REPORT ON THE

CALVERT CLIFFS UNIT 1

LOSS OF SERVICE WATER

ON MAY 20, 1980

by the

Office for Analysis and Evaluation

of Operational Data

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Prepared by: Eugene V. Imbro

NOTE: This report documents results of studies completed to date by the Office for Analysis and Evaluation of Operational Data with regard to a particular operating event. The findings and recommendations contained in this report are provided in support of other ongoing NRC activities concerning this event. Since the studies are ongoing, the report is not necessarily final, and the findings and recommendations do not represent the position or requirements of the responsible program office of the Nuclear Regulatory Commission.

PREFACE

The findings, recommendations, and conclusions contained in this report are based on information gathered through both formal and informal communications between Baltimore Gas and Electric (BG&E) Company and the U.S. Nuclear Regulatory Commission Headquarters and Regional Offices. To the extent possible, the information used in this report has been verified by cross checking with other sources. The findings contained in this report relate mostly to Calvert Cliffs Units 1 and 2. However, similarities among pressurized water reactors (PWRs) leads us to believe that some of the findings and recommendations concerning the analysis of the steam generator tube rupture event may be broadly and generally applicable to all pressurized water reactors licensed prior to the issuance of the Standard Review Plan. To this end, we recommend that a plant-by-plant review, not possible in this investigation, be undertaken by others to assess the applicability of these findings and recommendations to other PWRs and to analyze and evaluate plant-unique design features not addressed in this investigation.

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EXECUTIVE SUMMARY

On May 20, 1980, Calvert Cliffs Unit 1 experienced a loss of both redundant trains of their service water system (SWS) when the system became air bound as a result of the failure of a non-safety-related instrument air compressor aftercooler. The loss of service water occurred at 1747, after service water heat exchanger (SWHX) 12 was returned to service following routine maintenance.

The Calvert Cliffs' Units 1 and 2 SWSs supply cooling water to both safety-related and non-safety-related components. The non-safety-related components, located in the turbine building, are supplied by both redundant safety-related service water subsystems via a common header.

The loss of service water caused an increase in the bearing temperatures of the main turbine and main feed pump turbine. Consequently, the reactor was manually tripped at 1803 to prevent equipment damage. At 2030 plant operators shut the instrument air compressor 11 aftercooler discharge valve and within minutes service water pump 11 discharge pressure began increasing and open vents began discharging solid streams of water. The 11 and 12 service water subsystems were both operational at 2145.

The consequences of this event were minor. However, this event, involving the failure of a single non-safety-related component causing the disablement of both redundant trains of the safety-related service water system, is nonetheless significant since it involved two fundamental aspects considered in the design of safety-related systems:

1) Interaction between safety and non-safety-related systems and components; and

2) Common caused failure of redundant safety systems.

The review of this event revealed no immediate safety concerns; however, there is a need to reevaluate the following: the assumptions used in analysis of the steam generator tube rupture for Calvert Cliffs and possibly other PWRs licensed prior to the "Standard Review Plan"; the assumption of atmospheric dump valve operability on two-loop PWRs having one atmospheric dump valve per steam generation following a steam generator tube rupture; and for the isolation provisions at the interface between the safety and non-safety-related portions of the service water system at Calvert Cliffs.

1. EVENT DESCRIPTION

On May 20, 1980, Calvert Cliffs Unit 1 experienced a loss of both redundant trains of their service water system (SWS) when the system became air bound at 1747, after service water heat exchanger (SWHX) 12 was returned to service following routine maintenance.

At 0345 on May 19, 1980, the SWHX 12 was removed from service to clean the sacrificial zinc anodes. During this planned maintenance the salt water side (tube side) of the SWHX was drained and the service water discharge valve was closed. The 11 and 13 service water pumps were both running and discharging to service water subsystem 11.

The following day at approximately 1740, SWHX 12 was returned to service. The salt water side had been refilled and the service water discharge valve was opened. At 1747, the operators began receiving high temperature alarms on components cooled by service water. Simultaneously, operators observed low pressure in both service water headers and high levels in both head tanks. Service water pumps 11 and 12 were both running at this time, however; they were drawing only 15 amps instead of the 70 amps they draw during normal operation. This indicated to the operators that the pumps were cavitating. Service water pump 13 was started at 1800 and continued to run until 1841 at which time it was secured. Service water pump 12 was secured at 1801. The reactor was manually tripped at 1803 due to increasing main turbine and main feed pump turbine bearing temperatures.

The loss of service water on Unit 1 caused the Unit 1 air compressors to trip. The Unit 1 instrument air system (IAS) and plant air system (PAS) were then automatically supplied by the Unit 2 plant air system, causing a reduction in Unit 2 air pressure. Concerned that instrument air might be lost, the operators attempted to supply cooling water to the Unit 1 air compressors from the Unit 2 SWS via a "temporary" cross-connect, installed during construction, that was never removed. This caused low pressure alarms on both Unit 2 service water subsystems, indicating probable air entrainment. Operators shut this cross-connect and Unit 2 SWS pressure returned to normal.

At 2030 plant operators shut the instrument air compressor 11 aftercooler discharge valve and within minutes service water pump 11 discharge pressure began increasing and open vents began discharging solid streams of water. The 11 and 12 service water subsystems were both operational at 2145.

2. SYSTEM DESCRIPTIONS

2.1 Service Water System

The Calvert Cliffs' Units 1 and 2 SWSs supply cooling water to both safety-related and non-safety-related components, as shown in Figure 1. The safety-related portion of the SWS located in the auxiliary building is comprised of two redundant subsystems with a third service water pump that can be aligned to either subsystem. (Tables 1 and 2 show the normal electrical and mechanical lineup of the service water pumps.) As indicated in Table 2, the preferred mechanical alignment of the third service water pump is to service water subsystem 12. The SWS serves the following safety-related equipment:

Emergency diesel generators

Containment air coolers

Spent fuel pool heat exchanger

There are three emergency diesel generators at the site that serve Units 1 and 2. Diesel generator 11 is normally aligned to Unit 1 (bus 11) and diesel generator 21 is normally aligned to Unit 2 (bus 24). Diesel generator 12 is shared by Units 1 and 2 and normally is aligned to supply power to either bus 14 on Unit 1 or bus 21 on Unit 2. The diesel generator 12 transfer logic is so designed that an SIAS on either Unit 1 or 2 will cause the diesel generator to be automatically transferred to the unit that has the SIAS. As shown in Figure 2, diesel generator 12 can also be supplied with service water from either Unit 1 or Unit 2. Usually, diesel generator 12 is supplied with service water from subsystem 12 on Unit 1. Referring to Table 3, it can be seen that if the pressure in service water subsystem 12 decreases below the setpoint of the installed pressure switches (45 psig), the service water supply to diesel generator 12 would automatically transfer to subsystem 21 on Unit 2. This transfer is accomplished by the automatic repositioning of four air-operated butterfly valves. All four of these valves fail closed on loss of instrument air and fail open on loss of DC. Since the instrument air is not a safety-related system, and two of the four valves must remain open to allow service water from either Unit 1 or Unit 2 to be supplied to diesel generator 12, safety-grade air accumulators have been provided to permit valve operation or maintenance of valve position on loss of the instrument air system. Check valves on the instrument air lines to each of the valves prevents blowdown of the accumulators through a break in the instrument air system.

