File: Technical Inquiry of November 7, 1979

Reference: PTC 4.1 on Steam Generating Units

Question: As per clause 1.07 (p. 13), the "Abbreviated Test Procedure" ignores the minor losses and heat credits. Where heat losses are to be adjusted to compensate for variations in fuel, or changes in inlet air temperature, as would be done in verifying an efficiency guarantee, the procedure given in Section 7, corrections to standard or guarantee conditions of the code should be followed.

As per clause 7.2.8.1 (p.48): t_{A7} or t_{A8} = F = "Inlet air temperature. If the unit is equipped with a steam or water coil air heater before the main air heater and it is supplied with heat from a source external to the unit being tested, the inlet air temperature t_{A8} shall be measured in the air stream after this heater and in this case the heat added to the inlet air is a heat credit."

The use of "Abbreviated Test Procedure," as it ignores the heat credits, results in higher efficiency figures, compared to the detailed procedure. With steam coil air heating similar to the case mentioned above, if the reference temperature is taken after the steam coil air heater in the Abbreviated Test, it gives a very high efficiency which is far from the one obtained by the detailed method.

We request you to give your opinion in this regard whether we can use Abbreviated Test Procedure, taking the reference temperature after the steam coil air heater.

Reply: If you have air heating from an external source, then you must account for it as a heat credit. Instead of using the heating value of the fuel as the input, one must use the heating value plus the proportional heat credit added to the air. The idea of increasing the reference temperature to that of the discharge side of this externally supplied heater is wrong. All you do is raise the whole level of reference and thereby artificially decrease the major losses from a steam generator to that of the dry flue gas and the moisture in the flue gas. Therefore, this is an improper solution. We have to use a reference temperature that is the temperature ambient around the system and usually the inlet or discharge to the forced draft fan. If there is any heat added from an external source, it must be corrected for that heat. The abbreviated test form procedure can be used. However, the input would have to include the heat credit from the external heat source. This could be done by appropriately proportioning that external heat energy and adding it to the fuel heat value. The determination of this value must be such that the losses as computed on the form respond not just to the Btu per pound of "as fired" fuel, but include this heat credit. In brief, the procedure of using the referenced temperature as that measured after the externally supplied steam coil air heater is improper and will give an incorrectly high efficiency for the unit.

ATTACHMENT B S-76 CODE

NC-3600 PIPING DESIGN

NC-3610 GENERAL REQUIREMENTS

NC-3611 Acceptability

The requirements for acceptability of a piping system are given in the following subparagraphs.

NC-3611.1 Allowable Stress Values. Allowable stress values to be used for the design of piping systems are given in Tables I-7.0 for acceptable materials at various temperatures.

NC-3611.2 Limits of Calculated Stresses Due to Sustained Loads and Thermal Expansion

(a) Internal Pressure Stress. The calculated stress due to internal pressure shall not exceed the allowable stress values except as permitted in NC-3612.3.

(b) External Pressure Stress. Piping subject to external pressure shall be considered safe when the wall thickness and means of stiffening meet the requirements of NC-3641.2.

(c) Allowable Stress Range for Expansion Stresses. The expansion stress, S_E, (NC-3672.9) shall not exceed the allowable stress range, S_A, given by the following formula:

$$S_A = f\,(1.25\ S_c + 0.25\ S_h)$$

where

S_c = basic material allowable stress at minimum (cold) temperature, psi

S_h = basic material allowable stress at maximum (hot) temperature, psi

f = stress range reduction factor for cyclic conditions for total number, N, of full temperature cycles over total number of years during which system is expected to be in operation, from Table NC-3611.2(c)-1

(1) In determining the basic material allowable stresses, S_c and S_h, joint efficiencies need not be applied.

TABLE NC-3611.2(c)-1
STRESS RANGE REDUCTION FACTORS

Number of Equivalent Full Temperature Cycles N	f
7,000 and less	1.0
7,000 to 14,000	0.9
14,000 to 22,000	0.8
22,000 to 45,000	0.7
45,000 to 100,000	0.6
100,000 and over	0.5

(2) Stress reduction factors apply essentially to noncorrosive service and to corrosion resistant materials, where employed to minimize the reduction in cyclic life caused by corrosive action.

