A main objective of the SMR-160 design was to eliminate large bore piping. To achieve this objective the Reactor Pressure Vessel (RPV) and the Steam Generator (SG) had to be brought sufficiently close together to allow them to be joined without any intervening piping. This objective is met by utilizing an innovative reverse flange design for the RPV closure, which has been disclosed as patent No. US 10,665,357 B2.

The forging which connects the RPV and the SG, referred to as the Planar Inter-vessel Forging (PIF), is welded to the RPV shell and SG bottom head forming the "RPV/SG Connection". Classifying the PIF and the forgings that constitutes the SG Riser as pipes is inappropriate on both technical and regulatory grounds. The reasoning is explained in detail for the PIF in the attached Holtec Position Paper. A similar argument applies to the SG Riser, which is a cylindrical forging constructed in the same manner as an RPV in presently operating Pressurized Water Reactors (PWR).

The Combined Vessel is made up of the RPV, the reactor coolant pressure boundary (RCPB) of the SG, and the integral pressurizer. Holtec understands that the Staff needs additional information to concur with Holtec's designation of the Combined Vessel, being fully constructed in accordance with the ASME BPV Code Section III, Subsection NB, Class 1 Vessels, is in fact a vessel without any interconnecting piping. We respectfully submit that the Staff's allusion to Paragraph U-1(c)(2) of Section VIII of the ASME BPV Code, Section VIII-1 (a commercial service pressure vessel code) which refers to piping in colloquial terms, is technically non-rigorous and inapplicable. Further, the Staff's quoted material is not a definition, rather a set of descriptive words used to delineate the scope of treatment by that Code.

While it is true that reactor coolant flows through the Combined Vessel and the *interconnecting nozzles*, the nozzles are defined as belonging to the jurisdictional boundary of the pressure vessel. In particular, the nozzles are emphatically not considered a piping even though the fluid flows through them. Thus, it can be readily concluded that fluid flow inside a part does not render it into being piping. Furthermore, the primary safety function of the Combined Vessel is to maintain the Reactor Coolant Pressure Boundary (RCPB). The PIF and SG Riser are integral parts of the Combined Vessel, as they provide the needed reinforcement to the openings (which are regions of reduced structural strength) per ASME BPV, Section III, Article NB-3334. The Code has an appropriate term for such integral appurtenances which is "Communicating Chamber" as set down in ASME B&PV Code Section III, Subsection NB, Subarticle 3350. The above mentioned code paragraph defines communicating chambers as portions of the vessel which intersect the shell or heads of a vessel and form an integral part of the pressure-retaining closure.

Holtec agrees that in 1972 the Commission stated that protection against pressure vessel failures is subject to the licensing process *if there are special considerations present or special safety significance* (USNRC Docket 50-247, In the Matter of Consolidated Edison Company of New York (Indian Point Unit No.2) Memorandum and Order, October 26, 1972).

The Atomic Safety and Licensing Board in its 1973 decision to grant Indian Point Unit No. 2 the approval to operate at full power (LBP-73-33, September 25, 1973) also reiterated,

> "Although the potential consequences of a pressure vessel failure at the Indian Point site might be greater than for other sites that have been approved, the term 'special safety significance' generally refers to considerations directed to the design, mode of manufacture and proposed limits of operation of the reactor

> vessel. The intervenor CCPE did not contend that any features of the reactor vessel or of other parts of the plant or of their construction or operation might increase the likelihood of failure of the vessel or the consequences of such a failure. The Board, however, examined the evidence submitted by Applicant in response to the Board's inquiries related to the design, fabrication, and testing of the reactor vessel for Unit No. 2. On the basis of all the evidence, the Board finds that the reactor vessel for Unit No. 2 was designed and constructed and will be operated in accordance with the requirements of the rules and regulations of the Commission and that there is reasonable assurance that it can be operated without undue risk to the health and safety of the public."

Further, on April 4, 1974, the Atomic Safety and Licensing Appeal Board further upheld the Atomic Safety and Licensing Board's September 25, 1973, decision, stating:

> "It would appear that the term "special safety significance" as used by the Commission referred to such matters as design, mode of manufacture and proposed limits of operation of the reactor vessel."

