BACKGROUND INFORMATION FOR

REACTOR VESSEL HEAD VENT OPERATION

REVISION 0

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REACTOR VESSEL HEAD VENT OPERATION

I. GENERAL DISCUSSION

A. Purpose

The operator actions and precautions specified in this guideline are those instructions necessary for the removal of gases from the reactor vessel head by operation of the reactor vessel head vent system.

B. Guideline Assumptions

1. The specific design of the reactor vessel head vent system used in this guideline includes a single connection to the vessel head with redundant flow paths and isolation valves extending from a common line. The common line includes a 7/32" orifice which limits the flowrate to within the makeup capability of the chemical and volume control system. The redundant flow paths discharge to the reactor containment building. Note that those plants which have vent systems installed which vent to the pressurizer or the pressurizer relief tank may desire to modify or make additions to the existing guideline in order to incorporate the plant specific design.

2. Although the guideline does not require a reactor vessel level system it is recommended that any venting operation be performed in conjunction with an accurate vessel level indication for both with and without reactor coolant pump operation. For plants without a level system, the performance of Appendix A, "RCS Gaseous Void Detection and Sizing" may provide an estimate of the total volume of gaseous voids in the RCS (other than the pressurizer).

3. The reactor coolant system can be stabilized with a constant pressurizer level and adequate reactor coolant sub-cooling established. These conditions are required to ensure adequate core-cooling is maintained during the venting period.

4. The pressurizer level and pressure requirements throughout the guideline do not include error allocations due to an adverse containment environment. Therefore, it is assumed that containment temperature is near normal operating conditions.

5. Any venting operation must be performed prior to the initiation of safety injection flow throttling during a POST-LOCA cooldown and depressurization operation. Several guideline actions require the initiation of safety injection if pressurizer level cannot be restored. The POST-LOCA cooldown and depressurization operation begins to throttle safety injection flow and therefore full SI flow could not be delivered to the RCS when required.

6. The head vent system is not designed for and should not be used as the primary means to mitigate an inadequate core cooling event. The vent flowpath is not sized to provide this capability and should only be used in conjunction with the Inadequate Core Cooling Guidelines.

C. Symptoms

The following are symptoms that may indicate the presence of a gaseous void in the reactor coolant system. Note that any one or combination of symptoms may indicate that a void exists.

For Plants with a RV level indication:

1. Reactor vessel level indication <u>less</u> than (plant specific) percent of span. The plant specific value should include an allowance for normal channel accuracy. If the level system does not include a reference leg temperature compensator, then an additional allowance should be included for conditions where the RCS temperature is not equal to the channel calibration temperature.

For Plants with/without a RV level indication:

2. Variations from the normal pressurizer pressure and level response due to normal charging and spraying operations may not be observed if a gaseous void exists in the RCS. The pressurizer level may decrease during a RCS pressurization from charging due to gaseous void contraction and level may rise rapidly during a spraying operation due to a gaseous void expansion.

3. An indication of reactor vessel head temperatures equal to or greater than saturation temperature warrants the presence of a steam bubble being generated in the RCS.

4. Gases in the reactor coolant system may result from several types of plant events. An accumulator tank discharge or a core uncovery may result in non-condensible gases (e.g. nitrogen and hydrogen) being trapped in the RCS. A rapid RCS cooldown may result in the vessel head temperature being greater than the primary saturation temperature and result in a steam bubble being developed. The operator should suspect the presence of gases in the RCS if any of the above events occur.

II. BASIS FOR SUBSEQUENT ACTIONS

The CAUTION preceding Step 1 warns the operator to maintain the existing mode of core cooling during the performance of the subsequent actions. Tripping an operating reactor coolant pump could result in gases in the reactor coolant loops collecting in the steam generator U-tubes and may disturb natural circulation and primary to secondary heat transfer. Starting reactor coolant pumps would disperse any gases already collected in the vessel head and make their removal more difficult. Therefore, the existing status of the reactor coolant pumps should be maintained during the venting operation. If possible and if conditions require so, then a reactor coolant pump should be started following the completion of the venting operation.

The NOTE preceding Step 1 identifies certain steps (marked by an asterisk) which are not applicable if safety injection has been initiated and these steps should be skipped during the venting operation.

1. Once a gaseous void is detected or suspected in the RCS, then any changes being made to the primary system should be terminated and a steady-state condition should be established. This step refers to events like a POST-LOCA cooldown, a normal plant cooldown, or a plant recovery from a design basis event. The intent is to allow the RCS to stabilize so that the size and position of the void can be determined. Note that a normal pressurizer pressure control condition may not be attainable due to the reasons stated in symptom 2.