(3) If the range of temperature change varies, equivalent full temperature cycles may be computed as follows:

$$N = N_E + r_1{}^5 N_1 + r_2{}^5 N_2 + \dots\, r_n{}^5 N_n$$

where

N_E = number of cycles at full temperature change, ΔT_E, for which expansion stress, S_E, has been calculated

$N_1, N_2, \dots N_n$ = number of cycles at lesser temperature changes, $\Delta T_1, \Delta T_2, \dots \Delta T_n$

$r_1, r_2, \dots, r_n$ = $(\Delta T_1)/(\Delta T_E)$, $(\Delta T_2)/(\Delta T_E)$, $\dots$, $(\Delta T_n)/(\Delta T_E)$ = the ratio of any lesser temperature cycles for which the expansion stress, S_E, has been calculated. S75

(d) Additive Stresses. The sum of the longitudinal stresses due to pressure, weight and other sustained loads shall not exceed the allowable stress in the hot condition, S_h. Where the sum of these stresses is less than S_h, the difference between S_h and this sum may be added to the term $0.25S_h$ in Formula (1) for determining the allowable stress range, S_A.

NC-3611.3 Limits of Calculated Stresses

(a) Normal Operating Conditions. The sum of stresses due to design pressure, weight, and other sustained loads shall not exceed S_h and the requirements of Equation 8, NC-3652.1 shall be met. In addition, either the stress range due to thermal expansion as calculated by Equation 10, NC-3652.3 shall not exceed S_A, or the sum of stresses due to design pressure, weight, other sustained loads and the stress range due to thermal expansion shall not exceed the sum of S_A and S_h as required by Equation 11, NC-3652.3.

(b) During Upset Conditions. The sum of the stresses produced by maximum pressure, live and dead loads and those produced by occasional loads such as wind or earthquake defined in the Design Specifications as normal or upset, may be as much as 1.2 times the allowable stress values given in Tables I-7.0. Under upset conditions, the requirements of all equations of NC-3651 shall be met.

(c) During Emergency Conditions. The sum of the stresses produced by internal pressure, live and dead loads and those produced by occasional loads defined in the Design Specifications or emergency conditions

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may be as much as 1.8 times the allowable stress values given in Tables I-7.0. Under emergency conditions, the requirements of Equation (9) of NC-3651 shall be met using a stress limit of $1.8S_h$. Equations (8), (10) and (11) need not be considered.

(d) During Test. Occasional loads shall not be considered as acting concurrently with live and dead loads at time of test.

NC-3612 Pressure-Temperature Ratings for Piping Products

NC-3612.1 Piping Products Having Specific Ratings

(a) Pressure-temperature ratings for certain piping products have been established and are contained in some of the standards listed in Table NC-3691-1. The pressure ratings at the corresponding temperatures given in the standards listed in Table NC-3691-1 shall not be exceeded and piping products shall not be used at temperatures in excess of those given in Tables I-7.0 for the materials of which the products are made.

(b) Where piping products have established pressure-temperature ratings which do not extend to the upper material temperature limits permitted by this Subsection, the pressure-temperature ratings between those established and the upper material temperature limit may be determined in accordance with the rules of this Subsection.

NC-3612.2 Piping Products Not Having Specific Ratings. Should it be desired to use methods of manufacture or design of piping products not now covered by this Subsection it is intended that the Manufacturer shall comply with the requirements of NC-3640 and NC-3690 and other applicable requirements of this Subsection for the design conditions involved. The Manufacturer's recommended pressure-ratings shall not be exceeded.

NC-3612.3 Allowance for Variations from Design Conditions

(a) It is recognized that variations in pressure and temperature inevitably occur and therefore the piping system shall be considered safe for occasional

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TABLE NC-3521-1
STRESS AND PRESSURE LIMITS FOR UPSET, EMERGENCY, AND FAULTED CONDITIONS

Condition	Stress Limits[1–4]	P_{max}[5]
Upset	$\sigma_m \leq 1.1\ S$	
	$(\sigma_m \text{ or } \sigma_L) + \sigma_b \leq 1.65\ S$	1.1
Emergency	$\sigma_m \leq 1.5\ S$	
	$(\sigma_m \text{ or } \sigma_L) + \sigma_b \leq 1.8\ S$	1.2
Faulted	$\sigma_m \leq 2.0\ S$	
	$(\sigma_m \text{ or } \sigma_L) + \sigma_b \leq 2.4\ S$	1.5

NOTES:
(1) A casting quality factor of 1 shall be assumed in satisfying these stress limits.
(2) These requirements for the acceptability of valve design are not intended to assure the functional adequacy of the valve.
(3) Design requirements listed in this table are not applicable to valve discs, stems, seat rings, or other parts of the valves which are contained within the confines of the body and bonnet.
(4) These rules do not apply to safety relief valves.
(5) The maximum pressure shall not exceed the tabulated factors listed under P_{max} times the design pressure or times the rated pressure at the applicable operating condition temperature.

NC-3600 PIPING DESIGN

NC-3610 GENERAL REQUIREMENTS

W76 NC-3611 Acceptability

The requirements for acceptability of a piping system are given in the following subparagraphs.

