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MAINE YANKEE

RCS HEAD VENT

OPERATIONAL GUIDELINES

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1.0 INTRODUCTION

This document describes the design basis, system description and the recommended strategy for operation of the Reactor Coolant System Vent System. Guidance as to when the operator should and should not manually vent the reactor coolant system is suggested. The underlying philosophical approach is to give the operator as much flexibility in use of the system without burdening him with unnecessary decisions or operational maneuvers during an event.

The guideline gives venting an active role in post-accident recovery. It is based on the following assumptions. An accident has occurred that results in a significant depletion of RCS inventory. Hydrogen generation resulting from an extended period of core uncovery may or may not have occurred. Regardless, the first venting of the reactor vessel head region will begin approximately one hour into the event and end when there is adequate assurance that the head is vented, that containment hydrogen levels warrant termination of the venting operation, or that other requirements are not met.

The venting operation potentially removes any non-condensible gases while they are being formed rather than allowing them to build up in the upper head region or elsewhere in the RCS. For most events, negligible amounts of non-condensible gases will be present following an accident, making the use of this system unnecessary. However, the use of the head vent aids in system recovery for a wide variety of events resulting in significant depletion of RCS inventory. Thus, venting of the head assures removal of non-condensible gases should they be present.

The components of the system which play a role in the venting process are examined and classified as to their active or passive role on the operation of the vent system. These include the reactor vessel, the pressurizer, the vent system, the Quench Tank, the containment, the reactor coolant pumps and the associated instrumentation, namely, the H analyzers. In addition to the component's role in the venting process is the operational framework in which the venting is carried out. This operational framework is presented and ascribes to the philosophy discussed above.

2.0 SYSTEM DESCRIPTION AND DESIGN BASES

The Reactor Coolant System Vent System is designed to remotely vent non-condensible gases from the reactor vessel head and pressurizer steam space to either the quench tank or the containment during post-accident situations. If the non-condensible gases accumulate in these locations, they could potentially interfere with core cooling or reactor coolant system pressure control.

The system is not intended for use during normal operation, and administrative controls will be provided to minimize the possibility of inadvertent operation. If the vent system is inadvertently operated during normal operation, the design of the system is such that the resulting liquid or vapor loss through either the reactor head vent path or the pressurizer path would not exceed charging capability. Furthermore, the quench tank capacity is such that it could handle a liquid release from the head region via the vent system for approximately one hour before reaching the 100 psig rupture disc set point.

The purpose of the vent system is to remove non-condensible gases from the RCS in a timely manner. A system flow diagram is shown in Figure 1. Since it may be required to operate under a variety of post-accident conditions, the RCS Vent System is designed to remove non-condensible gases from the RCS without reference to a specific bubble size or reactor coolant temperature and pressure condition.*

The system is designed to permit the operator to vent the reactor vessel head or pressurizer steam space from the control room under post-accident conditions, and is operable following most events except those requiring evacuation of the control room or a complete loss of all ac power. The vent path from either the pressurizer or reactor vessel head is single active failure proof with active components powered from two emergency power sources (refer to Figure 1). Two series valves powered off alternate power sources as shown, are provided in each vent path with a common cross-connect assures a vent path exists in the event of a single failure of either a valve or power source.

The system provides a redundant vent path from the RCS to the quench tank. Use of the quench tank provides a discharge location which can be used to store small quantities of gas without influencing containment hydrogen concentration levels. However, venting large quantities of gas to the quench tank will result in rupture of the quench tank rupture disc providing a direct path to containment for vented gas.

As shown on Figure 1, non-condensible gases are removed from either the pressurizer or reactor vessel through their respective vent paths and delivered to the quench tank. Venting under accident conditions would be accomplished using only one source (reactor vessel or pressurizer) and one sink (quench tank or containment atmosphere) at a given time. Should valve failure in the open position occur (unlikely due to the use of fail-closed valves), that source may be isolated by use of other series valves. However, due to the valving arrangements and the cross-connect between the pressurizer and head vent paths, a failed-open "upstream" valve in either line implies that both sources be vented simultaneously.