Based on the above rulings, Holtec submits that by designing, constructing, and operating a pressure vessel in accordance with the requirements of the rules and regulations of the Commission there are no special considerations or matters of special safety significance, and there is reasonable assurance that such a pressure vessel can be operated without undue risk to the public.

The Combined Vessel, like all nuclear RPVs, will be designed, constructed, and inspected within the requirements of the rules and regulations of the Commission as indicated in Section 3.2 of the Topical Report. The Combined Vessel will also be operated well within its design limits, which are typical of existing PWRs operating in the United States today. In Topical Report HI-2201064, Holtec imposed additional conservatism on the RPV/SG Connection, beyond the Code limits, for primary and secondary stress intensities and the cumulative damage factor for cyclic fatigue. As part of this RAI response (see item 7) additional conservatism will be added to the SG Riser as well. On this basis alone it should be sufficient to determine that the likelihood of failure of the Combined Vessel, in any location, is at least equivalent to, but more likely less than, a rupture of a RPV in a currently operating PWR. Therefore, it is appropriate to conclude that there is no special safety significance associated with the proposed design embodiments.

The Staff has indicated that 10 CFR 50 Appendix A, General Design Criterion (GDC) 35, "Emergency Core Cooling," 10 CFR 50.46, and 10 CFR 100.21 apply. Holtec agrees that these will apply in the SMR-160 design for postulated piping breaks which result in a loss of coolant accident as discussed in Section 3.5 of the Topical Report. It is apparent from the proceedings above that postulation of a rupture of pressure vessels in PWRs has never been required by the Commission. The Staff states the practice for "designing the emergency core cooling systems (ECCS) in operating PWRs considering the largest pipe break in the RCS results in the design having an ECCS capability and capacity that can well exceed most failure mechanisms of a reactor vessel"; however, there is no specific evidence that the ECCS would mitigate a rupture of the RPV in current PWR, nor is there any regulation requiring it.

Holtec posits GDC 14, “Reactor Coolant Pressure Boundary”, GDC 30, “Quality of reactor coolant pressure boundary”, and GDC 31, “Fracture prevention of reactor coolant pressure boundary”, are applicable to the Combined Vessel and its resistance to failure. By following the ASME BPV Code, as required by 10 CFR 50.55a, with added conservatism as discussed later, the Combined Vessel meets GDC 14. To meet GDC 30, the Combined Vessel will be designed, fabricated, erected, and tested to the highest quality standards practical and monitoring systems, in accordance with guidance in Regulatory Guide 1.45, will be employed to detect if there is any leakage from the RCPB. This will provide an early indication that an adverse condition exists in the RCPB. This is current practice in operating PWRs and the ability to detect a leak reduces the probability of a rupture occurring in the Combined Vessel. The SMR-160 design requirements listed in Section 3.2 of the Topical Report relating to fracture toughness ensure GDC 31 will be met. The analysis that demonstrates GDC 31 will be met will be provided in a future licensing application. Meeting these three GDCs will ensure the likelihood of failure of the Combined Vessel is very low, such that postulation of a rupture anywhere in the Combined Vessel should not be considered as a Design Basis Accident.

We do believe that it is incumbent on us as the designer to demonstrate that the Combined Vessel does not suffer from any intrinsic vulnerability that may cause it to fail under the credible loads it may encounter during its design life. By utilizing massive forgings rather than pipes we have successfully eliminated degradation effects resulting from low frequency vibrations. The failure from overstress, brittle fracture, fatigue, and other transient loadings must and will be answered by rigorous analysis, consistent with the American Society of Mechanical Engineers Boiler and Pressure Vessel Code (hereafter referred to as the “Code”) requirements as part of a future licensing application. The information provided in these responses to the nine questions in the RAI provides our basis for concluding that a break in the Combined Vessel will have a very low probability of occurrence at least equivalent to current PWRs and likely lower.

1. **Degradation mechanisms:**
   All potential unusual operating conditions which could contribute to degradation or failure or any degradation mechanism, including environmental conditions of the Combined Vessel and weld locations, that could compromise its structural integrity will be addressed as part of a future licensing application wherein the applicant will propose the ASME Service Level Transients and consequent loads and load combinations with appropriately specified design and service limits. This analysis will provide a complete basis for the design of the RCPB for all conditions and events expected over the service lifetime of the plant. The design transients define thermal-hydraulic conditions and bounding thermal-hydraulic design transients are defined for the components of the RCPB. The number of cycles for each design transient is based on the plant’s operating life.