NC-3611.1 Allowable Stress Values. Allowable stress values to be used for the design of piping systems are given in Tables I-7.0 for acceptable materials at various temperatures.

NC-3611.2 Stress Limits

(a) Design and Service. Conditions shall be specified in the Design Specification.

(b) Design Conditions. The sum of stresses due to design internal pressure, weight, and other sustained loads shall not exceed S_h. This requirement is satisfied by meeting Equation (8), NC-3652.1.

(c) Service Conditions. Service Conditions include Normal Conditions and shall include Upset, Emergency, Faulted, and Test Conditions. The following stress limits shall apply to Service Conditions.

(1) Normal Conditions. The stress range due to thermal expansion shall not exceed S_A, or the sum of stresses due to internal pressure, weight, other sustained loads, and the stress range due to thermal expansion shall not exceed the sum of S_A and S_h. This requirement is satisfied by meeting Equations (10) or (11), NC-3652.3.

(2) Upset Conditions. The sum of stresses due to internal pressure, live and dead load, and those due to occasional loads such as wind or earthquake identified in the Design Specification as acting during the Upset Condition shall not exceed 1.2 times the allowable stress value, S_h. This requirement is satisfied by meeting Equation (9), NC-3652.2. During Upset Conditions, the peak pressure, P_{max}, alone shall not exceed 1.1 times the pressure, P, calculated in accordance with Equation (4), NC-3641.1. The stress range due to thermal expansion shall not exceed S_A, or the sum of stresses due to internal pressure, weight, other sustained loads, and the stress range due to thermal expansion shall not exceed the sum of S_A and S_h. This requirement is satisfied by meeting Equations (10) or (11), NC-3652.3.

(3) Emergency Conditions. The sum of stresses due to internal pressure, live and dead load, and those due to occasional loads identified in the Design Specifications as acting during the Emergency Condition shall not exceed 1.8 times the allowable stress, S_h. This requirement is satisfied by meeting Equation (9), NC-3652.2, using a stress limit of 1.8 S_h in lieu of 1.2 S_h. During Emergency Conditions,

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TABLE NC-3611.2(e)-1
STRESS RANGE REDUCTION FACTORS

Number of Equivalent Full Temperature Cycles, N	f
7,000 and less	1.0
7,000 to 14,000	0.9
14,000 to 22,000	0.8
22,000 to 45,000	0.7
45,000 to 100,000	0.6
100,000 and over	0.5

the peak pressure, P_{max}, alone shall not exceed 1.5 times the pressure, P, calculated in accordance with Equation (9), NC-3641.1.

(4) Faulted Conditions. The sum of stresses due to internal pressure, live and dead load, and those due to occasional loads identified in the Design Specification as acting during the Faulted Condition shall not exceed 2.4 times the allowable stress, S_h. This requirement is satisfied by meeting Equation (9), NC-3652.2, using a stress limit of 2.4 S_h in lieu of 1.2 S_h. During Faulted Conditions, the peak pressure, P_{max}, alone shall not exceed 2.0 times the pressure, P, calculated in accordance with Equation (4), NC-3641.1.

(5) Test Conditions. Testing shall be in accordance with NC-6000. Occasional loads shall not be considered as acting at time of test.

(d) External Pressure Stress. Piping subject to external pressure shall meet the requirements of NC-3641.2.

(e) Allowable Stress Range for Expansion Stresses. The allowable stress range, S_A, is given by Equation (1):

$$S_A = f\,(1.25\ S_c + 0.25\ S_h) \qquad (1)$$

where

S_c = basic material allowable stress at minimum (cold) temprature, psi

S_h = basic material allowable stress at maximum (hot) temperature, psi

f = stress range reduction factor for cyclic conditions for total number, N, of full temperature cycles over total number of years during which system is expected to be in operation from Table NC-3611.2(e)-1.

(1) In determining the basic material allowable stresses, S_c and S_h, joint efficiencies need not be applied.

(2) Stress reduction factors apply essentially to noncorrosive service and to corrosion resistant materials, where employed to minimize the reduction in cyclic life caused by corrosive action.

(3) If the range of temperature change varies, equivalent full temperature cycles may be computed as follows:

$$N = N_E + r_1^5 N_1 + r_2^5 N_2 + \ldots . r_n^5 N_n \qquad (2)$$

where

N_E = number of cycles at run temperature change, ΔT_E, for which expansion stress, S_E, has been calculated

$N_1, N_2, \ldots . N_n$ = number of cycles at lesser temperature changes, ΔT_1, $\Delta T_2, \ldots . \Delta T_n$

$r_1, r_2, \ldots . r_n$ = $(\Delta T_1)/(\Delta T_E)$, $(\Delta T_2)/(\Delta T_E)$, $\ldots .\ (\Delta T_n)/(\Delta T_E)$

= the ratio of any lesser temperature cycles for which the expansion stress, S_L, has been calculated.

