



UNITED STATES
NUCLEAR REGULATORY COMMISSION
WASHINGTON, D. C. 20555

OCT 05 1989

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Dear Mr. Thomas:

Subject: NUREG/CR-5404 Vol. 1, "Auxiliary Feedwater System Aging
Study Volume 1. Operating Experience and Current
Monitoring Practices

Enclosed for your review and comment is a draft of the final
Phase I aging report on the auxiliary feedwater system. Any
comments the EQAG utility review group would like considered
should be sent to me by November 17, 1989.

Sincerely,

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**NUREG/CR-5404
VOLUME 1
ORNL-6566/V1**

AUXILIARY FEEDWATER SYSTEM AGING STUDY

VOLUME 1. Operating Experience and Current Monitoring Practices

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Work Performed for
U.S. Nuclear Regulatory Commission
Office of Nuclear Regulatory Research
Under DOE Interagency Agreement DOE 1886-8082-8B

DRAFT

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ACKNOWLEDGMENTS

The guidance and organizational direction provided by D. M. Eissenberg, W. S. Farmer, and W. L. Greenstreet is appreciated.

Assistance provided in the acquisition of failure data by G. A. Murphy, W. E. Norris, and W. P. Poore III was instrumental to the historical failure analysis portion of the study.

The help provided by C. P. Stafford in the retrieval of plant configuration information and the general support that he provided in the conduct of this study is greatly appreciated.

A major portion of this study would not have been possible without the help of a number of utility employees. The assistance and information provided by R.L. Clark, R. Galante, and J. R. Wolfgang is gratefully acknowledged.

Finally, the advice and contributions, both prior to and during this study, of colleagues who prefer to remain nameless was of immense value. The perspectives gained by interaction with these fellows is of inestimable worth.

ABSTRACT

This report documents the results of a study of the Auxiliary Feedwater (AFW) System which has been conducted for the U. S. Nuclear Regulatory Commission's Nuclear Plant Aging Research Program. The study reviews historical failure data available from the Nuclear Plant Reliability Data System, Licensee Event Report Sequence Coding and Search System, and Nuclear Power Experience databases. The failure histories of AFW System components are considered from the perspectives of how the failures were detected and the significance of the failure. Results of a detailed review of operating an monitoring practices at a plant owned by a cooperating utility are presented. General system configurations and pertinent data are provided for Westinghouse and Babcock and Wilcox units.

CHAPTER 1 INTRODUCTION AND SUMMARY

The Nuclear Plant Aging Research (NPAR) program was established by the Office of Nuclear Regulatory Research of the Nuclear Regulatory Commission (NRC) to identify sources of degradation, their effects, and available methods of degradation and failure detection.

Nuclear plant safety related systems are composed of combinations of electrical and mechanical pieces of equipment which are intended to function in a coordinated manner to support and/or allow normal plant operation while fulfilling specific roles in the mitigation of anticipated transients and design basis accidents. The NPAR program has identified a number of types of components for detailed study. The studies of these individual components have identified component specific failure modes and causes, associated stressors, and available monitoring methods.

This review of the Auxiliary Feedwater (AFW) System, used at Pressurized Water Reactor (PWR) plants, has been conducted under the auspices of the NPAR program. The primary purposes of the review were:

- a) Determine the potential and historical sources and modes of failure within the AFW System.
- b) Identify currently applied means of detecting known sources and modes of degradation and failure.
- c) Evaluate the general effectiveness of the current monitoring practices and identify specific areas where enhancements appear needed.

This study, which was conducted by Oak Ridge National Laboratory (ORNL), consisted of the following elements:

- a) Identification of general types of AFW System design configurations.
- b) Analysis of historical failure data.
- c) Detailed review of a cooperating utility's AFW System design and their current operating and monitoring practices.

BACKGROUND

The AFW System has historically, and particularly since the Three Mile Island 2 accident, been recognized as critical to successful mitigation of plant transients and accidents. In recent years, operating incidents involving failures of AFW System components have been among the leading events identified in the "Precursors to Potential Severe Core Damage Accidents" reports¹, which identify the leading risk significant events for calendar years. In the years 1984 through 1986, seven of the top ten events at PWRs, from a core damage risk standpoint, involved partial or total failure of the AFW System.

Operational problems with the AFW System have been diverse in nature. There have been a number of Information Notices and Bulletins and other mechanisms of information feedback and regulatory action issued by the NRC which identify operating problems that have been experienced with AFW Systems. The following are provided as examples of failures involving the AFW System which have resulted in NRC feedback.

Bulletin 85-01: Steam Binding of Auxiliary Feedwater Pumps

Discussed a number of historical events in which backleakage of hot feedwater into the AFW System had resulted in overheating of AFW discharge and suction piping and steam binding of AFW pumps. The bulletin required the establishment of routine monitoring of AFW piping for backleakage and the development of procedures to identify backleakage and restore the system to operable condition should it occur.

Bulletin 85-03: Motor Operated Valve Common Mode Failures During Plant Transients Due to Improper Switch Settings

This bulletin was issued primarily as a result of the June 9, 1985 loss of Main Feedwater and AFW at the Davis-Besse plant. AFW was lost because of improper torque and limit switch settings on AFW System motor operated valves. (This episode was also discussed in Information Notice 85-50).

Information Notice 86-01: Failure of Main Feedwater Check Valves Causes Loss of Feedwater System Integrity and Water-Hammer Damage

This Notice was issued to provide information feedback on the November 21, 1985 failure of several check valves in the Main Feedwater System at San Onofre 1. Failure of these check valves allowed draining of the steam generators (SGs) and prevented AFW from reaching the SGs until gate valves were closed by operator action. Sufficient draining occurred to result in condensation-induced water hammer when AFW began to refill the drained Main Feedwater piping.

Information Notice 86-09: Failure of Check and Stop Check Valves Subjected to Low Flow Conditions

This Notice was issued as a result of a number of failures of stop check valves in the steam supply piping to the AFW turbines at the Turkey Point Units. The failures occurred as the result of chattering induced by low flow which resulted from leakage past motor operated valves in series with the stop check valves.

Information Notice 86-14: Overspeed Trips of AFW, HPCI, and RCIC Turbines

Following the Davis-Besse event in 1985, a review of overspeed events of turbine driven pumps was conducted by the NRC Office of Analysis and Evaluation of Operating Data. This review resulted in the publication of "Operational Experience Involving Turbine Overspeed Trips", AEOD/C602, which in turn provided the basis for this Information Notice. The Notice discussed several types of overspeeding events that had occurred.