   However, it is relevant ahead of this future analysis, to consider the facts that make SMR-160 inherently safe against some of the degradation mechanisms specified in the RAI, for example:

   a. *Thermal Stratification:* The Reynolds number of the primary coolant in the Combined Vessel is in the turbulent range during power operations. Because the flow is turbulent, adverse conditions such as laminar flow and thermal stratification are not possible. During heat up and cooldown operations (at the beginning and end of each fuel cycle) a small pump is used to enhance flow to ensure turbulence to ensure these adverse conditions are not present.

b. *Vibrations:* The flow in the RCS during full power operations is propelled by natural circulation; there is no forced flow driven by a pump. Although the flow is turbulent, the level of turbulence in SMR-160 is less than 15% of that in a typical forced flow pressurized water reactor (PWR). Because the propensity for mechanical vibrations rises rapidly with the coincident flow velocity, the structures within SMR-160 are substantially better protected from flow induced vibrations than the current PWR operating fleet.

c. *Water hammer:* Water and steam hammer loads primarily affect piping. Pressure waves are created when the flow of fluid in a piping system is abruptly altered. This can be initiated by mechanisms such as rapid valve actuation, pumps starting, or the collapsing of steam voids. If water or steam hammer loads are credible and significant, they will be included in the analysis. However, these loads are not expected to be the limiting loads on the welds or forgings of the Combined Vessel.

d. *Thermal transients in the Combined Vessel wall:* The flow in the RCS during full power operations is propelled by natural circulation; there is no forced flow driven by a pump. As a result, there is a lower surface film coefficient on the Reactor Coolant Pressure Boundary (RCPB). A lower surface film coefficient inherently reduces the severity of the effects of thermal transients on the Combined Vessel walls by reducing the rate of heat transfer between the be primary coolant and the Combined Vessel. Thus, the SMR-160 RCPB has a better margin of safety under thermal transients than in a forced flow PWR. [[

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e. *Corrosion effects:* [[ ]] made of a corrosion-resistant alloy , mentioned above, adds an extra layer of protection of the RCPB from corrosion in the locations where it is employed. Furthermore, all materials used in the RCPB will be Code Section II materials that have decades long, unblemished history of performance in PWRs. Table 1 has a list of the Code Section II materials that have been selected for the SMR-160 RCPB. The pressure, temperature, and soluble boron concentration of the primary coolant are also well inside the range of the proven performance of the proposed materials. Primary chemistry will be controlled to minimize corrosion using operating experience from current operating PWRs.

f. *Protection from cyclic fatigue:* Cyclic fatigue is the thermal transient that arises from the temperature change in the primary coolant. Because the temperature of the RCPB metal follows the bulk temperature of the primary coolant, which in turn follows the load on the plant, it is reasonable to expect there will be many thermal cycles in the service life of the SMR-160 plant. It is necessary, therefore, to ensure that the service life of the plant is not limited by cyclic fatigue. Thermal transients in natural circulation systems are less rapid than in forced flow systems and the impact of the thermal transients can be reduced, as discussed above, by using a [[ ]]. The Code fatigue analysis will be performed and submitted as part of the licensing application contemplated for submittal in the near future.

g. *Brittle fracture:* The Combined Vessel will meet the requirements of Code Section III, Subsection NB, Appendix G for fracture toughness. 10 CFR 50 Appendix G is applicable to determine the effects of neutron embrittlement on the materials as well. The PIF, the SG Riser, and their welds will be subject to significantly less neutron flux than the RPV and the RPV welds because of their locations relative to the reactor core, making the probability of brittle fracture in these areas less likely than in the RPV itself.

The necessary analysis and evaluations will be provided by a future applicant to demonstrate that the effects of the above degradation mechanisms (as articulated in the Staff's RAI) on the Combined Vessel are inconsequential.