(f) Allowable Stress for Nonrepeated Stresses. The allowable stress due to any single nonrepeated anchor movement (e.g., predicted building settlement) calculated in accordance with Equation (10a) of NC-3652.3(b) shall be 3.0 S_c.

NC-3612 Pressure-Temperature Ratings for Piping Products

NC-3612.1 Piping Products Having Specific Ratings W76

(a) Pressure-temperature ratings for certain piping products have been established and are contained in some of the standards listed in Table NC-3132-1. The pressure ratings at the corresponding temperatures given in the standards listed in Table NC-3132-1 shall not be exceeded and piping products shall not be used at temperatures in excess of those given in Tables I-7.0 for the materials of which the products are made.

(b) Where piping products have established pressure-temperature ratings which do not extend to the upper material temperature limits permitted by this Subsection, the pressure-temperature ratings between those established and the upper material temperature limit may be determined in accordance with the rules of this Subsection.

NC-3612.2 Piping Products Not Having Specific Ratings. Should it be desired to use methods of manufacture or design of piping products not now

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ARTICLE NC-3000
DESIGN

NC-3100 GENERAL DESIGN

NC-3110 LOADING CRITERIA

W75 **NC-3111 Loading Conditions**

The loadings that shall be taken into account in designing a component shall include, but are not limited to, those of (a) through (g) below:

(a) internal and external pressure;

(b) impact loads, including rapidly fluctuating pressures;

(c) weight of the component and normal contents under operating or test conditions, including additional pressure due to static and dynamic head of liquids;

(d) superimposed loads such as other components, operating equipment, insulation, corrosion resistant or erosion resistant linings and piping;

(e) wind loads, snow loads, vibrations and earthquake loads where specified;

(e) reactions of supporting lugs, rings, saddles or other types of supports;

→ *(g)* temperature effects.

NC-3112 Design Conditions

The components shall be designed in accordance with the Owner's Design Specification (NA-3250).

NC-3112.1 Design Pressure.[1] Components shall be designed for at least the most severe condition of coincident pressure and temperature expected in normal operation. For this condition, the maximum difference in pressure between the inside and outside of a component or between any two chambers of a combination unit shall be considered.

NC-3112.2 Design Temperature

(a) The temperature used in design shall be not less than the mean metal temperature, through the thickness expected under operating conditions for the part considered. If necessary, the metal temperature shall be determined by computation using accepted heat transfer procedures or by measurement from equipment in service under equivalent operating conditions. In no case shall the temperature at the surface of the metal exceed the maximum temperature listed in Tables I-7.0 nor exceed the temperature limitations specified elsewhere in this Subsection.

(b) When the occurrence of different metal temperatures during operating can be definitely predicted for different zones of a component the design of the different zones may be based on their predicted temperatures. When sudden cyclic changes in temperature are expected to occur in normal operation with only minor pressure fluctuations, the design shall be governed by the highest or lowest probable operating metal temperature and the corresponding pressure.

NC-3112.3 Design Mechanical Loads. The specific combinations and values of mechanical loads which must be considered in conjunction with the design pressure and design temperature shall be those identified in the Design Specifications and designated as the Design Mechanical Loads. The requirements of (a), (b), and (c) below shall also apply.

(a) Impact forces caused by either external or internal conditions shall be considered.

(b) The effects of earthquake shall be considered in the design of components, component supports and restraints. The stresses resulting from these earthquake effects shall be included with pressure or other applied loads.

(c) Components shall be arranged and supported so that vibration will be minimized.

NC-3112.4 Design Allowable Stress Values

(a) Allowable stresses for design for materials are listed in Tables I-7.0. The materials shall not be used at metal and design temperatures above those for

[1]It is recommended that a suitable margin be provided above the pressure at which the vessel will normally be operated to allow for probable pressure surges in the vessel up to the setting of the pressure relieving devices (NC-7500).

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either the S_f plot defined in NC-3649.4(d) or the curve consistent with NC-3649.4(e)(2) or (3). If the fatigue curve has been developed based on a total stress difference, then the full value of $S_1, S_2, \ldots S_n$, of Step 1 must be used to determine N; however, if the curve is based on an alternating stress, then the values $S_1, S_2, \ldots S_n$ become the alternating stresses.

Step 3: For each type of stress cycle, calculate the usage factors, $U_1, U_2, \ldots U_m$ from $U_1 = n_1/N_1$, $U_2 = n_2/N_2$, etc.