The non-safety-related part of the SWS, located in the turbine building, is fed by both redundant safety-related subsystems and returns to the safety-related part of the SWS in the auxiliary building via a common header. Isolation of the safety and non-safety-related systems is accomplished by four redundant air-operated valves in the supply to the turbine building (two for each redundant subsystem) and by three check valves on the return side (one check valve in the common header and one in each of the redundant subsystems). The air-operated isolation valves on the supply to the non-safety-related part of the system close automatically on an SIAS. On loss of instrument air these isolation valves fail in the closed position.

2.2 Instrument Air System

The major components of the instrument air system are: two air compressors, two instrument air receivers, and a dryer package. It supplies dry, oil-free air for various pneumatic instruments and controls throughout the plant. The compressor of the plant air system is available as a backup to the instrument air compressors by virtue of an air-operated normally closed, fail closed, valved cross-connect between the two systems. An instrument air system pressure of 85 psig or less will cause the cross-connect valve between the instrument air system and plant air system to open. The plant air systems of Units 1 and 2 are connected via a normally open cross-connect. Neither the instrument air system nor the plant air system are safety-related systems but the instrument air system is necessary for plant operation as it controls a number of important valves. The following is a partial list of some of the more significant air-operated valves:

Valve(s)	Failure Position on Loss of Instrument Air
Letdown Isolation	Closed
Charging Isolation	Open
Auxiliary Spray	Closed

Valve(s)	Failure Position on Loss of Instrument Air
Pressurizer Spray Control	Closed*
Atmospheric Dump	Closed
Turbine Bypass	Closed
Reactor Coolant Pump Cooling Water Return	Closed
Diesel Generator 12 SWS Transfer	Closed*
Service Water System Turbine Bldg Isolation	Closed

* Accumulators are provided to permit a limited number valve open/close cycles following loss of instrument air.

3. EVENT SEQUENCE ANALYSIS

During the time the SWHX 12 was out of service, air accumulated on the shell side due to the fact that the heat exchanger outlet valve was closed. (The source of air, as later determined, was a tube failure in the instrument air compressor 11 aftercooler.) When the heat exchanger was brought back on line, the trapped air was swept into the system, and due to the common header in the turbine building, disabled both safety-related subsystems. Although the SWS is provided with a number of constant vent valves, their relieving capacity was exceeded by the sudden influx of the large quantity of air that had accumulated in the SWHX while it was out of service. In addition, because the Unit 1 instrument and plant air compressors tripped after losing service water, the Unit 2 plant air system began supplying the total Unit 1 compressed air demand, both plant air and instrument air.

Therefore, even though the Unit 1 air compressors tripped, air continued to be pumped into the SWS through the ruptured aftercooler tube by the Unit 2 plant air compressor.

Since the Unit 2 plant air system was supplying instrument air for Unit 1 during the event, in addition to its normal function, the operators noted a reduction in air pressure. In an attempt to avert a potential loss of instrument air on Unit 1, operators opened an existing cross-connect that allowed the Unit 1 air compressors to be cooled by Unit 2 service water. This would have allowed Unit 1 air compressors to be restarted. Following the opening of this cross-connect line, a "temporary" line installed during construction, low service water header alarms were received on Unit 2, indicating air entrainment. Unit 2 service water pressure returned to normal after the operators closed the cross-connect.

4. POTENTIAL EVENT SCENARIOS

This event involved the failure of a single non-safety-related component causing the disablement of both redundant trains of the safety-related service water system. Although the consequences of the event were relatively minor, the event is nonetheless significant since it involved two fundamental aspects considered in the design of safety-related systems:

1) Interation between safety and non-safety-related systems and components; and
2) Common caused failure of redundant safety systems.

These scenarios consider the loss of instrument air and loss of offsite power in conjunction with this event. The FSAR analyzed steam generator tube rupture has also been reviewed considering a coincident loss of instrument air.

4.1 Loss of Offsite Power

The emergency diesel generators are the principal pieces of safety-related equipment that are cooled by the SWS. Therefore, the effect of the loss of both redundant service water trains combined with a loss of offsite power has been examined.

Diesel generator 11 is supplied by service water subsystem 11 and diesel generator 12 can be supplied either by service water subsystem 12 of Unit 1 or subsystem 21 of Unit 2. The preferred alignment of diesel generator 12 is to subsystem 12 of Unit 1. The service water transfer logic, as shown in Tables 3 and 4, is designed such that if, for example, diesel generator 12 is initially aligned to subsystem 12 and either the service water inlet or outlet valves are closed or the service water pressure drops below 45 psig, both the subsystem 12 service water inlet and outlet valves are automatically closed and the inlet and outlet valves aligning the diesel generator to subsystem 21 of Unit 2 are opened. If diesel generator 12 was initially aligned to subsystem 21, an identical logic would transfer the service water supply to subsystem 12 if similar conditions existed on subsystem 21. Therefore, if the sequence of events that actually occurred happened during a loss of offsite power, diesel generator 11 would trip on high jacket coolant temperature or low jacket coolant pressure and would be unavailable. Diesel generator 12, if aligned to Unit 1,[1/] may also trip if the service water initiated trips

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1/ On a loss of offsite power diesel generator 12 starts automatically and the operator must manually close the breakers to power either bus 14 of Unit 1 or bus 21 of Unit 2. Once a bus is energized, the logic prohibits closing the breaker on the other bus, preventing simultaneous connection to both buses.

occur before service water is restored. In this instance, the service water transfer logic will reposition the valves to align the diesel to service water system 21 on Unit 2. At this time, considering the loss of offsite power, bus 21 would be deenergized and, consequently, service water pump 21 would be idle since it is connected to that bus. Service water pump 23, although mechanically aligned to service water system 21, would not automatically start although it is normally powered from bus 24, as is service water pump 22. The system logic is designed such that service water pump 23 would start only if service water pump 22 did not. Therefore, diesel generator 12 is automatically transferred to an inactive service water system until the operators realign diesel generator 12 to energize bus 21 on Unit 2 or manually start service water pump 23. This scenario, although unlikely, could cause Unit 1 to have a temporary loss of AC (station blackout) while Unit 2 had only a single source of AC available (bus 24). The total loss of AC can, however, be sustained without adverse consequences.

In a subsequent event, on August 12, 1980, with Unit 1 operating at full power, an aftercooler tube on instrument air compressor 11 failed causing an ingress of air into the SWS. This was indicated by the rise in level in service water head tanks 11 and 12. The indicated level in these tanks went from normal to full scale indicating that both subsystems were affected. In this case, however, the automatic operation of the constant air vents provided sufficient air removal capability and the pressure in either subsystem did not drop below the normal operating range. This event indicates that if the constant vent valves are operable and have sufficient air removal capacity, the above scenario is precluded.

As a result of the similarity with the May 20, 1980 event, air in-leakage was immediately suspected and the aftercooler on instrument air cooler 11 was isolated.

4.2 Steam Generator Tube Rupture

One of the consequences of the event was the tripping of the instrument and plant air compressors due to the loss of service water. Since the service water flow to the plant and instrument air compressors is automatically terminated on an SIAS the impact of the loss of instrument air on plant operation and accident mitigation was evaluated.[2/] The atmospheric dump valves and the turbine bypass valves are air operated and fail closed on loss of instrument air, therefore, instances were reviewed where use of these valves would be helpful in plant cooldown.