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* (For the reactor vessel head vent, the chosen design point was taken as H_2 gas at 2200 psig and 650°F. The resulting design hydrogen flowrate under this condition was calculated to be approximately 198,000 SCFH (14.7 psia and 60°F). Similarly, the H_2 vent rate through the pressurizer gas vent under similar conditions is on the order of 270,000 SCFH.

The reactor vessel head vent path has the capability to vent all the potential hydrogen from 100% of the Zr-H_2O reaction in approximately 2.25 hours under the above stated design conditions. Similarly, the time for the pressurizer vent path is about 1.60 hours. When the 1/2 inch tubing cross-connect is utilized, the flow rate of H_2 from the head region is on the order of 150,000 SCFH and the time to vent the hydrogen from 100% Zr-water reaction is approximately 3 hours.)

It is not desirable to vent both from the pressurizer and the reactor vessel head region simultaneously. However, under certain circumstances, such as when the containment hydrogen level is above 3%, the reactor vessel head should be vented to the pressurizer. In this case, the gases would be directed from the vessel head region to the pressurizer. However, a judgement should be made if the RCS is not stabilized and, due to break location, the gas flow could potentially be from the pressurizer to the upper head region.

3.0 REACTOR COOLANT SYSTEM COMPONENT CONSIDERATION

The following discussion focuses on the components that will affect or be affected by the use of the RCS Vent System.

3.1 Reactor Coolant System (Passive)

The source of the non-condensible gases to be vented are all within the RCS. Briefly, these sources are:

1. Normally Entrained Gases - Nitrogen and Hydrogen

2. Entrained Gases in Injected SI Water

3. SI Tank Nitrogen

4. Fuel Rod Fill Gas (Helium) and Fission Gases

5. H_2 from Cladding Zr-Water Reaction

6. Radiolysis of RCS Water

All these sources can simultaneously add up to a very large amount of non-condensible gases. The oxidation of the zircaloy cladding is perhaps the most important source. For example, the upper head, the outlet plenum and the upper downcomer volume down to the upper lip of the RV nozzles is approximately 1317 cu. ft. At 2200 psig and $650^{o}F$, if this volume contained hydrogen it would represent the oxidation of approximately 21% of the zircaloy in the core. The oxidation of all the zircaloy in the core represents approximately 6300 ft^3 at the above conditions. The entire volume of the reactor vessel is approximately 5000 ft^3. To keep things in perspective, the curr.nt design basis H_2 generation is to be kept below 1% on a core wide basis.

3.2 Reactor Coolant Pumps (Passive)

It is assumed that reactor coolant pump status during venting operations need not change. 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 at all possible.

3.3 Quench Tank (Passive)

Any hydrogen being vented from the reactor vessel head is discharged directly to the quench tank. If a substantial hydrogen release rate is encountered, the quench tank rupture disc, set at 100 psig, will rupture within several minutes or less, after which the hydrogen is discharged directly to the containment.

If steam is flowing through the vent system, it will take approximately one-half hour or so to exceed the rupture disc set point. For liquid venting, the rupture disc failure would be slightly more than an hour. These estimates have been made on the assumption of a quench tank at normal conditions with no quench tank cooling or draining operations taking place.

A slow rate of quench tank pressurization and level increase is indicative of steam or liquid discharge through the vent system. The existence of this condition implies little, if any non-condensible gases are in the system. As such, the venting operation could be stopped at this point in time.

3.4 Containment (Passive)

With regard to venting, the containment plays no active role, merely serving as a repository of the vented gases in the event of a quench tank rupture and as a repository of vented gases through the break. The containment hydrogen level should be maintained below 4% by volume during venting operations. All containment air handling equipment should be on to assure mixing of released hydrogen with the containment atmosphere. However, since hydrogen diffuses quite readily, mixing the containment atmosphere is viewed as an added measure to assure an even distribution of hydrogen. Thus, the availability of containment air handling equipment is not a strict prerequisite to the venting operation.