2. The first action taken to remove any gases from the RCS is to attempt to recombine any condensible gases by increasing RCS pressure. This step may be slow acting and if an upward trend is witnessed on the vessel level indicator then maintain this mode until the head is refilled or the upward trend stops. If this step is successful in filling the head, then return to the appropriate operating instruction. If this step is not successful, then proceed to Step 4.

The CAUTION alerts the operator that charging flow may result in a sudden collapse of steam bubbles in the RCS and cause a rapid decrease in pressurizer level. The level should be restored by increasing the RCS makeup flowrate. If the increased makeup flow fails to restore level then safety injection should be initiated and the operator is to proceed to EOI-0, Immediate Actions and Diagnostics.

3. The venting operation will result in RCS gases being vented to the containment. Therefore the containment purge and exhaust system should be isolated to prevent the release of any radioactive gases to the environment. All available containment air circulation equipment should be started to prevent any hydrogen from forming a gas pocket and to ensure a representative hydrogen concentration is obtained in Step 5.

4. Increasing the reactor coolant sub-cooling 50°F above the minimum plant specific value ensures that reactor coolant sub-cooling will be maintained over the entire range of RCS operating conditions if the venting operation is terminated following a 200 psi decrease in RCS pressure. The preferred method of obtaining the additional sub-cooling is increasing RCS pressure since this will aid in condensing any steam bubbles present. If the additional 50°F sub-cooling is already established then proceed to Step 5.

5. The actions of Appendix B "Venting Time Period" determine the maximum allowable time period for venting which will limit the containment hydrogen concentration to less than 3 volume percent. This limit is required to prevent a potentially explosive hydrogen concentration from being developed inside the containment. (This step may not be applicable for plants which vent to the pressurizer or pressurizer relief tank.)

*6. Pressurizer level is increased to greater than 50% for the purpose of maintaining RCS mass inventory during the venting period. The operator is instructed to isolate letdown in order to obtain the level increase. Letdown will remain isolated until the venting operation is complete.

*7. This step and the following CAUTION warns the operator that RCS pressure will decrease during the venting and if initial pressure is near the low pressure safety injection actuation setpoint, then SI may be automatically initiated during the venting. The operator is instructed to block the low pressure SI actuation if and/or when the block permissive is energized to prevent an inadventent SI.

*8. Charging flow is increased to maximum to limit the net mass depletion of the RCS during the venting period. A second charging pump should be started if it will provide additional make-up flow. If the safety injection system is in operation then maintain the current plant configuration until the venting is complete.

The responses indicated in the NOTE will provide the probable status of the RCS for those plants without a level system. It may also identify the presence of voids in the RCS other than the reactor vessel head or pressurizer.

a) During a depressurization, any gaseous voids that exist in the RCS, other than the vessel head, will rapidly expand and result in an increase in the pressurizer level.

b) The orifice in the head vent discharge line is sized to limit water relief to within the make-up capability of a charging pump. Therefore, if no gases are present in the vessel head, then the vent flowrate will match the charging flowrate and the pressurizer level will remain constant.

c) The venting of gases will result in a rapid decrease in pressurizer level due to the mass flowrate of the gases being greater than the mass input being provided by the makeup flow.

9. Both isolation valves in one vent flowpath must be opened to initiate the venting operation. The NOTE instructs the operator to close both isolation valves in the flowpath if one or both of the valves fail to open. The isolation valves in the redundant flowpath should then be opened. This prevents two flowpaths being open if the failed valve suddenly opens.

10. The venting is terminated when the reactor vessel head is refilled or when the following criteria are met.

    b) The maximum time period allowable for venting which limits containment hydrogen concentration to less than 3 volume percent (determined by Appendix B, "Venting Time Period").

    c,d,e) These limiting conditions are consistent with the safety injection re-initiation criteria of the emergency operating instructions. They provide sufficient operating margin for the venting and at the same time, provide limits on the transient which ensures adequate system control can be maintained.

    f) Once the reactor vessel head is vented and refilled then water relief through the vent path will begin. At this time, the rate of RCS depressurization and the rate of pressurizer level decrease should change and may even terminate. This may be used as an indication that the head has been refilled for those plants without a vessel level system.

    Both isolation valves in the vent flowpath should be closed to terminate the venting.

The CAUTION instructs the operator to maintain the RCS venting if loss of reactor coolant pump operation occurs. The venting is maintained to remove as much gas as possible from the vessel head during the RCP coastdown and onslaught of natural circulation. This will minimize the amount of gas bubbles in the reactor coolant loops and steam generator U-tubes. The operator should refer to AOI-4 "Natural Circulation" to ensure adequate core cooling is being maintained.

*11. Normal pressurizer pressure and level control is restored after the completion of the venting. A stable level and pressure should be maintained while it is determined if further venting is required.