Step 4: Calculate the cumulative usage factor, U, from $U = U_1 + U_2 + \ldots U_n$

Step 5: The cumulative usage factor, U, shall not exceed 1.0.

(h) The Manufacturer shall submit a report which demonstrates compliance with NC-3649.

(i) Where necessary to carry the pressure, the cylindrical ends of the bellows may be reinforced by suitable collars. The design method used to assure that the stresses generated will not cause premature failure of the bellows material or weldment shall include the attachment weld between the bellows and end connections.

(j) The spring rates of the expansion joint assembly shall be provided by the Manufacturer. The spring rates of a bellows can be defined by several methods due to the hysteresis loop which can occur during deflection; a restoring force may be required to return the bellows to the original neutral position after deflection. When applicable, the Design Specifications shall state the maximum allowable force that can be imposed on the connecting parts or shall require the Manufacturer to determine the maximum force necessary to deflect the bellows a given distance, such as the maximum movement to be absorbed.

NC-3650 ANALYSIS OF PIPING SYSTEMS

NC-3651 General Requirements[1]

S75 W75 *(a)* The design of the complete piping system shall be analyzed between anchors for the effects of thermal expansion, weight, and other sustained and occasional loads. The system design shall meet the limits of NC-3650. The pressure portion of Equations (8), (9), and (11) may be replaced with the expression

$$S_{LP} = \frac{Pd^2}{D_o^2 - d^2}$$

where the terms are the same as in NC-3652 except:

$P = P$ or P_{max}

$d =$ nominal inside diameter of pipe, in.

(b) When evaluating stresses in the vicinity of expansion joints, consideration must be given to actual cross-sectional areas that exist at the expansion joint.

NC-3652 Consideration of Design Conditions

NC-3652.1 Sustained Loads. The effects of pressure, weight and other sustained mechanical loads must meet the requirements of Equation (8).

$$S_{SL} = \frac{PD_o}{4t_n} + \frac{0.75iM_A}{Z} \leqslant 1.0S_h \qquad (8)$$

$P =$ internal design pressure, psi

$D_o =$ outside diameter of pipe, in.

$t_n =$ nominal wall thickness, in.

$M_A =$ resultant moment loading on cross section due to weight and other sustained loads, in. lb (NC-3652.4)

$Z =$ section modulus of pipe, in.^{3} (See NC-3652.4)

$i =$ stress intensification factor (NC-3673.2(b)). The product of $0.75i$ shall never be taken as less than 1.0.

$S_h =$ basic material allowable stress at design temperature

NC-3652.2 Occasional Loads.[2] The effects of pressure, weight, other sustained loads, and occasional loads, including earthquake, must meet the requirements of Equation (9). W75 W76

$$S_{OL} = \frac{P_{max}D_o}{4t_n} + 0.75i\left(\frac{M_A + M_B}{Z}\right) \leqslant 1.2S_h \quad (9)$$

Terms same as in NC-3652.1 except:

$P_{max} =$ peak pressure, psi

$M_B =$ resultant moment loading on cross section due to occasional loads, such as thrusts from relief and safety valve loads from pressure and flow transients, and earthquake, if the Design Specifications require calculation of moments due to earthquake. For earthquake, use only one-half the range. Effects of anchor displacement due to earthquake may be excluded from Equation (9) if they are included in Equations (10) and (11) (NC-3652.3).

→ **NC-3652.3 Thermal Expansion.** The requirements of either Equation (10) or Equation (11) must be met.

[1]The pressure term in Equations (8), (9) and (11) may not apply for bellows and expansion joints.

[2]Design pressure may be used if the Design Specification states that peak pressure and earthquake need not be taken as acting concurrently.

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(a) The effects of thermal expansion must meet the requirements of Equation (10).

$$\frac{iM_C}{Z} \leq S_A \qquad (10)$$

Terms same as above except:

M_C = range of resultant moments due to thermal expansion. Also include moment effects of anchor displacements due to earthquake if anchor displacement effects were omitted from Equation (9) (NC-3652.2)

S_A = allowable stress range for expansion stresses (NC-3611.2)

W76 *(b)* The effects of any single nonrepeated anchor movements shall meet the requirements of Equation (10a).

$$\frac{iM_D}{Z} \leq 3.0\ S_c \qquad (10a)$$

Terms same as in NC-3652.1 except:

M_D = resultant moment due to any single nonrepeated anchor movement (e.g., predicted building settlement)

W76 *(c)* The effects of pressure, weight, other sustained loads and thermal expansion shall meet the requirements of Equation (11).

$$S_{TE} = \frac{PD_o}{4t_n} + 0.75i\left(\frac{M_A}{Z}\right) + i\left(\frac{M_C}{Z}\right) \leq (S_h + S_A) \quad (11)$$