The steam generator tube rupture incident was selected for review since it is an event analyzed in the FSAR that initiates an SIAS and relies on primary system depressurization and cooldown and a technical specification on the maximum permissible primary coolant activity to limit the release.

Since the secondary side overpressure protection is provided by ASME Code safety valves, the operability of the atmospheric dump and turbine bypass valves is not safety-related. The only safety function associated with these valves is maintenance of the secondary pressure boundary, and this applies only to the atmospheric dump valves since they are upstream of

2/ The plant air system of Units 1 and 2 are cross-connected and can be thought of as a single system that can act as a back-up to the instrument air systems of both units. Following an SIAS, the affected unit's instrument air system would continue to be supplied by the plant air system. However, the capability of plant air system to supply the instrument air system can be disabled by a single active or passive failure.

the main steam isolation valves (MSIVs). Based on the above reasoning, valve operability contingent on the non-safety-related instrument air system is justifiable. A review of the steam generator tube rupture analysis in the Calvert Cliffs FSAR indicates, however, that credit is taken for the automatic actuation of the atmospheric dump valves and turbine bypass valves.[3/] Without the availability of the atmospheric steam dump and turbine bypass capability, the principal means of heat removal from the reactor coolant system (RCS) is through the secondary safety valves, of which, the setpoint of lowest is 1000 psig. This would maintain T_{av} in the RCS at approximately 546°F, some 14°F above the zero power T_{av} of 532°F, and in itself is no problem. However, since the setpoints of the secondary safety valves are fixed, reactor cooldown and depressurization below 546°F and 1000 psig is precluded until the core decay heat is less than the RCS heat loss. Therefore, without instrument air and assuming no operator action, the plant would continue to discharge steam from the secondary safety valves for a substantial time.[4/]

Assuming that the heat loss from the RCS is 1% of rated core thermal power it would take about four hours for decay heat to get below 1% using the standard fission product decay heat curve. This means for approximately four hours slightly

3/ NUREG-75/087, USNRC, "Standard Review Plan," Section 15.6.3, "Radiological Consequences of a Steam Generator Tube, Failure (PWR)" presently requires this event to be evaluated with and without concurrent loss of offsite power. The assumption of loss of offsite power implies unavailability of the turbine bypass system due to the loss of the main condenser as a heat sink. Calvert Cliffs was licensed prior to issuance of the Standard Review Plan.

4/ The atmospheric dump valves at Calvert Cliffs are provided with chain-operated handwheels and can be manually operated, if necessary, to cooldown and depressurize the primary coolant system.

radioactive steam would be released directly to the atmosphere via the secondary safety valves. However, since the decay heat curve is very flat this long after a reactor trip, assuming a heat loss of 1/2% rated core thermal power would increase the four-hour steam release to 40 hours. In this situation, operator action clearly is necessary, and it would be unreasonable to assume operator action would not be taken to manually control the atmospheric dump valve associated with the non-affect steam generator. However, at Calvert Cliffs (and probably most other two-loop PWRs), successful operator action is contingent on the manual operability of a single atmospheric dump valve associated with the non-affected steam generator.

The radiological consequences of a steam generator tube rupture at Calvert Cliffs, using the FSAR analysis assumptions, are based on isolation of the affected steam generator after 1/2 hour and then cooldown of the plant using the turbine bypass system. Three and one-half hours after initiation of cooldown the reactor coolant system temperature and pressure would be low enough to allow cooldown by means of the residual heat removal system (RHR) and isolation of the condenser. Therefore, in the analysis, the release of activity to the condenser is terminated after 1/2 hour when the affected steam generator is isolated. During the 3.5 hour cooldown, using the turbine bypass system, activity is released to the atmosphere via the condenser air removal system, in the FSAR scenario.

In addition, in the FSAR, the operation of the atmospheric dump and turbine bypass system precludes lifting of the secondary safety valves. Thus, except perhaps for momentary actuation of the atmospheric dump system when the reactor trips, there is no other direct release to the atmosphere, and the release path during cooldown is via the turbine bypass system to the condenser and out the condenser air removal system. Since the iodine undergoes additional partition in the condenser, the unavailability of the turbine bypass system due to loss of offsite power or a loss of instrument air coincident with a steam generator tube rupture would result in a discharge of steam through the secondary safety valves with a higher concentration of iodine than that released through the condenser air removal system. Therefore, although more likely in terms of what would happen, the FSAR calculated releases are non-conservative if coincident loss of instrument air or loss of offsite power is postulated.

Given a steam generator tube rupture as the initiating event with a loss of the non-safety-grade instrument air system (the availability of which is not assumed during an accident on recently licensed plants), and postulating as the single failure the inability to manually open the atmospheric dump valve associated with the nonaffected steam generator, it is apparent that, at least for two-loop plants, the release of activity to the environment will be greater than that considered in the FSAR. This is due to the fact that initially, steam will be discharged via the secondary safety valves until other means are used to depressurize the RCS below the lowest setpoint of the secondary safety valves.

There are other techniques that could be used to control RCS pressure and cool down the reactor. These techniques which also depend on the availability of instrument air, are feed and bleed for cooldown and use of pressurizer spray to control RCS pressure. In some instances, feed and bleed is not very effective on CE plants, since the RCS pressure during normal operation is above the shutoff head of the high pressure safety injection pumps (HPSIs) and the capacity of the charging pumps is only 132 gpm. In this event, the RCS pressure would be low enough to use the HPSI pumps; however, letdown is precluded since the letdown valves are air operated and fail closed on loss of air. In addition, the operation of the power-operated relief valves (PORVs), to "bleed" the RCS, is not easily controllable since the controller on the control board has only two positions, Closed and Auto. Therefore, operation of the PORVs could only be accomplished by inserting a test signal in the opening logic, or by racking-out two of the four reactor protective system control drawers.

Pressurizer pressure control using pressurizer spray would also not be possible on loss of instrument air. Although the pressurizer spray valves are provided with air accumulators to allow a limited number of open/closed cycles following loss of instrument air, the valve on the common component cooling water (CCW) return line from the motor and seal coolers of the four RCPs is also an air-operated fail closed valve. Since the operation of the RCPs provides the driving head for the spray flow and the RCPs can only be run about ten minutes without cooling water, pressurizer spray would only be available until the RCPs were tripped.

Although the instrument air compressors are not safety-related, they are powered from redundant 480V safety-related buses and would be available following a loss of offsite power. Also, as previously described, the IAS of the attached unit is backed up by the plant air system of the other unit. Although these features increase the reliability of the IAS, it is not safety-related and should not be relied on for mitigation of a steam generator tube rupture.

4.3 Seismic Event

As discussed in Section 2, SYSTEMS DESCRIPTIONS, the SWS also serves non-safety-related equipment in the turbine building from a common header. In addition to providing cooling for the instrument air compressors and the plant air compressor, the SWS also provides cooling water to the main generator hydrogen cooler. Therefore, many potential paths that are not seismically qualified exist for ingress of gas into the service water system. Since the SWS supply valves (the seismic boundary to the turbine building header) close automatically only on an SIAS, a seismic event could potentially cause the ingress of large amounts of gas into the SWS, and by virtue of the common header could disable both service water subsystems, unless the operator acted quickly to close the turbine building supply valves. This could be postulated simultaneously for both Units 1 and 2. The constant vent valves provided throughout the system may give the operator additional time to isolate the turbine building service water header in this case.