The 4% hydrogen level above is based on the lower flammability limit for hydrogen/air mixtures. At no time should containment integrity be compromised due to potentially dangerous hydrogen levels. Containment integrity takes precedence over core cooling during venting. Venting must be terminated prior to reaching the 4% containment hydrogen level. (Note that it is quite possible for non-condensible gases to enter the containment via the break. In such a situation, keeping the vent system closed when high containment hydrogen levels are encountered helps minimize the severity of the release.)

3.5 Pressurizer (Passive)

During venting operations, the pressurizer is assumed to be bottled up with sprays off. If adequate level exists and the appropriate power supply is available, operation of the pressurizer heaters can help maintain RCS pressure during a venting operation.

Venting the reactor vessel head to the pressurizer in the event of high containment hydrogen levels is assumed No paths from the pressurizer to containment are open during this mode.

3.6 Hydrogen Analyzers (Active)

There are two containment hydrogen analyzers, each having ranges of 0 - 5% and 0 - 20% with recording capability. The source of the reading in the containment is a sampling point at the top of the dome and one at Elevation 13 feet. Sampling lines from these points meet in a common line to provide a mixed sample to the analyzer. There is approximately a six minute transit delay from the sample points to the analyzer plus a one minute response time on the analyzer itself for a seven minute total delay on the reading.

In order to determine the current containment hydrogen level, the above delay time must be accounted for along with the rate of increase in hydrogen level in order to arrive at the correct hydrogen concentration.

Assuming a conservative maximum allowable hydrogen level of 3% and hydrogen vent rates based upon design flow conditions at different pressures, a table of vent duration times and H_2 level at vent termination is given in Table 1. The rationale for the 3% number is that it allows ample margin to the 4% hydrogen deflagration level. The times given in Table 1 are based solely on hydrogen vent rates and assumes unlimited hydrogen supply. No attempt has been made to quantify the amount of hydrogen produced by the LOCA event. Thus, the duration of the venting following an accident is assumed to be limited to 15 minutes (at 2200 psig RCS pressure) unless the trend seen on the hydrogen analyzers indicates a smaller hydrogen release rate. If the reactor coolant system pressure is less, longer vent duration times are suggested as shown in Table 1.

3.7 Charging System/ECCS (Active)

Some form of overpressure capability for the RCS is required during venting operation. Either the charging system via the normal charging path or the emergency core cooling system (HPSIs) is acceptable. The reason for this is that the venting procedure results in a small, controllable leak from the reactor coolant system. Having either charging or HPSI available helps maintain system pressure and subcooling, helps vent steam or gas, and causes the upper head region to be filled with liquid quickly. (Note: Subcooling is also provided by assuring a bubble in the pressurizer by means of the heater operation if at all possible.)

4.0 RCS HEAD VENT PROCEDURE FRAMEWORK

A flow chart of a suggested RCS head vent procedure is shown on Figure 2. The procedure is to first vent the RCS 1/2 hour to 1 hour following an event. The duration of the initial vent is determined from the times given in Table 1. Subsequent ventings, if necessary, must be coordinated with EP-2-17, Post-Accident Hydrogen Purge. If, at any time during the event, an estimate of the RCS voids is desired, terminate any venting operation and follow the procedure outlined in Appendix A, "RCS Gaseous Void Detection and Sizing".

Since capability exists for venting both the upper head and the pressurizer, venting via the reactor vessel head vent path should be viewed as the primary means of venting with the pressurizer vent path as a backup. Simultaneously venting from both sources should not be allowed except in the event of system failures when caution should be applied due to potentially high H_2 release rates to containment and RCS depressurization. During the venting operation, containment H_2 level, RCS pressure and subcooling should be closely monitored.