NC-3652.4 Determination of Moments and Section Modulus

W76 *(a)* For purposes of Equations (8), (9), (10), and (11), the resultant moment for straight-through components, curved pipe, or welding elbows may be calculated as follows:

Determine resultant moment:

$$M_j = [M_{xj}^2 + M_{yj}^2 + M_{zj}^2]^{1/2}$$

where

$j = A, B, C,$ or D which are the subscripts of M_A, M_B, M_C, M_D defined in NC-3652.1, NC-3652.2, and NC-3652.3

(b) For purposes of Equations (8), (9), (10), and (11), the section modulus for straight through components, curved pipe, welded elbows, or full outlet branch connections may be calculated as follows:

$$Z = \pi r^2 t_n$$

where

r = mean cross sectional radius, in.

t_n = nominal wall thickness, in.

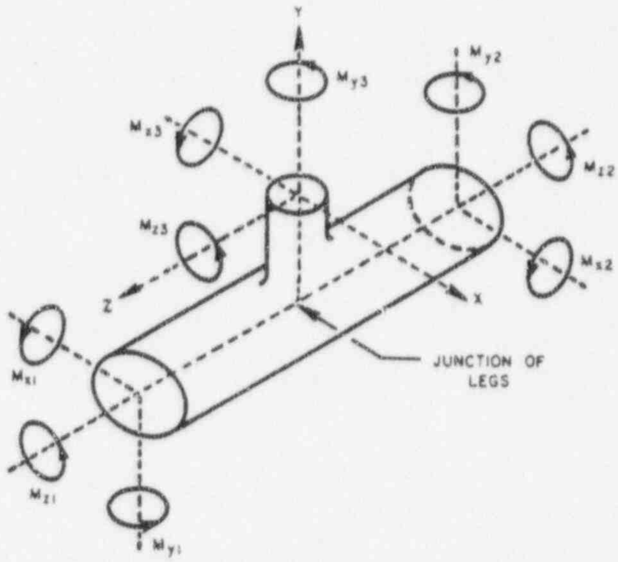

FIG. NC-3652.4-1 REDUCING OR FULL OUTLET BRANCH CONNECTIONS OR TEES

(c) For full outlet branch connections, calculate the resultant moment of each leg separately in accordance with (a) above. Moments are to be taken at the junction point of the legs (Fig. NC-3652.4-1).

(d) For reduced outlets, calculate the resultant moment of each leg separately in accordance with (a) above. Moments are to be taken at the junction point of the legs (Fig. NC-3652.4-1). W75 W76

For the reduced outlet branch:

$$M_A, M_B, M_C, M_D = \sqrt{M_{x3}^2 + M_{y3}^2 + M_{z3}^2}$$

and

$Z = \pi r'_m{}^2 t_s$

r_m' = branch mean cross-sectional radius, in.

t_s = effective branch wall thickness, in.
= lesser of T_r or iT_b

T_b = nominal branch wall thickness, in.

T_r = nominal wall thickness of run pipe, in.

NC-3660 DESIGN OF WELDS

NC-3661 Welded Joints

NC-3661.1 General Requirements. Welded joints may be used in accordance with the requirements of NC-4200.

NC-3661.2 Socket Welds

(a) Socket welded piping joints shall be limited to pipe sizes of 2 in. and less.

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W81 *(c) Service Loadings.* The following service limits shall apply to Service Loadings as designated in the Design Specifications.

W82 *(1) Level A and B Service Limits.* The stress range due to thermal expansion shall not exceed S_A, or the sum of stresses due to internal pressure, weight, other sustained loads, and the stress range due to thermal expansion shall not exceed the sum of S_A and S_h. This requirement is satisfied by meeting Eq. (10) or (11), NC-3653.2. In addition, for Service Loadings for which Level B Service Limits are designated in the Design Specification, the sum of stresses due to internal pressure, live and dead load, and those due to occasional loads such as wind or earthquake shall meet the requirements of NC-3653.1. When Level B Limits apply, the peak pressure $P_{max.}$ alone shall not exceed 1.1 times the pressure P calculated in accordance with Eq. (5), NC-3641.1.

(2) Level C Service Limits. For Service Loadings for which Level C Service Limits are designated in the Design Specification, the sum of stresses due to internal pressure, live and dead load, and those due to occasional loads shall meet the requirements of NC-3654. When Level C Limits apply, the peak pressure $P_{max.}$ alone shall not exceed 1.5 times the pressure P calculated in accordance with Eq. (5), NC-3641.1.