Information Notice 87-53: Auxiliary Feedwater Pump Trips Resulting From Low Suction Pressure

Several plants experienced low suction pressure trips of AFW pumps due to suction pressure fluctuations which resulted from a variety of transient system conditions.

The above identified problems are examples of the diverse types of failures experienced in the AFW System. There have been numerous other operating experiences which have been fed back to industry through both the NRC and the Institute of Nuclear Power Operations.

In reviewing the role that aging plays in failures such as these, there are some important points to be considered. First of all, a combination of factors, including design, maintenance, operation, aging, and other considerations may be involved. These factors are not necessarily independent from one another. For example, a poorly designed

component or system may require that it be operated in a manner that is not necessarily conducive to extended service of either that component or other components.

An example of this can be seen in many AFW system designs, in relation to flow paths available to a pump. If the only full flow path available for the pump is to the steam generators, required monthly or quarterly testing will normally be done under recirculation flow only. It has become clear that running these pumps at low flow rates is deleterious to the pump and pump life². But delivering flow to the steam generators also has undesirable effects in terms of nozzle thermal stress. The result is that the pumps are run under recirculation flow only for testing (as well as often being run at low flow rates during routine plant startup and shutdown) and accumulated wear results. In the event that failure of the pump ultimately results, it would be difficult to ascribe the failure to a particular cause such as aging. In reality, the failure may be due to the combination of poor system design, undesirable operating conditions, insufficient maintenance attention, excessive test frequency requirements, etc.

This difficulty of determining the extent to which a particular failure is aging related extends to most component failures. The only failures that can be readily dismissed as not being aging related are those that occur within a short time after a component is placed in service. The quantification of "short time" depends upon the particular component and its operating conditions. For example, through-wall erosion of piping downstream of a control valve would normally be viewed as an aging related failure. However, a failure of this nature could occur in a time span ranging from days to decades, depending upon the piping material and layout, service conditions, and other factors.

A second point relative to aging is pertinent when considering systems. A system, as noted above, is composed of a group of components, such as pumps, valves, motors, piping, etc. The system ages only as the individual components age. The types of components most subject to wear and aging may vary significantly from system to system, however. Furthermore, even for the same type of system, certain components may experience substantial service wear at one facility and very little at another due to the combination of design, maintenance, and operating factors involved. Other studies performed under the NPAR program address important components within the AFW System, and the aging stressors for these individual components.

A third important factor in determining the ORNL approach was the fact that a study that was performed by Idaho National Engineering Laboratory (INEL) reviewed historical failure data from NPRDS (similar to the NPRDS data that was reviewed by ORNL in this study) and made judgments as to whether or not individual failure episodes were aging related³. The INEL report was based upon some of the same failure data that was used in this study (the review of failure data is discussed in Chapter 4).

Because of these factors, the ORNL approach to the AFW System study has been to focus attention on how and to what extent the various AFW System component types fail, how the failures have been and can be detected, and on the value of existing testing requirements and practices, rather than attempting to focus on the extent to which aging (versus design or operating practices, for example) is responsible for failure or degradation.

On the other hand, in the review of a particular plant's design and operating practices, it is possible to determine, in a relative manner, the extent to which design and test and operating requirements can contribute to aging for particular components. For instance, where a check valve routinely experiences low flow rates as a result of how the system is operated, and is located just downstream of a flow disturbance, a judgement can be made

that the particular valve will be likely to experience a relatively high rate of service wear compared to a similar valve in more optimal conditions. Aging concerns of this nature are addressed in this study. It must be recognized, however, that individual component configuration and operating conditions may vary considerably from plant to plant, and even within the same system.

SUMMARY OF RESULTS

The analysis of historical failure data and the detailed review of a cooperating utility's AFW System design and monitoring practices provided complementary results. The single largest source of historical AFW System degradation, based upon the historical failure data review, is the turbine drive for AFW pumps. It should be noted that the turbine proper has been a relatively reliable and rugged piece of equipment. However, the turbine auxiliaries, including the governor control and trip & throttle valve have contributed substantially to the overall turbine problems.

The failures of motor and air operators for valves combined were found to have resulted in approximately the same level of degradation of the AFW System as the turbine drives alone. Pump failures and check valve failures were also significant contributors to system degradation.

For each of the component types, and for the various sources of component failures, the methods of failure detection were designated and tabulated. The most notable feature of this aspect of the study was that Instrumentation and Control (I&C) related failures dominated the group of failures which were detected during demand conditions (as opposed to failures detected as the result of periodic monitoring or routine observations made by operators or other personnel). This finding was corroborated by the detailed review of the operating plant's monitoring practices, in that many of the potential failure sources that were found to not be detectable by the current monitoring practices were related to the I&C portion of the system.

It was also observed that there were a number of conditions related to design basis demands that are not being periodically verified. Examples of these include pumps not being verified at design flow/pressure conditions, turbines not being verified to be capable of delivering required flow at low steam pressures, various control sequences not being checked, and automatic pump suction transfers not being tested.

Another observation made was that some components, or certain parts or aspects of components appear to be tested in excess of what failure history indicates to be appropriate. On the other hand, as can be gathered from comments above, other aspects of certain parts of AFW Systems are either never tested or receive less than thorough testing. It appears that enhanced testing requirements are needed in order to reduce excessive testing while at the same time ensuring that thorough performance verification is conducted periodically.

References

1. Precursors to Potential Severe Core Damage Accidents, NUREG/CR-4674.
2. Aging and Service Wear of Auxiliary Feedwater Pumps for PWR Nuclear Power Plants, NUREG/CR-4597, Volume 1.
3. An Aging Failure Survey of Light Water Reactor Safety Systems and Components, NUREG/CR-4747.

CHAPTER 2 GENERIC AFW SYSTEM DESIGN

2.1 Introduction

AFW System designs in U. S. PWRs vary considerably. This is in part due to the general evolution of design requirements imposed by the NRC, but largely due to the fact that the AFW System is generally designed by the plant's Architect-Engineer. As a result, even two plants with similar NSSS systems which are constructed during the same time frame may have significant differences in AFW System design. In order to provide some insight into AFW System designs, and the bases for those designs, both generic and plant specific discussions are provided. Section 2.3 briefly discusses generic system functional requirements and some typical designs, and is provided as an introductory overview of the AFW System. More specific insight into the design of an individual plant's system is provided in Chapter 3 in which the specific design details are included.