TABLE 1

CONTAINMENT HYDROGEN LEVEL FOR HEAD VENTING TERMINATION

RCS Pressure (PSIG)	Hydrogen[1] Level Change (%/Min)	Indicated[2] Hydrogen Level at 3% In Containment (%)	Approximate[3] Vent Duration (Min)
2200	0.20	1.48	15
1500	0.17	1.71	18
1000	0.14	1.95	22
500	0.09	2.23	32

Notes:

(1) Assumes unlimited hydrogen in the RV head at the given pressure and 650°F discharging into a dry, unpressurized containment.

(2) Accounts for 6.1 minute transit delay and 1.1 minute instrument delay. The indicated hydrogen level at 3% in containment for other rates of hydrogen level increase can be obtained from:

$$\% H_{2\,\text{INDICATED}} = \frac{1}{1.02*1.02} * [3.0 - 7.2 * (\frac{H_2\%}{MIN})]$$

(3) Time at which 3% H_2 is achieved based upon the given H_2 level change rate and a dry containment.

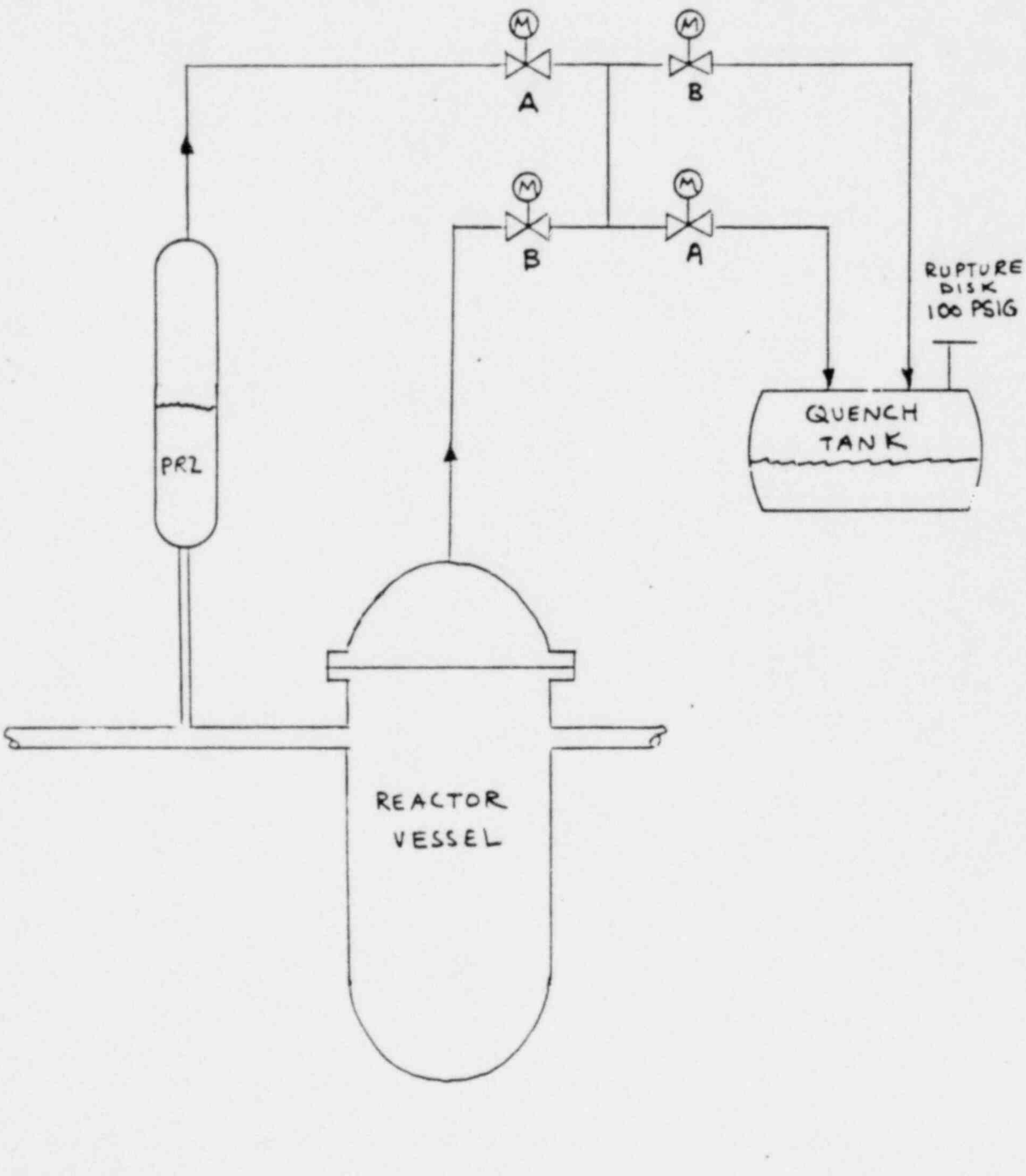


FIGURE 1	MAINE YANKEE RCS VENT SYSTEM

FIGURE 2

RCS VENT PROCEDURE
FLOW CHART

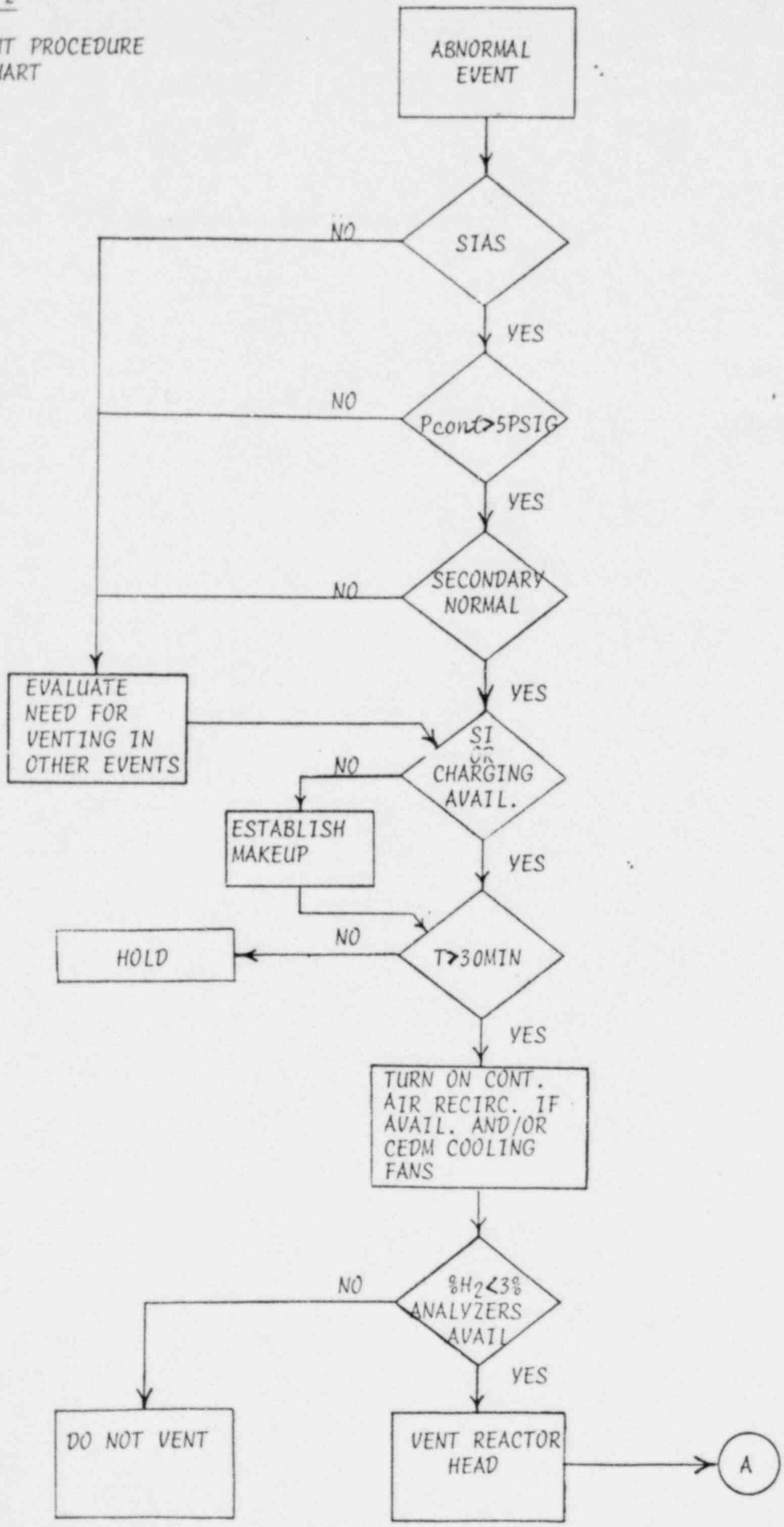
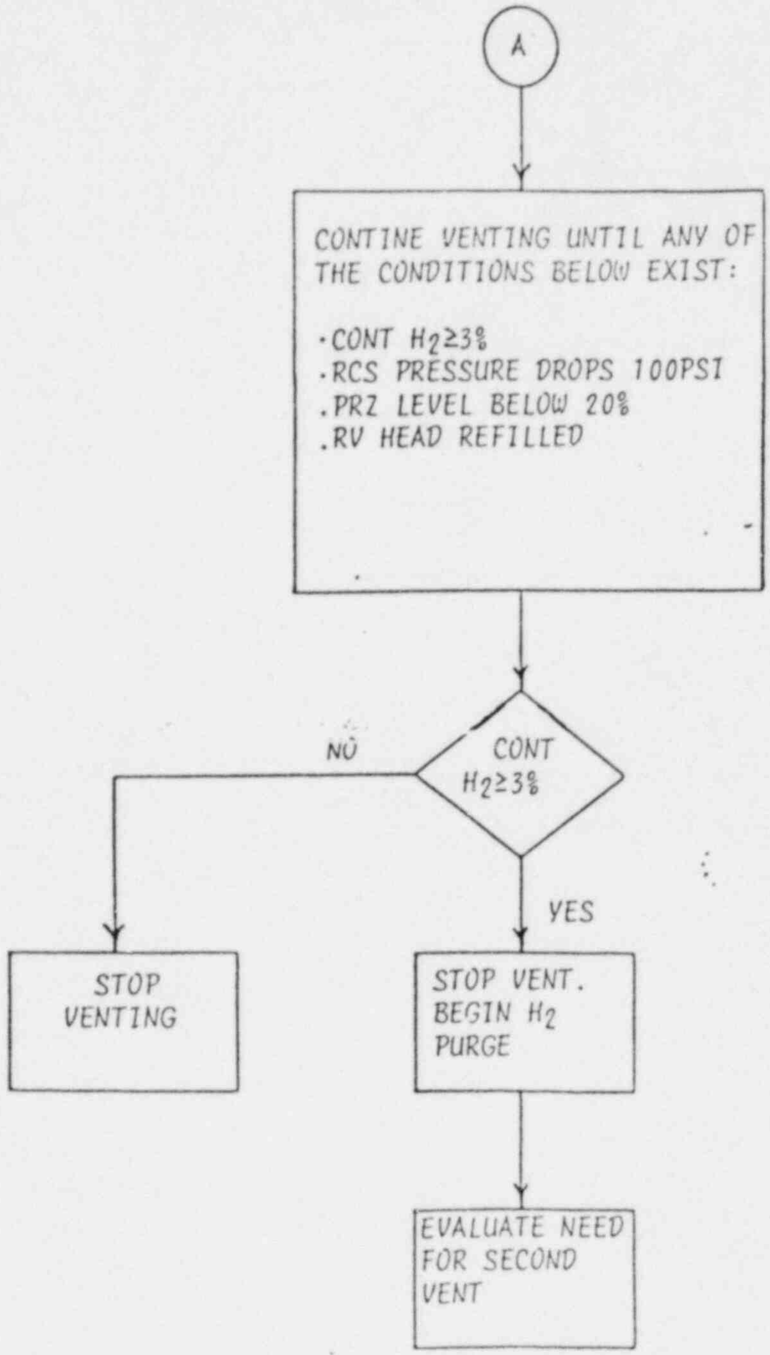