*12. If a gas bubble existed in the vessel head and the venting was terminated prior to the vessel head being completely refilled, then the operator should return to Step 4 and repeat the venting operation until the reactor vessel head has been completely refilled.

The NOTE alerts the operator that if the time period for venting determined in Appendix B is met before the vessel head is refilled, then the containment hydrogen concentration must be reduced and a new venting period calculated prior to performing additional venting. The hydrogen concentration could be reduced through the use of the containment hydrogen re-combiners or by the purge and exhaust system if radioactive gas concentrations are within limits. The new venting period will be based upon the reduced hydrogen concentration.

13. The operator should return to the appropriate operating instruction following the successful completion of venting the reactor vessel head. If, during subsequent actions, a gaseous bubble reforms in the vessel head, then the operator should return to Step 1 and repeat the venting operation.

III. BASIS FOR APPENDIX A "RCS GASEOUS VOID DETECTION AND SIZING"

If gases are present in the reactor coolant system, then the pressurizer pressure and level controls will not respond as they normally would. The total gas volume can be estimated by performing a routine pressurizer control operation and then comparing the expected results with the actual results. This is the technique utilized in the following steps. If the safety injection system is in service, then the following steps are not applicable since normal pressurizer control will not be maintained.

1. The operator is instructed to achieve a stable pressurizer pressure with normal controls being maintained.

2. System pressure and level are placed on trend recorders to achieve better accuracy for recording their values. The transient is not expected to exceed a 150 psi or 10% of span change in RCS conditions.

3. These recordings will become the initial parameters in the following calculation.

4. Letdown flow is isolated, pressurizer heaters are tripped, and pressurizer spray is terminated to establish a condition where the pressurizer level will change only as a result of mass being injected into the RCS.

5. The operator is instructed to allow the system pressure to increase 100 psi or the pressurizer level to increase by 5 percent of span (pressurizer level is the preferred response). These conditions are obtained by a slow continuous charging rate.

6. These recordings will become the final parameters in the following calculation.

7. Normal RCS pressure and level controls are re-established and maintained until otherwise directed by steps of this instruction.

8. The operator is instructed to calculate the total volume of the pressurizer vapor space. The total cylindrical pressurizer volume is the total volume of the pressurizer excluding the upper and lower spherical domes.

9. The total charged volume into the RCS is the difference between the (charging and seal injection flows) and the seal leakoff flow and then converted to cubic feet.

10. An expected pressurizer level change can be determined from the total charged volume in the preceding step.

11. If the actual pressurizer level change is less than the expected change (or if no level change was witnessed) then gaseous voids exist in the reactor coolant system. This is a result of the gaseous voids contracting when the pressure was increased by the charging flow. This will limit or prevent a normal pressurizer level increase. The void contraction may even be large enough to cause an actual decrease in the pressurizer level.

    Step 12 should then be performed to estimate the total volume of the gas voids in the RCS.

12. The RCS void volume contraction is equal to the change in pressurizer level converted to volume. Also the ratio of final void volume to initial void volume is equal to the ratio of initial RCS pressure to final RCS pressure. From these two equations the two unknowns (initial and final RCS void volume) can be determined by inserting one equation into another. The initial void volume is calculated first and then fit into the volume/pressure ratio to determine the final void volume.

IV. BASIS FOR APPENDIX B "VENTING TIME PERIOD"

During a core uncovery event, there exists the potential for a significant amount of hydrogen generated in the core which could be trapped in the reactor vessel head and released to the containment atmosphere during the venting operation. The containment hydrogen concentration is limited to less than 4 volume percent to prevent a potential explosive mixture with oxygen, therefore, the amount of hydrogen that can be vented to the containment is restricted. A maximum allowable time period for venting is determined to limit the containment hydrogen concentration.

1. The total containment volume in cubic feet is first determined and then converted to standard temperature and pressure conditions. Note that the pressure term for the conversion is only applicable to sub-atmospheric containments and can be deleted for the remaining plants.

2. The containment hydrogen concentration is then determined in volume percent units. This value can be found by direct sampling or by hydrogen monitors. Sufficient time should be allowed for the air circulation equipment to mix the containment atmosphere prior to sampling in order to determine a representative concentration.

   The NOTE identifies to the operator that the containment hydrogen concentration will be insignificant if there has been no leakage from the RCS to the containment. The operator may assume the H_2 concentration to be 0 volume percent.

3. The maximum volume of hydrogen that can be vented is calculated which will limit the containment hydrogen concentration to less than 3 volume percent.

4. The maximum allowable venting period is then determined from curve #1 (RCS Pressure vs. Hydrogen Flow Rate). This curve was generated from a calculation which determined the flow rate of hydrogen at various RCS pressures through a 3/8" orificed line. The calculation assumed pure hydrogen which is conservative since the gaseous void in the vessel head will probably be some mixture of gases including steam.