Similarly, a pipe break in the non-seismically designed common service water line in the turbine building could also disable both service water subsystems, unless the operators act quickly to isolate the turbine building supply header.

The operators receive both an audible and visual alarm in the control room on low turbine building service water header pressure. The alarm, however, is control grade and is common to the redundant pressure sensors that are located downstream of the turbine building supply header isolation valves.

A major seismic event, comparable to the design basis earthquake (DBE), could result in the loss of offsite power and a loss of instrument air. The four service water inlet and outlet valves to diesel generator 12 are air operated and fail closed on loss of instrument air. Since air is required to keep the valves open, safety-grade air accumulators and check valves have been provided to maintain a limited air supply following a loss of the instrument air system. If these check valves leak or there is leakage across the vent ports of the solenoid operated 3-way valves allowing the air to escape, the service water valves will drift closed causing diesel generator 12 to trip.

This scenario, when combined with a single failure such as the failure of one diesel to start, results in total loss of AC to one unit and one diesel being available to the other unit. This situation is not unsafe, but its likelihood of occurrence should be minimized, since it places heavy reliance on the auxiliary feedwater system and secondary safety valves for plant heat removal.

The above scenario demonstrates the importance of the leak tightness of the check valves that isolate the air accumulators from the balance of the instrument air system and the solenoid operated 3-way valves. In a similar vein, the common turbine building service water return header is isolated from the redundant portion of the SWS by redundant check valves. Therefore, a pipe rupture in the non-seismically designed turbine building service water piping would cause both redundant service water subsystems to slowly drain if these check valves are not leak-tight. Since both Unit 1 and Unit 2 have the same design, this could be postulated to occur on both units simultaneously. If the leakage across the valve seats is small, operators should have ample time to isolate these check valves before significant SWS inventory is lost.

5. FINDINGS

a. The event is significant since it involved two fundamental aspects considered in the design of safety related systems: 1) interaction between safety and non-safety related systems; and 2) common caused failure of redundant safety systems.

b. The operator's response to this event was appropriate and no other plant equipment was damaged during the event. The only operator action that was questionable was the use of the "temporary" service water cross-connect between the air compressors of Units 1 and 2. However, to their credit, the operators quickly closed the cross-connect when the Unit 2 service water system began to exhibit erratic behavior.

c. The commonality of the service water system inside the turbine building could result in draining both subsystems as a result of a pipe break (e.g., at locations A or B, as shown in Figure 1) in the non-safety-related service water piping in the turbine building, if no operator action was taken to close valves CV-1600, CV-1637, CV-1638, and CV-1639. These valves are operable from the control room. Valves SW-4 and 5 are manual locally-operated butterfly valves, therefore, initial reliance is placed on check valves SW-1, SW-2, and SW-3 to isolate the service water pump suction piping from the turbine building return header. The safety-related service water pump suction piping is protected from a break in the turbine building supply or return header, at location A or B, for example, by two check valves in series. A moderate-energy line through-wall leakage crack postulated at locations C (or D), however, could result in the impairment of both service water subsystems if valve SW-2 (or SW-1) failed to seat properly.[5/] In this case, redundant isolation could only be provided if the locally operated butterfly valves SW-5 (or SW-4) and at least one of the four turbine building service water supply valves (CV-1600, CV-1637, CV-1638 or CV-1639) were closed.

[5/] Moderate-energy line through-wall leakage cracks are defined in NUREG-0800, Section 3.6.2, "Determination of Break Locations and Dynamic Effects Associated with the Postulated Rupture of Piping."

d. The Calvert Cliffs' FSAR analysis of the steam generator tube rupture event and the analysis performed for Cycle 5 operation of Unit 1 (Reference 1) assumed the availability of offsite power and the turbine bypass which itself is a control-grade system that depends on instrument air to operate the turbine bypass valves. If the credit is not taken for the instrument air system during the steam generator tube rupture event, since it is not a safety-related system, and the operability of the atmospheric dump valve associated with the non-affected steam generator is postulated as the single-failure, the release of activity would be greater than that calculated. This is due to dumping steam directly to the atmosphere through the secondary safety valves and a delay in the cooldown due to the necessity for operator action to depressurize the reactor coolant system below the set point of the lowest set secondary safety valve.

e. The inability to open (either manually or otherwise) the atmospheric dump valve associated with the non-affected steam generator following a steam generator tube rupture has not been considered for two-loop PWRs with a single atmospheric dump valve per steam generator.

f. Due to the common service water piping in the turbine building, the potential exists for losing both redundant trains of service water. If this occurred, the service water subsystem supplying diesel generator 12, the shared diesel, would become unavailable, the service water supply would then automatically transfer to the counterpart system on the other unit. However, assuming a coincident the loss of offsite power, which is unlikely, the service water pump on this system would be idle. Timely operator action is required either to transfer the diesel to the bus to which the pump that is supplying its service water is connected or to start a third service water pump. Although both of these actions can be done from the control room, and in the case of the bus transfer the diesel support functions are among the first components energized as the loads are sequenced on the bus, there is a relatively small "window" for operator action before the diesel trips on high water jacket temperature.

g. Leaking check valves or leakage of the solenoid operated 3-way valves in the instrument air supply to diesel generator 12's air-operated service water supply and return valves would cause these valves to go to their fail closed position if initially open or remain closed on loss of instrument air. This would isolate all service water from diesel generator 12, making it inoperable until operators manually opened the appropriate valves, aligning the diesel to Unit 1 or Unit 2, by means of the handwheels provided.

h. The licensee has verified, by walking down the lines, that the instrument air supply for valves 1-CV-1645 and 1-CV-1646, the respective Unit 1 service water supply and return isolation valves for diesel generator 12, is from the Unit 1 instrument air system. Although the licensee is confident that the air supply for valves 2-CV-1645 and 2-CV-1646, the respective Unit 2 service water supply and return valves from diesel generator 12 is from the Unit 2 instrument air system, a similar verification was not possible since the lines go through a high radiation area. Since the instrument air system is not safety-related and these valves are proximate to each other, there is a possibility that they could all have been connected to the same instrument air system. Although this is not a safety concern since these valves have safety-grade air accumulators to permit limited operability following a loss of instrument air, having the Unit 1 and Unit 2 valves supplied from the instrument air systems of their respective units would increase the reliability of diesel generator 12.

i. The Calvert Cliffs service water system is provided with the capability to automatically isolate the safety and non-safety related portions of the system in accordance with Section 9.2.2, the Standard Review Plan (SRP).[6/]

This, however, did not preclude the common caused failure of the service water system that occurred. It is therefore conceivable that plants licensed under the current criteria could also be susceptible to a common caused failure of the redundant safety-related portion of the service water system due to a single failure in the non-safety related portion of the system.