2.2 System Boundaries and Interfacing Systems

In order for the AFW System to accomplish its design requirements, proper functioning of interfacing system components is required. The AFW System interfaces with a number of systems, including, but not limited to:

- Main Feedwater System
- Main Steam Supply System
- Steam Generator Blowdown System
- Emergency Service Water System
- Engineered Safety Features Actuation System
- AC/DC Electrical Distribution Systems

The components which comprise the interface for the AFW System have been reviewed, in part, by this study. The detailed review of a specific plant's AFW System (Chapter 3) included a review of the interfacing components; however, the failure data search (Chapter 4) did not address these interfacing components. The reason that the interfacing components were not included in the failure data search is that the system affected by the failure of these components would typically be assigned as the system to which the components belonged, rather than the AFW System. However, it should be recognized that a failure of an interfacing system component can degrade the associated AFW train(s) just as severely as failure of a component designated as an AFW System component.

2.3 AFW System Functional Requirements and Typical Designs

2.3.1 Generic Functional Requirements

The AFW System's principal role is to support removal of stored and decay heat from the Reactor Coolant System. The Steam Generators act as a heat sink during both normal operation and following reactor trips. During normal operation, the Main Feedwater system provides feedwater to the SGs, where it is converted to steam and then used to drive the main turbine and provide process steam for various plant equipment. During normal power operation, the AFW System is in standby (except when in test). Following

an operating transients or accident, as well as during routine startups and shutdowns* , the AFW system is used to provide a safety related source of water the Steam Generators. The water delivered by the AFW System is heated and vaporized in the Steam Generators. Steam thus generated can be released to atmosphere through the safety related Main Steam Safety Valves or Atmospheric Dump Valves, or to the atmosphere and/or condenser through non-safety related Steam Dump Valves.

The AFW System must not only support the heat removal, but allow the heat removal to take place in a controlled manner, even under design basis accident conditions. There are four general functional requirements of the AFW System:

- Provide flow to intact SGs following design basis transients/accidents
- Isolate flow to faulted or ruptured SGs
- Maintain a liquid barrier between the Reactor Coolant System and the environment following design basis accidents to ensure that any primary to secondary tube leakage is "scrubbed" before release
- Support normal startup and shutdown evolutions

As noted, the AFW System is used, at most plants, in support of normal plant startup and shutdown. However, this is not the primary basis for its design. Rather, it is specifically designed for the mitigation of the consequences of design basis transients and accidents, including Loss of Main Feedwater, Main Feed Line Break, Main Steam Line Break, Small and Large Break Loss of Coolant Accidents, Steam Generator Tube Rupture, and others. In addition, proper functioning of the AFW System is critical to the ability of a plant to deal with an important accident condition, Station Blackout, which has not been historically treated as a design basis accident.

2.3.2 Design Configurations

There is a broad range of AFW System designs in existence at operating plants. Figures 2.1 through 2.3 provide flow diagrams which are representative of the cross section of existing PWR AFW Systems. This section discusses some general design configuration features. Due to the diversity of AFW System designs, it is difficult to adequately depict AFW Systems in general. A compilation of operating plant pump and driver, valve and valve operator, and other general configurational information for Westinghouse and B&W plants is provided in Chapter 5.

2.3.2.1 Pump Suction Sources

Most plants have a dedicated storage tank, commonly designated as the Condensate Storage Tank (CST) that is used to maintain a reserve inventory of high quality water for the AFW pumps. The inventory available for the AFW pumps may actually come from multiple sources, depending upon plant design. For purposes of this discussion, the normal source(s) of water will be referred to as the CST. Plants which are under Standard Technical Specifications have a designated inventory that must be maintained in the CST during Modes 1-3. The CST is safety grade, seismically qualified at some plants, but not at others. Normal system alignment would have the suction flow path from the CST to the

* At some plants, non-safety related Startup Feedwater Systems are available and used to support plant startup and shutdown in lieu of the AFW System.

AFW pumps open, and in fact, manual valves in the suction flow path may be required to be locked open.

The majority of plants also include a backup source of water, normally from the plant's ultimate heat sink system which is commonly called the Emergency Service Water (ESW) System. Depending upon plant design, the ESW may be the safety grade source of water (for example, if the CST is non-safety grade). Switchover from the CST or other normal supply sources to the ESW may be either automatic or manual. Low suction pressure is the normal switchover condition monitored for plants including automatic switchover. Some plants use suction pressure transmitters to provide AFW pump tripping under low suction pressure conditions (it should be noted that this trip function has been removed at several plants, and replaced with an alarm only to avoid spurious tripping). Even for plants which do not use automatic switchover, low suction pressure instrumentation may furnish main control board indication and annunciation to provide the operator with an indication of the need for suction transfer. CST or other normal water source level instrumentation also provides the operator with suction status. For plants with manual switchover only, some provide totally remote switchover capability, while others require local valve realignment.

Check valves are normally included in the normal suction supply lines. These valves are depended upon to prevent flow reversal into the CST in the event that ESW must be used as the suction source. In some cases, where the normal suction sources are non-safety grade, the suction check valve forms the boundary between safety and non-safety grade portions of the AFW System.

2.3.2.2 Pumps

All three flow diagrams (Figures 2.1 through 2.3) indicate two motor driven and one turbine driven pump per plant. This is the most typical configuration; however, there are a number of pump combinations at operating plants. In addition to variations in the number of pumps per unit, the type of drivers vary. There are various combinations of motor, turbine, and diesel driven pumps in the AFW pump population. Among Westinghouse and B&W plants included in the ORNL failure database (discussed in Chapter 4), six different AFW System pump combinations were identified. A summary of general pump and steam generator configuration information for the plants in the failure database is provided in Table 2.1. Plant specific steam generator and pump configuration information is provided in Table 5.A.

Motor driven pumps receive their power from emergency busses (there are some plants which designate one or more non-safety related motor driven pumps as part of the AFW System; however, these pumps were not included in this study). Pump breaker closure not only starts the associated pump, but auxiliary contacts for the breaker are often used to provide control signals to other AFW System features.