FIGURE 2 CON'D



APPENDIX "A"

RV HEAD VENT GUIDELINE

RCS GASEOUS VOID DETECTION AND SIZING

The following procedure for RCS Gaseous Void Detection and Sizing is to be carried out by the operator on instruction from the Technical Support Center.

1. Achieve a constant pressurizer level and pressure condition.

2. Place the RCS wide range or pressurizer pressure and the pressurizer level on trend recorders. The scale should be 150 psi pressure and 10% of span for level.

3. Record the following parameters:

RCS Pressure	=	________	PSI
PZR Level (NR)	=	________	%
Charging Rate	=	________	GPM
Seal Injection Flow	=	________	GPM
Seal Leakoff Flow	=	________	GPM
Time	=	________	HRS MIN SEC

4. Isolate the RCS letdown flow, turn off all pressurizer heaters, and terminate the pressurizer spray by placing the spray control in manual and zeroing the demand signal.

5. Allow the RCS charging flow to either increase RCS pressure 100 psi or increase pressurizer level 5% of span.

6. Record the RCS pressure, pressurizer level and time:

RCS Pressure	=	________	PSI
PZR Level (NR)	=	________	%
Time	=	________	HRS MIN SEC

7. Reinitiate RCS letdown flow and restore normal pressurizer pressure and level control.

8. Obtain the initial and final pressurizer vapor space volumes from the attached Figure A1 at the above initial and final pressurizer levels.

Initial Vapor Volume = ________ GAL *0.134 FT^3/GAL = ________ FT^3

Final Vapor Volume = ________ GAL *0.134 FT^3/GAL = ________ FT^3

9. Determine the total charged volume into the RCS.

Charged Volume = ((Charging + Seal Injection - Seal Leakoff) $\frac{GAL}{MIN}$) X

(Elapsed Time, Min) X (0.134 Ft^3/Gal)

= ______________ FT^3

10. Determine the expected pressurizer level change.

$$\text{Expected Level Change} = (\text{Charged Volume}, FT^3) \times \frac{1\%}{14.85\ FT^3}$$

= ________________ %

11. If the actual pressurizer level change is less than the expected level change then a gaseous void exists in the reactor coolant system. Perform the following step to determine the volume of the RCS void.