(3) Level D Service Limits. For Service Loadings for which Level D Service Limits are designated in the Design Specification, the sum of stresses shall meet the requirements of NC-3655. When Level D Limits apply, the peak pressure $P_{max.}$ alone shall not exceed 2.0 times the pressure P calculated in accordance with Eq. (5), NC-3641.1. As an alternative, the rules of Appendix F may be used in evaluating those Service Loadings independently of all other Design and Service Loadings.

(4) Test Conditions. Testing shall be in accordance with NC-6000. Occasional loads shall not be considered as acting at time of test.

(d) External Pressure Stress. Piping subject to external pressure shall meet the requirements of NC-3641.2.

(e) Allowable Stress Range for Expansion Stresses. The allowable stress range S_A is given by Eq. (1):

$$S_A = f\,(1.25\,S_c + 0.25\,S_h) \qquad (1)$$

TABLE NC-3611.2(e)-1
STRESS RANGE REDUCTION FACTORS

Number of Equivalent Full Temperature Cycles N	f
7,000 and less	1.0
7,000 to 14,000	0.9
14,000 to 22,000	0.8
22,000 to 45,000	0.7
45,000 to 100,000	0.6
100,000 and over	0.5

where

S_c = basic material allowable stress at minimum (cold) temperature, psi

S_h = basic material allowable stress at maximum (hot) temperature, psi

f = stress range reduction factor for cyclic conditions for total number N of full temperature cycles over total number of years during which system is expected to be in service from Table NC-3611.2(e)-1

(1) In determining the basic material allowable stresses S_c and S_h, joint efficiencies need not be applied.

(2) Stress reduction factors apply essentially to noncorrosive service and to corrosion resistant materials, where employed to minimize the reduction in cyclic life caused by corrosive action.

(3) If the range of temperature change varies, equivalent full temperature cycles may be computed as follows:

$$N = N_E + r_1^5 N_1 + r_2^5 N_2 + \ldots + r_n^5 N_n \qquad (2)$$

where

N_E = number of cycles at run temperature change ΔT_E for which expansion stress S_E has been calculated

$N_1, N_2, \ldots, N_n$ = number of cycles at lesser temperature changes, $\Delta T_1, \Delta T_2, \ldots, \Delta T_n$

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temperature condition expected to be produced by heat exchangers in that section.

NC-3613 Allowances

NC-3613.1 Corrosion or Erosion. When corrosion or erosion is expected, the wall thickness of the piping shall be increased over that required by other design requirements. This allowance shall be consistent with the specified design life of the piping.

NC-3613.2 Threading and Grooving. The calculated minimum thickness of piping that is to be threaded or grooved shall be increased by an allowance equal to the depth of the cut.

NC-3613.3 Mechanical Strength. When necessary to prevent damage, collapse, or buckling of pipe due to superimposed loads from supports or other causes, the wall thickness of the pipe shall be increased, or, if this is impractical or would cause excessive local stresses, the superimposed loads or other causes shall be reduced or eliminated by other design methods.

NC-3613.4 Steel Casting Quality Factors. The quality factors for castings required in Tables 1A, 1B, and 3, Section II, Part D, Subpart 1 apply to castings which are designed using the stresses contained in this Subsection. The minimum examination required for these castings is that stipulated in the applicable material specification and in NC-2570. Castings satisfying these minimum requirements shall be designed with a quality factor of 1.00.

NC-3620 DESIGN CONSIDERATIONS

NC-3621 Design and Service Loadings

The provisions of NC-3110 shall apply, except as modified in this Subarticle.

NC-3621.1 Cooling Effects on Pressure. When the cooling of a fluid may reduce the pressure in the piping to below atmospheric, the piping shall be designed to withstand the external pressure or provision shall be made to break the vacuum.

NC-3621.2 Fluid Expansion Effects. When the expansion of a fluid may increase the pressure, the piping system shall be designed to withstand the increased pressure or provision shall be made to relieve the excess pressure.

NC-3622 Dynamic Effects

NC-3622.1 Impact. Impact forces caused by either external or internal loads shall be considered in the piping design.

NC-3622.2 Earthquake. The effects of earthquake shall be considered in the design of piping, piping supports, and restraints. The loadings, movements, including earthquake anchor movements, and number of cycles to be used in the analysis shall be part of the Design Specifications. The stresses resulting from these earthquake effects must be included with weight, pressure, or other applied loads when making the required analysis.

NC-3622.3 Vibration. Piping shall be arranged and supported so that vibration will be minimized. The designer shall be responsible, by design and by observation under startup or initial service conditions, for ensuring that vibration of piping systems is within acceptable levels.