Steam for the turbine driven pumps is supplied by one or more (typically two) SGs. There are a number of steam supply control arrangements. Some plants start the turbine by opening a normally closed Trip & Throttle (T&T) valve, located immediately adjacent to the turbine. Other plants leave the T&T valve normally open and start the turbine by opening one or more upstream isolation valves. Some plants have pressure control valves in the steam supply line which limit steam pressure available to the turbine, while at other plants, full steam pressure is available to the turbine (less line and governor losses). Turbine speed, and therefore pump flow, is controlled by turbine governor valve position, which in turn receives control signals which are typically based on turbine speed and, for some

controllers, a flow or other differential pressure sensor (such as steam supply to pump discharge differential pressure).

Some plants include non-safety related pumps that are similar in function to the AFW pumps. Where available, these pumps are used in support of normal startup/shutdown (in some cases, they are referred to as Startup Feed Pumps). While these pumps have not been considered in this study, their availability can have a substantial impact upon the service wear of AFW pumps and other AFW equipment, since the AFW pumps would not be routinely used for startup/shutdown purposes. The non-safety related pumps can also substantially enhance the availability of post-accident secondary cooling. As an example, following the June, 1985 Davis-Besse loss of feedwater and AFW, feed flow to the SGs was ultimately restored by use of a startup feed pump.

2.3.2.3 Pump Discharge and Recirculation Flow

Pump discharge lines include flow paths to the SGs and minimum recirculation flow paths. The recirculation flow may be controlled by orifices, line size, control valves, or a combination of these means. Some plants include both a minimum recirculation flow path and a full flow test loop, both of which recirculate flow to the CST or other suction source. Other plants use a common flow path for both, while others do not have a full flow test loop, but only a mini-flow recirculation path. A tabulation of full flow test loop availability is provided in Table 5.G.

Recirculation flow paths, both of the full flow and the mini-flow variety, may include valves which automatically isolate under certain conditions. For instance, plants with full flow recirculation test loops typically include automatic isolation valves which close in the event that an automatic start signal occurs. Other plants provide for automatic isolation of the mini-flow path in the event that the associated pump is the only available pump or if delivered flow to the SGs is sufficient to provide what has been determined to be adequate for pump protection.

In a number of plants, the miniflow recirculation flow paths include check valves upstream of where the individual pump lines join to form a common recirculation line header. The apparent design function of these valves is to provide train separation, although there are no such valves in some plants. For those plants which do not include the check valves, the apparent rationale is that orifices or other flow limiting devices would limit cross train flow, thereby eliminating the need for train separation offered by check valves. For a sample of plants for which nominal minimum recirculation flow rates were specified in the FSAR, the flow velocities at check valves in the miniflow lines ranged from 1 to 15 ft/sec. While, as noted, the only apparent function of these valves is to provide train separation, those valves which routinely experience flow velocities less than that required for full stroking (estimated to be in the range of roughly 8 to 15 ft/sec, depending upon the specific check valve design), may be fairly susceptible to service wear. Inasmuch as testing, if any, associated with the recirculation check valves is to verify that the required flow rate is supported, substantial degradation or failure of these valves may not be detectable.

Valving between the pumps and the SGs provides for control of individual pump flow, flow to specific SGs, and a means of preventing backleakage from the SGs or from Main Feedwater. The arrangements of valves between the pump discharge and the SGs vary considerably in terms of numbers, operator types, layout configuration, control signal sources, and normal standby position.

Some plants use automatic discharge pressure control valves for motor driven pumps to provide pump runout protection. These valves may be either normally closed or open, and

receive a control signal following pump start. The valve control signal is normally geared toward maintaining discharge pressure or flow at a designated setpoint. The control setting may or may not be adjustable from the main control room. Other plants do not use automatic valve positioning to regulate individual pump flow/discharge pressure; rather, non-adjustable, fixed means, such as cavitating venturis, flow restricting orifices, or valves locked in a throttled position are utilized. For yet other plants, it is not clear, from FSAR descriptions and other information available, what, if any, pump runout protection, other than operator action is available.

Most pump discharge lines include discharge check valves. These valves are depended upon to prevent reverse flow from other pumps as well as to prevent backleakage of main feedwater. For a sample of plants reviewed, the flow velocities that would be experienced at design flow rates for the motor driven pumps ranged from 5 to 12 ft/sec. It should be recognized that when AFW pumps are used during startup/shutdown evolutions, they would normally be run at substantially less than the design flow rates. For the pumps that are used for this service, discharge check valves may be subject to accelerated service wear. Unlike the miniflow check valves, the function performed by these valves is critical to successful system operation.

2.3.2.4 Flow Distribution

Pump discharge line configurations normally allow more than one SG to be fed by each pump (although some two loop plants are arranged such that only one pump normally feeds one SG). All three loop plants are configured such that all three SGs are fed by all pumps, while most four loop plants are designed and normally aligned to allow feeding of all four SGs by a turbine driven pump and feeding of two SGs by each motor driven pump. Control of flow to individual SGs is provided by a variety of combinations. Motor, air, electrohydraulic, and solenoid operated valves are used as flow control devices. There are diverse control designs for the valves. Control valves at some plants are normally closed while corresponding valves are normally open at other plants. Those that are normally closed typically receive an open signal on associated pump start or AFW actuation signal. At some plants, the flow distribution valves automatically modulate to maintain a preset flow or SG level, while at other plants, the valves go to a full open or other fixed position and remain there unless repositioned by an operator.

The flow distribution valves may be used as a part of a faulted SG isolation system, a system which automatically detects and isolates any SG which is depressurized. This system supports the functions of both assuring that intact SGs can receive AFW flow as well as minimizing the adverse impact of feed or steam line breaks on the RCS and Containment. Other plants rely upon flow limiting devices, such as cavitating venturis, on a temporary basis following a faulted SG event, and ultimately upon operator action to detect and then to isolate flow to the faulted SG. Yet other plants depend solely upon operator recognition and isolation of the faulted SG, with no automatic break detection and isolation or fixed flow limiting devices available. It is important to note that the valves used in the AFW System to isolate flow are not normally seat leak tested, even if they are classified as containment isolation valves.

Some plants have dedicated AFW SG nozzles, while the AFW discharge lines at other plants connect with Main Feedwater piping upstream of the SGs. Various combinations of check valves and isolation valves are used to avoid backleakage of hot feedwater or steam into the AFW System. There are typically several check valves, and in some cases, closed isolation valves in series between the pumps and the SGs.