12. The initial and final RCS gaseous void volumes can be calculated from the following equations:

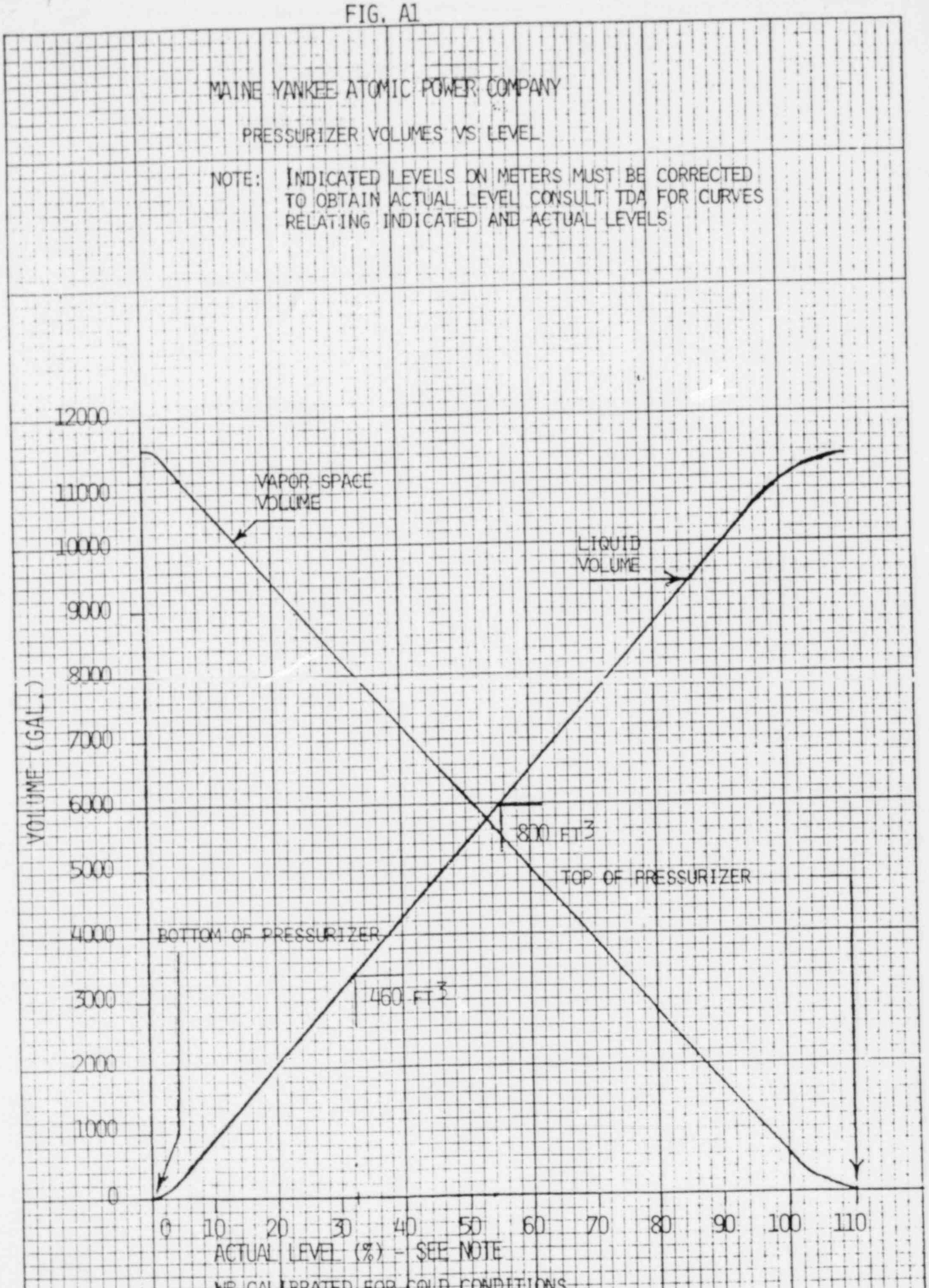
$$\text{Initial RCS Void} = \frac{\text{Charged Volume} - [(\text{Initial Vapor Volume})-(\text{Final Vapor Volume})]}{\left(1 - \frac{\text{Initial Pressure}}{\text{Final Pressure}}\right)}$$

= ________________ FT^3

$$\text{Final RCS Void} = \frac{(\text{Initial RCS Void}) \times (\text{Initial Pressure})}{(\text{Final Pressure})}$$

= ____________ FT^3

FIG. A1


MAINE YANKEE ATOMIC POWER COMPANY
PRESSURIZER VOLUMES VS LEVEL
NOTE: INDICATED LEVELS ON METERS MUST BE CORRECTED TO OBTAIN ACTUAL LEVEL CONSULT TDA FOR CURVES RELATING INDICATED AND ACTUAL LEVELS
VAPOR SPACE VOLUME
LIQUID VOLUME
800 FT^3
TOP OF PRESSURIZER
BOTTOM OF PRESSURIZER
1460 FT^3
VOLUME (GAL.)
12000
11000
10000
9000
8000
7000
6000
5000
4000
3000
2000
1000
0
0 10 20 30 40 50 60 70 80 90 100 110
ACTUAL LEVEL (%) - SEE NOTE
WR CALIBRATED FOR COLD CONDITIONS
NR CALIBRATED FOR HOT CONDITIONS