NC-3622.4 Exposed Piping. Exposed piping shall be designed to withstand wind loadings, using meteorological data to determine wind forces. When State, Province, or Municipal ordinances covering the design of building structures are in effect and specify wind loadings, these values shall be considered the minimum design values. However, it is not necessary to consider earthquake and wind loadings to be acting concurrently.

NC-3622.5 Relief and Safety Valve Thrust. The effects of thrusts from relief and safety valve loads from pressure and flow transients shall be considered in the design of piping, pipe supports, and restraints. See Appendix O. ←

NC-3623 Weight Effects

Piping systems shall be supported to provide for the effects of live and dead weights, as defined in the following subparagraphs, and they shall be arranged or properly restrained to prevent undue strains on equipment.

NC-3623.1 Live Weight. The live weight shall consist of the weight of the fluid being handled or of the fluid used for testing or cleaning, whichever is greater.

NC-3623.2 Dead Weight. The dead weight shall consist of the weight of the piping, insulation, and other loads permanently imposed upon the piping.

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temperature condition expected to be produced by heat exchangers in that section.

NC-3613 Allowances

NC-3613.1 Corrosion or Erosion. When corrosion or erosion is expected, the wall thickness of the piping shall be increased over that required by other design requirements. This allowance shall be consistent with the specified design life of the piping.

NC-3613.2 Threading and Grooving. The calculated minimum thickness of piping that is to be threaded or grooved shall be increased by an allowance equal to the depth of the cut.

NC-3613.3 Mechanical Strength. When necessary to prevent damage, collapse, or buckling of pipe due to superimposed loads from supports or other causes, the wall thickness of the pipe shall be increased, or, if this is impractical or would cause excessive local stresses, the superimposed loads or other causes shall be reduced or eliminated by other design methods.

NC-3613.4 Steel Casting Quality Factors. The quality factors for castings required in Tables 1A, 1B, and 3, Section II, Part D, Subpart 1 apply to castings which are designed using the stresses contained in this Subsection. The minimum examination required for these castings is that stipulated in the applicable material specification and in NC-2570. Castings satisfying these minimum requirements shall be designed with a quality factor of 1.00.

NC-3620 DESIGN CONSIDERATIONS

NC-3621 Design and Service Loadings

The provisions of NC-3110 shall apply, except as modified in this Subarticle.

NC-3621.1 Cooling Effects on Pressure. When the cooling of a fluid may reduce the pressure in the piping to below atmospheric, the piping shall be designed to withstand the external pressure or provision shall be made to break the vacuum.

NC-3621.2 Fluid Expansion Effects. When the expansion of a fluid may increase the pressure, the piping system shall be designed to withstand the increased pressure or provision shall be made to relieve the excess pressure.

NC-3622 Dynamic Effects

NC-3622.1 Impact. Impact forces caused by either external or internal loads shall be considered in the piping design.

NC-3622.2 Reversing Dynamic Loads. Reversing dynamic loads are those loads which cycle about a mean valve and include building filtered loads, earthquake, and the reflected waves in a piping system due to flow transients resulting from sudden opening or closure of valves (see Fig. NC-3622-1). A reversing dynamic load shall be treated as a nonreversing dynamic load in applying the rules of NC-3600 when either of the following conditions exist: A94

(a) The frequency ratio of the dynamic dominant load driving frequency to the lowest piping system natural frequency is less than 0.5.

(b) The number of reversing dynamic load cycles, exclusive of earthquake, exceed 20.

NC-3622.3 Vibration. Piping shall be arranged and supported so that vibration will be minimized. The designer shall be responsible, by design and by observation under startup or initial service conditions, for ensuring that vibration of piping systems is within acceptable levels.

NC-3622.4 Exposed Piping. Exposed piping shall be designed to withstand wind loadings, using meteorological data to determine wind forces. When State, Province, or Municipal ordinances covering the design of building structures are in effect and specify wind loadings, these values shall be considered the minimum design values. However, it is not necessary to consider earthquake and wind loadings to be acting concurrently.

NC-3622.5 Nonreversing Dynamic Loads. Nonreversing dynamic loads are those loads which do not cycle about a mean value and include the initial thrust force due to sudden opening or closure of valves and waterhammer resulting from entrapped water in two-phase flow systems (see Fig. NC-3622-1). A94

NC-3623 Weight Effects

Piping systems shall be supported to provide for the effects of live and dead weights, as defined in the following subparagraphs, and they shall be arranged or properly restrained to prevent undue strains on equipment.

NC-3623.1 Live Weight. The live weight shall consist of the weight of the fluid being handled or of the fluid used for testing or cleaning, whichever is greater.

NC-3623.2 Dead Weight. The dead weight shall consist of the weight of the piping, insulation, and other loads permanently imposed upon the piping.

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