2.3.3 AFW System Starting

AFW Systems are started automatically when monitored plant conditions provide indication that AFW operation is warranted. The specific signals monitored, like all other aspects of the AFW System, vary from plant to plant. There are several sources of automatic starting, however, which are fairly common, including Safety Injection, Low SG Level, Loss of Offsite Power (typically emergency bus undervoltage), Reactor Coolant Pump trip, and Main Feed Pump trip. Typically, automatic start signals will either start AFW pumps immediately, or as a part of load sequencing. In either case, the pumps are usually started within a minute following the start signal initiation.

AFW start signals also actuate other equipment which is crucial to AFW System success. For example, some plants include normally closed discharge valves which must open to allow flow to reach the SGs. These valves receive an open signal on AFW initiation. Other equipment which is not specifically a part of the AFW System may also respond automatically on an AFW start signal. For example, SG Blowdown Isolation valves may receive an automatic closure signal from the AFW start signal, thereby helping to assure that the flow delivered to the SGs can be converted to steam (versus draining off without changing phase).

Manual start capability for all AFW pumps is typically provided at the main control board as well as at the remote shutdown panel. Additionally, local stations may be provided for pump starting and stopping.

A typical logic diagram, showing the origination of AFW start signals and the equipment actuated as a result is provided in Figure 2.4. A detailed discussion of AFW System actuation for a specific unit is provided in Chapter 3.

2.3.4 AFW System Operation

Following AFW System starting, whether as the result of automatic or manual starting, the system responds to both manual and automatic control functions. The sources of the control signals are diverse. Flow to the SGs is controllable through valves that open/close/modulate in response to automatic control and/or manual control signals. These signals may be based on flow, level, or pressure. Turbine driven AFW pump speed is controlled automatically, normally based on flow, differential pressure, speed, and/or other signals. Turbine speed can also normally be controlled by remote manual action.

Typical AFW System design would initiate flow to the SGs automatically at full flow, and require operator action to control or isolate flow. However, as noted previously, some plants do have automatic level controls. Some facilities also have an automatic isolation feature which detects and isolates faulted (depressurized) SGs. Other plants incorporate flow limiting venturis or orifices to prevent excessive flow from being delivered to a faulted SG.

Following a reactor trip, as well as during normal startup and shutdown evolutions in which the AFW System is actuated, the instantaneous flow to the SGs may vary from zero to several hundred gallons per minute. Following a reactor trip, while decay heat load is fairly high, typical practice for a plant with a turbine/motor driven pump combination would be to stop the turbine driven pump following plant stabilization, and then control SG level using only the motor driven pump(s). Under very low decay heat conditions, for

example during routine startup and shutdown, SG feed control practices may vary from plant to plant, and even from operator to operator. For example, if there are no specific procedural requirements, and demand is low, one operator may elect to "batch" feed the SGs by starting and stopping a pump periodically. Another may also "batch" feed, but leave the pump running in recirculation flow in between batching. A third method would be to continuously feed at very low flow rates, while also maintaining recirculation flow. During these low flow periods, the minimum number of pumps possible would be run (the minimum number depending upon plant configuration, and specifically how many SGs can be fed by a particular pump). It should be noted in this context that some plants with non-safety Startup Feed pumps can avoid running at low flow for protracted periods or repeated starting and stopping of the AFW pumps.

Operating guidance and practices for a specific plant are included in Chapter 3.

2.3.5 Example AFW System Requirements for Various Accident Conditions

The various accident scenarios create somewhat different types of demands upon the AFW System. In order to provide some insight into these demands, three types of events, Loss of Main Feedwater, Main Feed Line Break, and Main Steam Line Break will be discussed in relationship to the AFW System functions. In considering these events, it should be remembered that the general role of the AFW System is to support stabilization of the plant at hot standby conditions, and then to support plant cooldown and depressurization to the point where the Residual Heat Removal System can be placed into service. The discussion of these events is intended to serve to illustrate both this general role, and supplementary functions as well.

The following discussions of plant response to various transient/accident conditions are based on general trends noted in the review of the Accident Analysis sections from a number of plants' Final Safety Analysis Reports (FSARs). It should be recognized that the overall response of one plant to an initiating transient may differ substantially from the response of another plant to the same transient conditions. Furthermore, the plant response, as presented in FSAR analyses, is generally overstated (as a result of conservatism built into licensing based analyses), and is heavily dependent upon modeling methodology. As an example, no control system operation is assumed in safety analyses, unless it would be adverse to the analysis results. In reality, operation of control systems, when available, substantially mitigates overall plant response in most cases.

One aspect worthy of note in the review of the figures associated with the transients discussed is the fact that response of the parameters monitored (RCS and SG pressure) is very sluggish with respect to AFW initiation; that is, starting of an AFW pump does not create an immediately observable effect. In contrast, the effect of the lifting of a Main Steam Safety Valve (MSSV) can be immediately seen. There are two reasons for this: relative size and thermodynamic effect. AFW pump capacity is small relative to MSSV capacity. A typical single MSSV is capable of relieving a mass flow rate of roughly two to four times the design mass flow rate of a typical AFW pump. Note that there are several safety valves per SG. Secondly, since the preponderance of heat removal is associated with the vaporization of SG fluid, and since in safety analyses the SG level never falls to a point where no fluid exists, there is no observable change associated with delivery of AFW to the SGs. However, it should be recognized that failure to deliver AFW to the SGs would have substantial impact on the results of any transient, since the RCS heat sink would degrade and eventually be lost.

2.3.5.1 Loss of Main Feedwater

The Loss of Main Feedwater (LOFW) scenario is an event that can be classified as expected; that is, it is to be expected that all plants will suffer at least partial LOFW events several times during plant life. The LOFW event is a heatup type of event (one in which the Reactor Coolant System (RCS) temperature, pressure, and Pressurizer (PZR) level increase in response to the transient), and represents the most general type of demand for the AFW System, that is, to merely provide flow to the SGs for heat removal when the normal feedwater supply is not available.

Total or partial LOFW can be initiated by any one of several circumstances, including Main Feedwater Pump trip, Main Feedwater Control Valve closure, Main Feedwater Isolation Valve closure, and a host of other events. (In turn, these LOFW initiators can occur as the result of a multitude of causes, such as blown fuses, solenoid valve failure, Main Feedwater Pump motor or turbine failure, etc.).