A review of Section 9.2.2 of the Standard Review Plan indicates that the guidance for isolation of non-safety and safety-related portions of the service water system needs to be elucidated. The present guidance can be gleaned from the following excerpts from Section 9.2.2:

1) Paragraph I.2.a - "The effects of the failure of nonseismic Category I equipment, structures or components on safety-related portions of the SWS are taken into account in the design."

2) Pargraph II.3.c - (Acceptance is based on ...) "The capability to isolate components, subsystems, or piping if required so that the system safety function will not be compromised."

3) Paragraph III.3.a - "The drawings and descriptions are reviewed to verify that automatically operated isolation valves separate non-essential portions and components from the essential portions."

6/ Standard Review Plan for the Review of Safety Analysis Reports for Nuclear Power Plants, NUREG-0800, July 1981.

The guidance needs to clarify when the automatic isolation of the safety and non-safety related portions of the system is necessary. The concern is that it could be inferred from the above excerpts that automatic isolation on an SIAS is: 1) necessary, since the safety function then would not be compromised by a failure in the non-safety related portion of the system; and 2) sufficient, since the primary area of concerns, particularly for the older operating plants, has been the loss of coolant accident.

The isolation of the non-safety related portions of the service water system on a SIAS is neither necessary nor sufficient for the following reasons: 1) in the event of an SIAS, the isolation could cause the unavailability of some non-safety related features, such as instrument air, that could be useful, although not necessary, in accident mitigation; and, 2) for plants having a non-safety related service water header common to both redundant safety related subsystems, the automatic isolation on SIAS alone does nothing to safeguard the safety related portion of the system during other instances when the system is performing a safety function. A failure in the common header, for example, during a loss of offsite power, could jeopardize both emergency diesel generators.

6. SUMMARY OF LICENSEE ACTIONS

As a result of the May 20, 1980 loss of service water in Unit 1, the licensee has implemented both procedural and facility changes. The facility changes involve the addition of a constant "float type" vent in the service water discharge lines from each plant and instrument air compressor and four vents, one in each service water discharge line from the main generator hydrogen cooler. The capacity of each constant vent valve is 25 SCFM. Each group of vents will be alarmed in the control room; i.e., there will be four alarms (two per unit) in the control room, one for the four vents on each of the two hydrogen coolers, and one for the three air compressors for each unit. On receipt of an alarm, an operator will locally determine which vent is discharging. The service water to the affected component can then be isolated, terminating the ingress of gas into the service water system.

The scenario of gas ingress into the service water system has been incorporated into the operators simulator training to assure prompt recognition of the event, thereby shortening the response time. In any case, until the source of gas ingress can be manually isolated, the vents will act to control or slow down the rate of gas accumulation in the system, depending on the size of the leak and the capacity of the vents. This will give operators additional time to detect and isolate the leaking component. In addition, the vents on the hydrogen coolers are at the high point of the service water system and this will enable them to vent the entire service water system.

The Unit 1 air compressors were provided with vent valves in their service water discharge lines, as previously described, when Unit 1 was built. The capacity of these valves is 3.11 SCFM each. These will be replaced by vent valves with a capacity of 25 SCFM. Although branch connections were installed in the service water discharge piping from the Unit 2 air compressors for vent valves when the plant was built, the valves were not installed. The licensee, as previously mentioned, will install identical 25 SCFM vent valves on these existing branch connections.

The "temporary" service water cross-connect between the Unit 1 and Unit 2 air compressors was cut and capped shortly after the May 20, 1980 event. The attempt by operators to use this cross-connect during the event led to a temporary degradation of the Unit 2 service water system.

The common cause loss of service water prompted the licensee to conduct an in-depth review of the service water system. As a result of this review, the three check valves in the service water system return header from the turbine building are being added to the Inservice Test Program (IST). A facility change has been approved to add the necessary test connections. This was deemed necessary since the operability of these valves is relied on to form the pressure boundary between the safety-related, seismically designed, portion of the service water system and the non-seismically designed, common turbine building cooling loop.

A procedural change was also made that would preclude the accumulation of large quantities of air in the service water system during maintenance outages. This change requires that during the maintenance of a service water subsystem the pump discharge valve be closed. This then eliminates having a large inactive run of piping in which air can accumulate. Also instituted was a monthly check of air compressor heat exchangers to prevent recurrence of the event.

7. SUMMARY OF NRC ACTIONS

7.1 Office of Nuclear Reactor Regulation

On June 25, 1980 members of AEOD and NRR visited Calvert Cliffs to investigate the event. During this visit a summary of licensee proposed corrective actions and recommendations was obtained. Reference 2 summarized the investigation and concluded that although the licensee's review of the event was thorough and competent, "measures should be taken to remove the commonality of the service water loops in the turbine building and the pumps suction line."

Reference 2 also concluded that IE should issue a Circular on the service water system failure.

A further study of this event was conducted by the Operating Reactor Assessment Branch (ORAB), Reference 3. This study discussed the safety significance of the event and some of the licensee's short-term actions, one of which (the removal of all air compressors from the service water system.) will not be implemented by the licensee.7/ In the long term, the ORAB study recommended that the Operating Experience Evaluation Branch (OEEB) perform a generic study on service water system malfunctions. This was agreed to by OEEB and under an existing technical assistance contract, "Special Studies of Reactor Operating Experience," (FIN B0755) with ORNL, a case study on the loss, or impairment, of service water systems in operating reactors has been initiated. As a part of the same technical assistance contract a similar case study on the loss, or impairment of compressed air and nitrogen systems has also been initiated.

7.2 Office of Inspection and Enforcement

Reference 4, originated by the Calvert Cliffs' resident inspector on June 10, 1980, identified the common cause failure of service water systems as a potential generic issue. This will be evaluated by IE Headquarters.

7/ In lieu of this the licensee is installing additional vent capability in the service water system. This is discussed in Section 6.

8.0 RECOMMENDATIONS

a. The review of this event revealed the potential for unacceptable interactions between safety and non-safety related portions of service water systems, and the potential for common caused failure of the redundant safety related portions of service water systems. The following specific recommendations have been developed to address this area of concern.

(1) The isolation of redundant service water subsystem does not meet the single failure criteria if a moderate-energy line through-wall leakage crack is postulated in one of the service water pump suction lines. In this case, reliance is placed on a single check valve and closure of at least one of the four turbine building supply valves to prevent impairment of both service water subsystems. Although these check valves (See Figure 1, valves SW-1, SW-2, and SW-3) which isolate the return lines from safety-related equipment served by the service water from the turbine building return header will be added to the IST program, it is recommended that butterfly valves SW-4 and SW-5, as shown in Figure 1, have valve operators added (pneumatic or electric motor) and that these valves either close automatically as do the valves on the turbine supply header, or as a minimum, have the capability to be remote manually operated from the control room.

(2) It is recommended that the four check valves and the four solenoid operated three-way valves in the instrument air lines that provide control air for the four diesel generator 12 service water supply and return valves be added to the IST program. (Refer to Figure 1.) These check valves are necessary to prevent the control air stored in the

seismically designed accumulators from being lost through a break in the non-seismically designed instrument air system. The solenoid operated three-way valves are also part of the same seismically designed pressure boundary as the check valves described above. The service water supply and return valves fail closed on loss of instrument air. Therefore, the inability of these check valves or the solenoid operated three-way valves to maintain a leak-tight pressure boundary will result in service water isolation to the 12 diesel generator. Handwheels are provided for the service water supply and return valves and valve position is indicated in the control room by open/close status lights; therefore, these valves can be manually repositioned, allowing for some delay due to operator action, following a loss of instrument air.