2. **Experience with combined vessels in the nuclear and other industries:**
Irregularly shaped pressure vessels are commonplace in the chemical and the food industries. The ASME BPV Code, Section III, Subsection NB for Class 1 Vessels describes communicating chambers and the welds which connect them in a manner wholly consistent with the configuration proposed by Holtec for the Combined Vessel. The Combined Vessel will be constructed[1] to the Code without exceptions, therefore although this exact geometry may not have been used in the nuclear industry, it is still a valid configuration within the Code and can be constructed as such. Combined vessels are characterized by having a single operating pressure across them without any valves that may isolate one section from the others. Combined vessels have a single operating pressure but may have different operating temperatures. Examples of combined vessels abound in the process industry: for example, the distillation column and the knock-back condenser in the food industry is a "combined vessel". In the nuclear industry, the typical assemblage of the RPV, the primary side of the steam generator and the pressurizer constitute a combined vessel. In large PWRs these components must be spaced far apart and therefore require piping to connect them. In the SMR-160, we have successfully located these three components close enough to eliminate the need for any interconnecting piping.

In 2011, Pacific Northwest National Laboratory (PNNL) assessed (in PNNL-20869) a similar arrangement in the high temperature gas reactor (HTGR). It should be noted that the HTGR "cross-duct" is much longer and has a significantly smaller diameter, than the PIF. Notwithstanding the geometry of the "cross-duct", the conclusion by PNNL for the HTGR was that designing the "cross-duct" as a "pipe" is the more appropriate choice but that the ASME BPV code allows the owner of the facility to select the preferred designation, and that either designation can be acceptable.

3. **Materials and construction methods:**
   a. *Materials:* Table 1 provides information on the principal materials utilized in the RCPB. All materials used are listed in Section II of the ASME Code and are acceptable for Section III, Subsection NB, Class 1 construction. They are also qualified for the SMR-160 operating

[1] The term "constructed" in the context of this RAI response and the Topical Report is used as "an all-inclusive term comprising materials, design, fabrication, examination, testing, inspection, and certification required in the manufacture and installation of an item" as defined by the ASME BPV Code.

conditions. The materials chosen are based on lessons learned from the operating experience of the current PWRs and meet established regulatory guidance, as applicable. The material will be compatible with the primary and secondary coolants, as applicable.

All material requires a QA validated Purchase Specification to be developed. For raw materials, the material specification must also include any special requirements imposed in NB-2000 of the Code.

Table 1: Materials for the Combined Vessel	
Item	**ASME Code Designation for the Material**
RPV shell, heads, flanges, Planar Inter-vessel Forging (PIF); SG lower head, tubesheets; Pressurizer shell and head, manway, manway cover, manway diaphragm, manway studs, pressurizer heater nozzles	SA508 Gr3 Cl2
RPV CRDM nozzles	SB-564 UNS N06690
All other RPV nozzles	SA-182 F304
All other Pressurizer nozzles	SA-312 TP304

b. *Heat treatment*: Post-weld heat treatment will follow the ASME Code requirements. The heat treatment requirements in the Code are specified to reduce the residual stresses in weld joints and the heat affected zone (HAZ) to ensure that there is sufficient ductility in the welded region.

c. *Field vs. Shop welding*: The design of the RCPB is guided by three fundamental principles which apply to the Combined Vessel, namely:
   (i) Minimize the number of field welds: In the Combined Vessel there is only one weld required in the field to join the Steam Generator to the Reactor Vessel. This weld is the weld between the PIF and the SG bottom head.
   (ii) Minimize the total number of welds.
   (iii) To the extent possible, avoid locating welds in regions of large discontinuity stresses.

d. *Welds and non-destructive examination*: The welds in the Combined Vessel must meet the provisions in the Code. The requirements on the weld configurations for the Combined Vessel are as follows (note they exceed Code requirements) and will be included in the revised Topical Report:
   (i) Category A and B welds: Double bevel thru-thickness welds; PT of root pass, progressive VT and UT every ½ inch of weld deposit, and final PT and 100% RT of the completed weld.
   (ii) Category C and D welds: Double bevel corner welds with covering fillet weld; PT of root pass, progressive VT and UT every ½ inch of weld deposit, and final PT and 100% UT of the completed weld.