Charts showing typical accident analysis trends of RCS and Secondary pressure following LOFW are presented in Figures 2.5 and 2.6. These parameters are shown because certain key conditions can be readily seen from their curves. Following LOFW, Steam Generator (SG) levels drop, and RCS temperature and pressure begin to increase. Reactor trip could occur on any one of a number of trip signals, such as steam/feed flow mismatch, low SG level, high pressurizer pressure, etc. For total LOFW events, reactor trip would be expected to occur in short order (less than a minute). Following the reactor trip, RCS temperature and pressure would initially drop, but then gradually start to increase due to loss of forced RCS coolant flow (assumed to occur at the time of reactor trip). The AFW system is neither designed to prevent reactor trip nor to prevent the initial heatup response that occurs prior to trip; rather, it serves to mitigate the longer term post-trip heatup.

Following the reactor trip and the associated initial cooldown/depressurization, the RCS pressure increases to the point where the PZR safeties again lift to limit pressure. Secondary pressure increases to reach Main Steam Safety setpoint pressure. Both hot and cold leg temperatures increase due to loss of forced flow. Natural circulation flow develops due to the hot leg/cold leg temperature differential created by the steam generators. Primary to secondary temperature differential may reach 30-40 degrees F. Ultimately, as decay heat input decreases, even a single AFW pump is able to deliver adequate flow to allow heat removal to equal, and then exceed decay heat input. Under the most limiting conditions, from a safety analysis standpoint, where no credit for control functions or for operator intervention is taken, and assuming a limiting single failure, it may be in the range of 10 to 30 minutes following the reactor trip before heat input/heat removal equilibrium is reached. After this point, the RCS could be maintained at roughly Hot Standby conditions (although at an elevated temperature due to natural circulation vice forced circulation conditions), using only AFW and the Main Steam Safety valves. Cooldown can be effected by use of SG Power Operated Relief Valves or Atmospheric Dump Valves.

2.3.5.2 Main Feed Line Break

The response of the plant to a Main Feed Line Break (MFLB) can vary considerably, depending upon a number of variables, and particularly upon the SG design and the location of the break. If the break occurs upstream of a Main Feedwater Isolation Valve (MFIV) or Main Feedwater Isolation check valve, and those components function properly, the plant response will not be considerably different than that for a LOFW event. If the break occurs downstream of a MFIV, plant response can range from that associated with a substantial cooldown to the most severe analyzed heatup event.

If the Main Feedwater nozzle is located in a position such that a break in the line would result in the portion of the SG which is above the operating water level being exposed, the plant response will be a rapid cooldown, and will appear similar to, though not quite as severe as the response to a Main Steam Line Break (MSLB). On the other hand, if the nozzle connection is such that the liquid portion of the SG is exposed, the plant response will differ substantially. The latter type event will be discussed here.

Figures 2.7 and 2.8 provide an indication of the response of RCS and SG pressure following a liquid portion feedline break (again, based on FSAR type accident analyses-not best estimate). Level in the affected SG is lost fairly rapidly, resulting in a reactor and turbine trip. Secondary pressure rises quickly following the turbine trip. At the same time, the broken feedline is a source of depressurization for all SGs, resulting in a rapid turnaround of the pressure spike. Pressure in all SGs continues to drop rapidly until a Main Steam Isolation Signal (MSIS) occurs. Following the MSIS, the SGs are decoupled, and the faulted SG is readily identifiable.

The feedline break serves to both prevent or minimize feedwater flow reaching the SGs as well as to drain the water from the affected SG, thereby reducing the inventory that is available for heat removal (although some heat is removed by the water that is blowing out the break, it is primarily sensible heat, and represents a small fraction of the potential heat removal associated with the heat of vaporization).

From the perspective of the AFW System, the main feature associated with the MFLB event that is different from the LOFW event is that one SG is totally depressurized. The early plant response is somewhat similar to a steam line break (cooldown), but following the MSIS and the decoupling of the SGs, the event becomes a heatup transient similar to the loss of feedwater transient, with the exception that one less SG is available for heat removal. Also, note that unless automatic or manual control takes action to minimize or isolate flow to the faulted SG, very little AFW flow may actually reach the intact SGs, since flow would preferentially go to the low pressure SG.

As a result, various combinations of design features and operator actions are employed to ensure that the intact SGs can be fed following a MFLB. Some plants employ an automatic isolation scheme in which a faulted SG is sensed by process instrumentation and automatically isolated by means of AFW discharge valves. Some other plants rely, at least in part, upon flow limiting devices, such as cavitating venturis, to prevent an excessive amount of flow going to a faulted line (thereby robbing the intact SGs of feed). Other plants depend upon operator action to detect and isolate a faulted SG.

2.3.5.3 Main Steam Line Break

The Main Steam Line Break (MSLB) is a design basis accident which creates a substantially different plant response than LOFW or MFLB. The MSLB causes a rapid cooldown, depressurization, and contraction of the RCS. Using the most limiting assumptions associated with design basis accident analyses, a MSLB may create a sufficient cooldown to cause a return to criticality, even after the reactor is tripped (due to a high negative moderator temperature coefficient). While not required during the early phases of a MSLB, since the break itself causes a substantial cooldown of the RCS, the AFW System, for most plant designs, would be automatically initiated by conditions resulting from the MSLB. Since any flow delivered to the faulted SG would serve to enhance the cooldown, termination of the flow is necessary. Also, if a MSLB were to occur inside containment, a substantial increase in containment temperature and pressure could occur. Any AFW flow delivered to the faulted SG would serve to magnify the

temperature and pressure increase. As in the case of the MFLB, the various combinations of design features and operator actions are required to terminate flow to the faulted SG, although in this case, the need to terminate flow is driven more by the need to avoid excessive cooldown and steam phase to containment than by the need to ensure adequate flow is delivered to intact SGs.