(3) As previously described in Section 5f, if there is a loss of offsite power and the service water system supplying diesel generator 12 becomes unavailable, the diesel will transfer to an inactive service water loop. Since operator action is necessary to realign the diesel generator such that it energizes the bus which powers the service water pump in the loop to which it was transferred or alternatively, to start a third service water pump, it is recommended that the human factors of these actions be evaluated against the length of time the diesel can run without service water before it trips.

(4) For operating plants and plants currently in the licensing process that have service water systems that contain both safety and non-safety related portions, it is recommended that the system isolation provisions

be reviewed to identify any procedural or hardware changes necessary to protect the safety related portion of the service system from a failure in the non-safety related portion during normal operation and accident conditions.

(5) It is recommended that an IE Circular on common cause failures of service water systems be issued.

(6) In the long-term, it is recommended that the guidance in the SRP be clarified to emphasize automatic isolation of the non-safety related portion of the service water system when it degrades the operability of the safety related portion of the system. This could be accomplished by adding the following to Sections 9.2.1 and 9.2.2 of the SRP as Paragraph II.3.f: "The effects of failure of non-safety related components, subsystems or piping on safety related portions of the service water system are precluded by automatic isolation during normal operation and accident conditions."

b. The evaluation also revealed a need to reevaluate certain assumptions made in the analysis of the steam generator tube rupture event. The specific recommendations in this area are:

(1) In the next reload application, the Calvert Cliffs' analysis of the steam generator tube rupture should be redone assuming the unavailability of the turbine bypass system due to the loss of instrument air. Loss of offsite power and consequent loss of the main condenser circulating water pumps would also negate the use of the turbine bypass system; however, loss of instrument air is a more conservative

assumption since it then requires manual operation of the atmospheric dump valves in order to cooldown and depressurize the plant below the setpoint of the secondary safety valves.

(2) PWRs licensed prior to the issuance of the Standard Review Plan should be reviewed to determine if their steam generator tube rupture analysis was done assuming coincident loss of offsite power and unavailability of control power, if not safety-related, to the atmospheric dump valves. It is recommended that all PWRs be analyzed using the above assumptions.

(3) Implicit in the evaluation of the steam generator tube rupture analysis is that the atmospheric dump valves on the non-affected steam generators are always manually operable. This is particularly critical for two-loop PWRs that have a single atmospheric dump valve for each steam generator since the inoperability of the atmospheric dump valve associated with the non-affected steam generator, coincident with a tube rupture, would result in a release of radioactivity larger than calculated in the FSAR. It is, therefore, recommended than an evaluation be performed for operating two-loop PWRs with an atmospheric dump system as described above to assess whether the incremental increase in safety achieved by the addition of redundant atmospheric dump capability to each steam generator is great enough to justify its inclusion. In the interim, it is recommended that the emergency procedures of the applicable operating plants be reviewed to determine if they adequately address plant cooldown and depressurization following a steam generator tube rupture without the availability of the intact steam generator.

9. CONCLUSIONS

The loss of service water event at Calvert Cliffs did not result in damage to any plant equipment either safety or non-safety-related, and taken by itself does not represent a cause for concern. The significance of the event lies in the fact that it involved two fundamental aspects considered in the design of safety-related systems:

1) Interaction between safety and non-safety-related systems and components; and

2) Common caused failure of redundant safety systems.

The review of the event revealed no immediate safety concerns; however, there is a need to reevaluate the following: the assumptions used in analysis of the steam generator tube rupture for Calvert Cliffs and possibly other PWRs licensed prior to the "Standard Review Plan"; the assumption of atmospheric dump valve operability on two-loop PWRs having one atmospheric dump valve per steam generator following a steam generator tube rupture; and the isolation provisions at the interface between the safety and non-safety-related portions of the service water system at Calvert Cliffs as well as generically.

The licensee's review of the event was thorough and comprehensive and will result in additional vents being installed in the service water system.

Also as a result of the licensee's review, the check valves in the turbine building return header were added in the IST program. Although this is a step in the right direction, the need for automatic isolation of the turbine building return header on SIAS, or the capability for remote manual isolation as are provided for the turbine building supply header, need to be evaluated.

The event was also given a thorough review by NRR and resulted in the issuance of an Operating Reactor Event Memorandum, Reference 3, "Loss of Service Water System" and the initiation of a study by ORNL.

10. REFERENCES

1. Letter from A. E. Lundvall, Jr., (Baltimore Gas and Electric) to R. A. Clark (USNRC) dated September 22, 1980. Calvert Cliffs Unit 1, Fifth Cycle License Application.

2. Memo from T. M. Novak to D. G. Eisenhut dated July 29, 1980. Staff Investigation into the May 20, 1980 Loss of Service Water,etc.

3. Memo from D. G. Eisenhut to R. H. Vollmer, et.al., dated December 1, 1980. Operating Reactor Event Memorandum No. 80-25 Loss of Service Water System.