4. Configuration of components and welds:

The figures in Section 3 of the Topical Report show the configuration of the components and welds in the Combined Vessel. The PIF is a monolithic cylindrical forging that is welded to the RPV shell and the bottom head of the SG. The SG Riser is made from monolithic cylindrical forgings that are circumferentially welded together. Neither have longitudinal welds. The SG Riser is supported along its length approximately every two feet by the SG baffle plates.

5. Fracture mechanics analysis and acceptance criteria:

A fracture mechanics analyses will be performed as part of a future licensing application. The acceptance criteria for the welds will ensure that there is sufficient margin to failure should a flaw exist during service.

Controlling hidden flaws and their propagation is an important part of pressure vessel construction. A ¼ inch flaw is well within the detectable range of UT or RT which is prescribed by the Code; therefore, the minimum fracture strength of the Combined Vessel material will be determined for the lowest service temperature of the material with a flaw of ¼ inch adversely orientated to the stress field. These measures will render the potential for a latent flaw and its propagation to an extremely low probability of occurrence.

6. Preservice and in-service inspections:

The pre-service and in-service testing will follow the ASME Code Section III and XI, as applicable. Holtec plans on manufacturing the Combined Vessel and the pre-service inspections for SMR-160 will generally follow a similar evolution that Holtec currently employs in its dry storage and transportation cask manufacturing program with adjustments made to ensure compliance with the appropriate sections of the Code. All tests and inspections are carried out using written procedures by personnel trained and qualified for the specific test or inspection.

The in-service inspection (ISI) of the Combined Vessel must adhere to the stipulations of ASME Section XI. There is access to the welds of the Combined Vessel; and the equipment used to perform these inspections is readily available. The ISI program, as in current practice in the industry, will ensure that during the life of the plant any degradation will be detected and remedied as appropriate.

As discussed earlier, to meet GDC 30 leak detection equipment will be used to identify and address degradation should it develop.

7. Limits on stresses:

All materials and weld materials chosen for the Combined Vessel are required to have a minimum elongation of [[ ]]. This requirement ensures that initiation of cracks have a very low probability of occurrence during operation.

The Topical Report committed to more conservative limits on RPV/SG Connection for the primary and secondary stress intensity limits given in the Code. For the balance of the Combined Vessel, including the SG Riser, additional conservatism, as provided in Table 3 are applied. These will be added to the revised Topical Report. [[

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8. Consideration of Beyond-Design-Basis events:

One of the purposes of the Topical Report is to obtain NRC approval that a postulated break in the Combined Vessel is not postulated as a design basis accident (DBA) and that such event is considered beyond-the-design-basis. Based on the information provided above, Holtec considers that a rupture anywhere in the Combined Vessel will have a very low probability, similar to a rupture of a reactor pressure vessel in currently operating PWRs and therefore, would similarly be considered a beyond design basis accident (BDBA). Initiating events, including different breaks in the Combined Vessel, will be evaluated as part of the Probabilistic Risk Assessment (PRA) protocol which will support the planned licensing application. Sufficient defense-in-depth in the design, operational attributes including leak detection, and processes will also exist such that the consequences to the public and the environment will be very low. With very low probability of occurrence and consequences, the risk to the public is very low providing reasonable assurance of adequate protection of the public and the environment.

As discussed in the Topical Report, the safety systems are redundant and meet the single failure criterion. In addition, during BDBA non-safety systems can be credited along with proceduralized operator action to mitigate the events and address recovery actions. The combination of systems and operator actions further lowers the risk to the public and the environment.

9. Consequences of a SG Riser Failure:

One of the purposes of the Topical Report is to obtain NRC approval that a postulated break in the Combined Vessel, including the SG Riser, is not classified as a DBA. Holtec considers that a rupture anywhere in the Combined Vessel will have a very low probability, similar to or less than a rupture of a reactor pressure vessel in a currently operating PWR and therefore, would similarly be considered a beyond -the-design- basis accident (BDBA). An initiating event in the PRA will be a SG Riser failure. The details of the event and the results of the evaluation will be submitted as part of a future licensing application. Sufficient defense-in-depth in the design, operational attributes including leak detection, and procedures will also exist such that the consequences to the public and the environment will be very low. With very low probability of occurrence and consequences, the risk to the public is very low providing reasonable assurance of adequate protection of the public and the environment.