4. Potentially Generic Issue Data Sheet, Number RI:RO&NS:80-05, "Common Mode Failure of Service Water Systems."

SERVICE WATER PUMP → SWP

DIESEL GENERATOR → DG

DG	BUS \ SWP	11	12	21	22	13	23
11	11	X				X	
12	14		X				
12	21			X			
21	24				X		X

Table 1 Normal Electrical Lineup

SERVICE WATER PUMP → SWP

SERVICE WATER SYSTEM → SWS

SWS \ SWP	11	12	21	22	13	23
11	X					
12		X			X	
21			X			X
22				X		

Table 2 Normal Mechanical Lineup

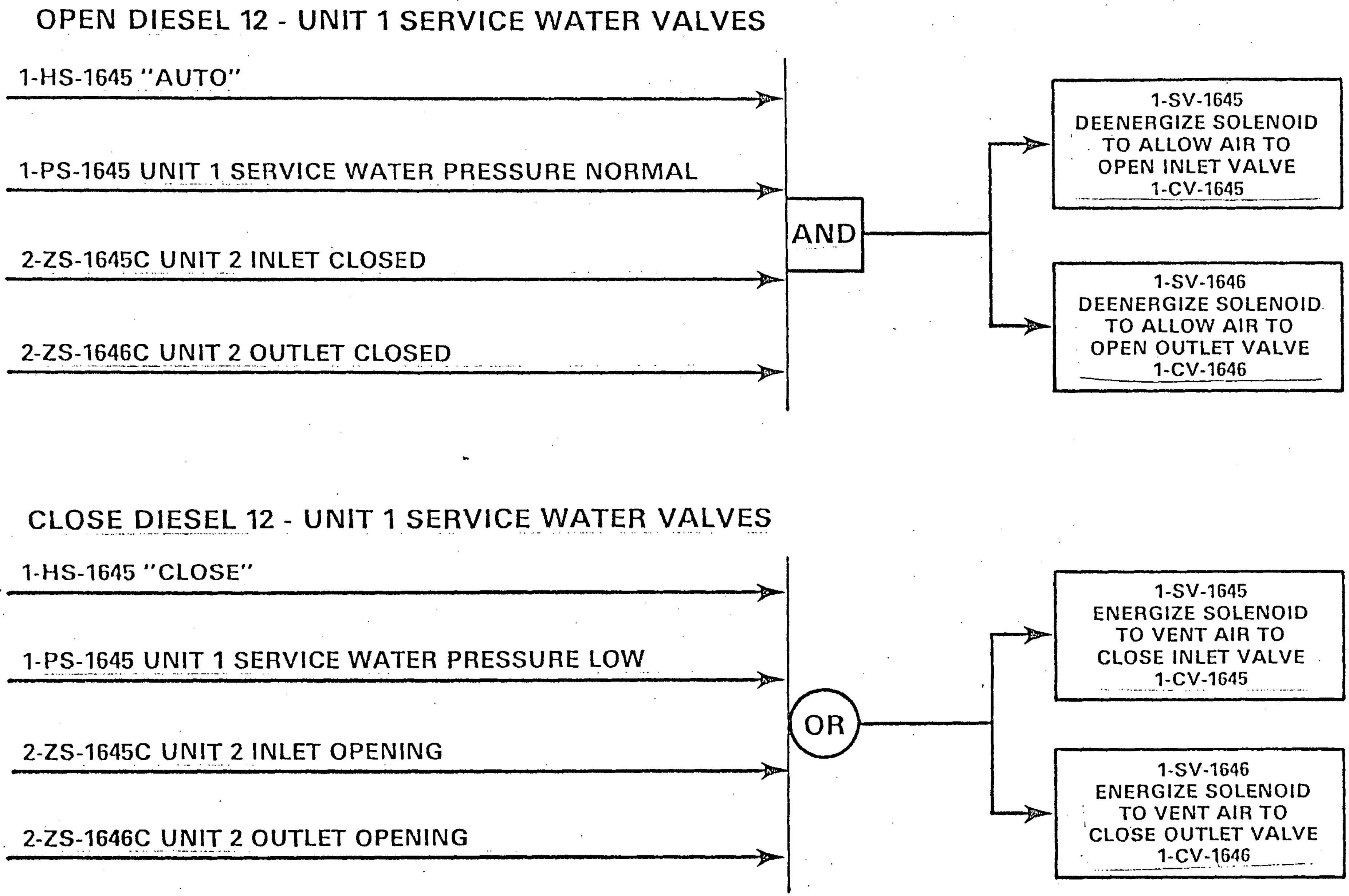


Table 3 Diesel Generator 12 - Unit 1 Service Water Transfer Logic

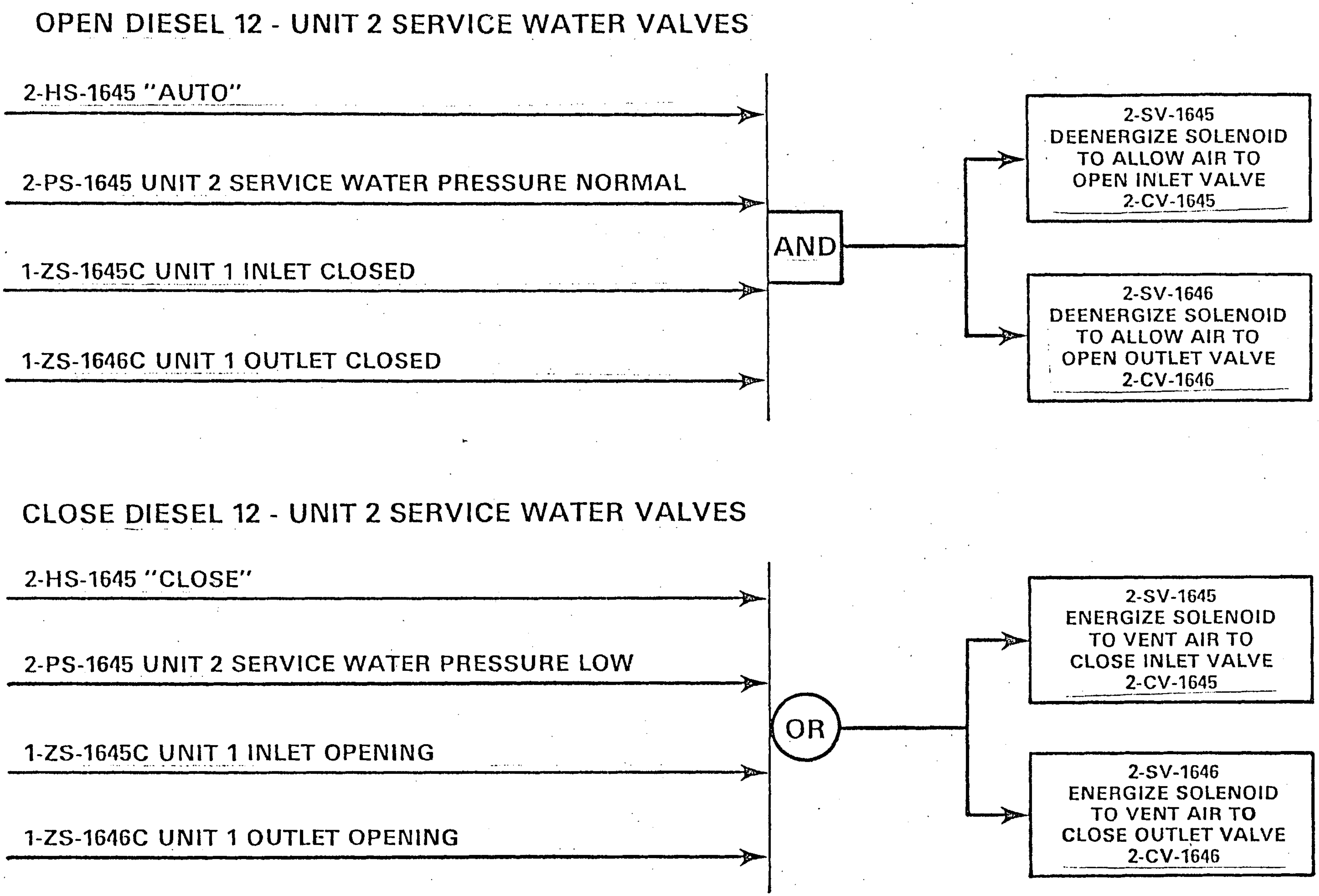


Table 4 Diesel Generator 12 - Unit 2 Service Water Transfer Logic

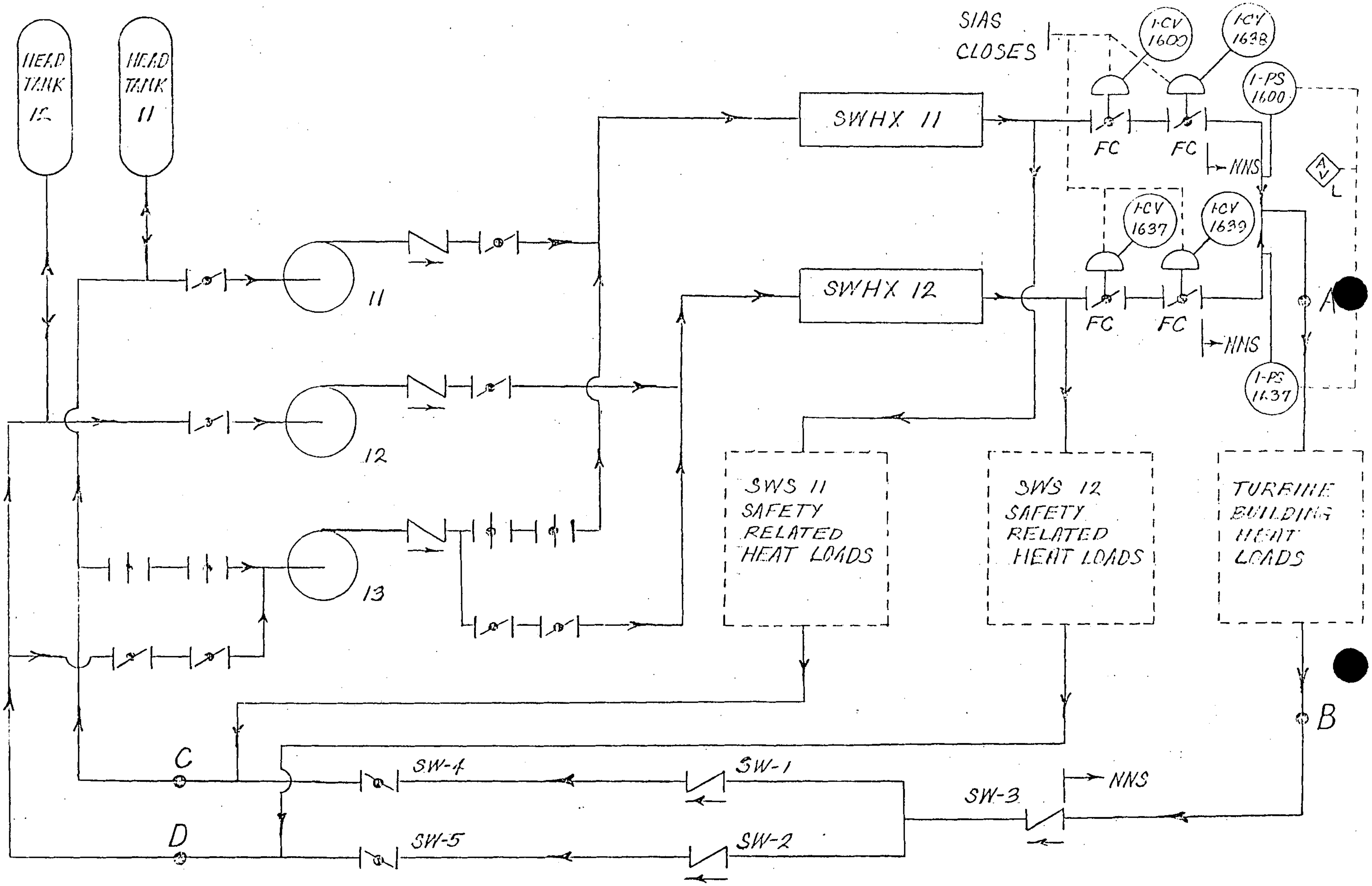
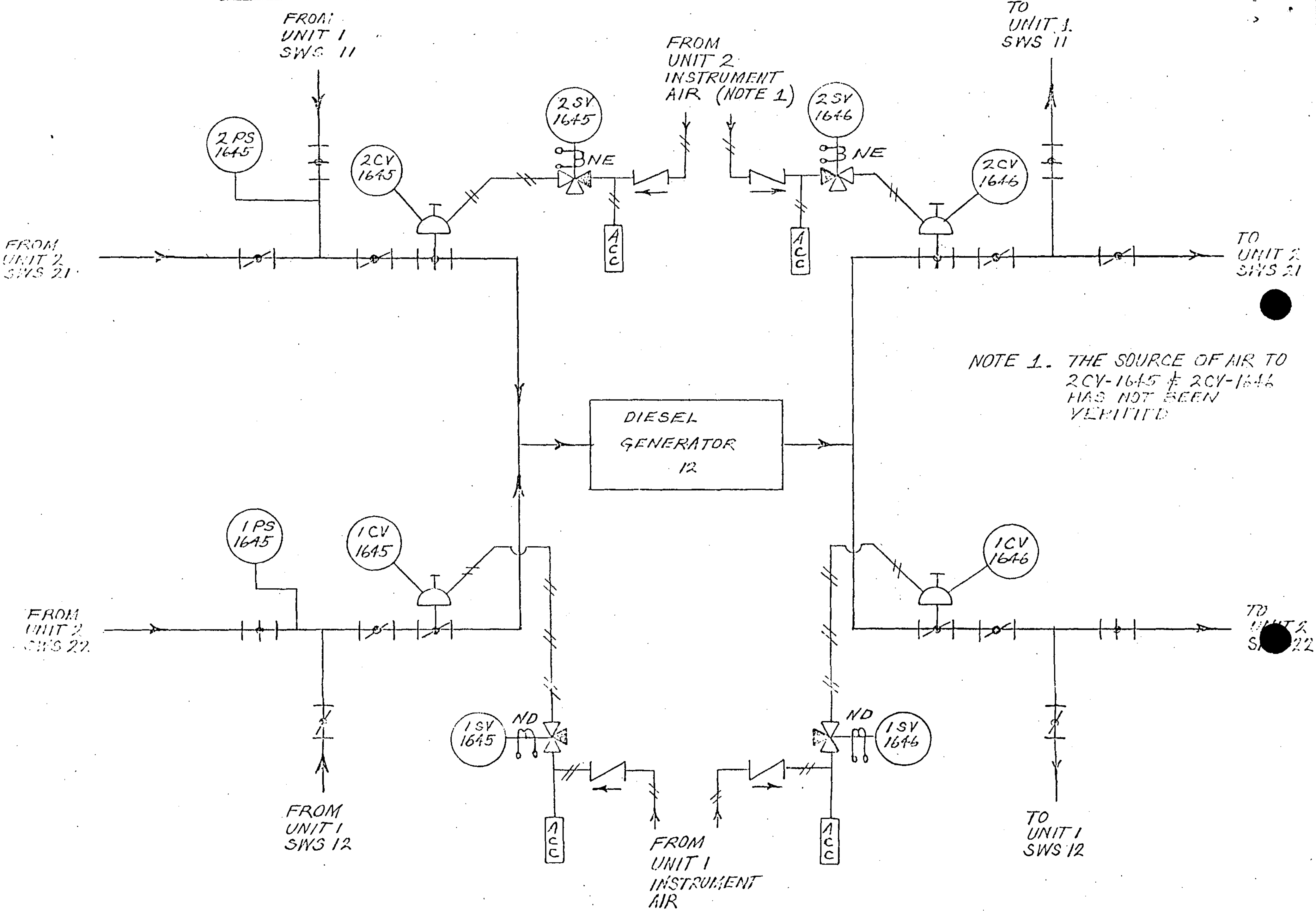


FIGURE 1 SIMPLIFIED SERVICE WATER SYSTEM PIPING DIAGRAM

FIGURE 2 SERVICE WATER SUPPLY TO DIESEL GENERATOR 12



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