Table 2.1 CONFIGURATION OF PLANTS IN FAILURE DATABASE

CONFIGURATION	NUMBER OF TWO LOOP PLANTS	NUMBER OF THREE LOOP PLANTS	NUMBER OF FOUR LOOP PLANTS	TOTAL
ONE MDP, ONE TDP	5	1	0	6
TWO MDP, ONE TDP	8*	9	20	37
ONE MDP, ONE DDP	0	0	1	1
ONE TDP, ONE DDP	0	0	1	1
TWO TDP	1	0	1	2
THREE TDP	0	2*	0	2
TOTAL	14	12	23	49

	TWO LOOP PLANTS	THREE LOOP PLANTS	FOUR LOOP PLANTS	TOTAL
TOTAL/AVERAGE NUMBER MDPS	17/1.50	19/1.58	41/1.78	77/1.65
TOTAL/AVERAGE NUMBER TDPS	15/1.07	13/1.33	23/1.00	51/1.10

*NOTE: INCLUDES UNITS SHARING ONE OR MORE PUMPS.

FIGURE 2.3 AFW SYSTEM FOR A FOUR LOOP PLANT

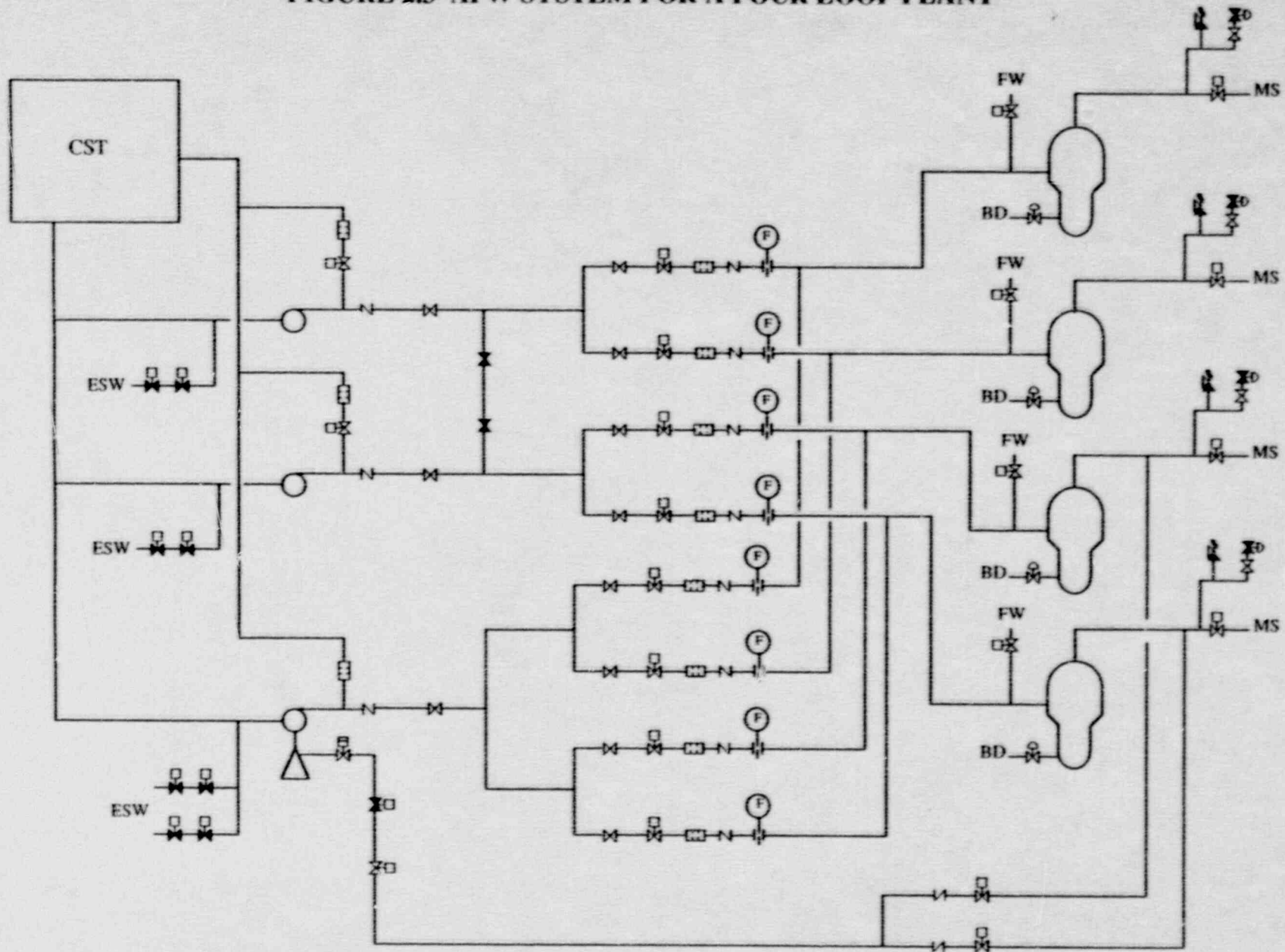


FIGURE 2.4 TYPICAL AFW SYSTEM ACTUATION LOGIC

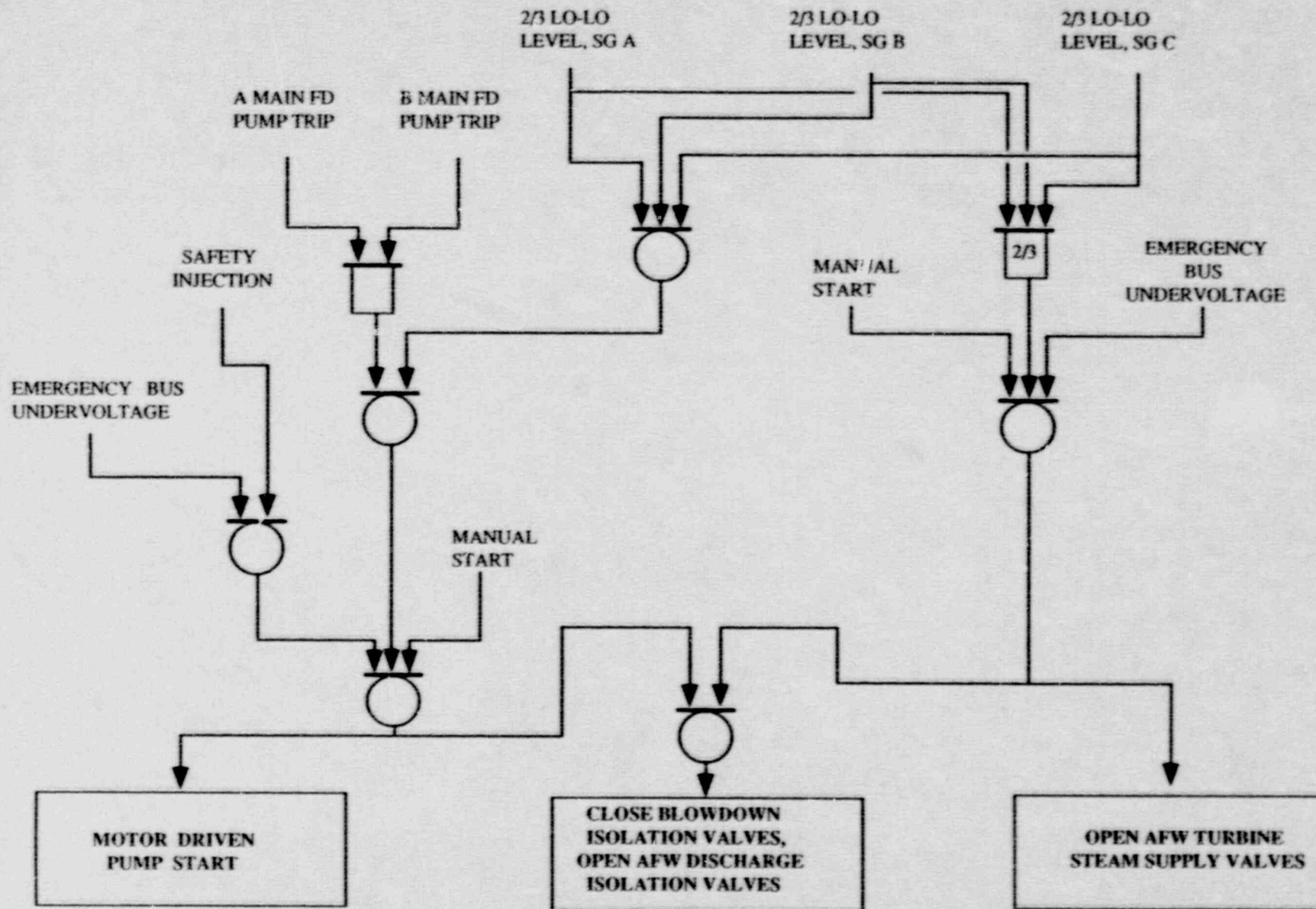


FIGURE 2.5 RCS PRESSURE RESPONSE TO LOSS OF FEEDWATER

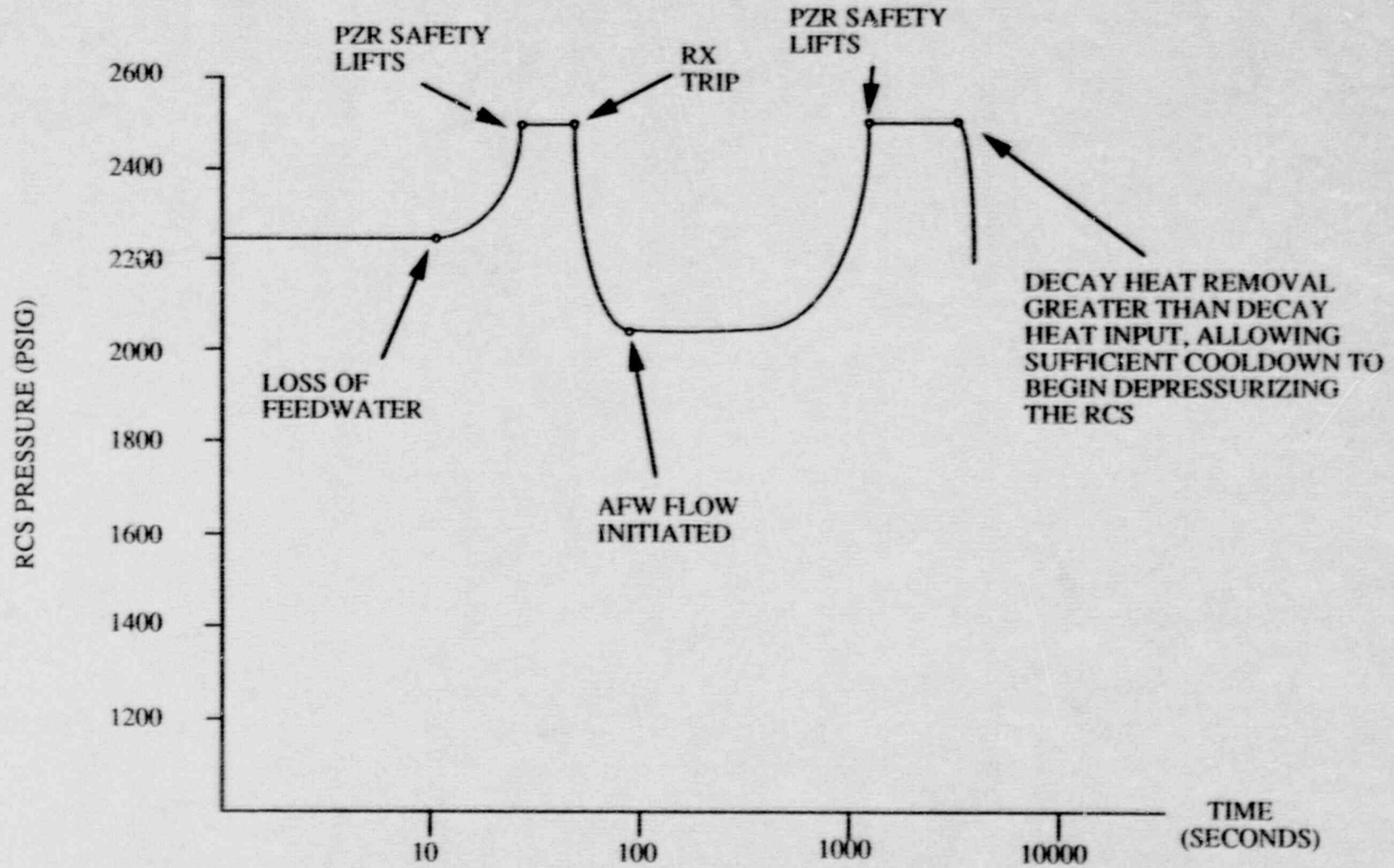


FIGURE 2.6 STEAM GENERATOR PRESSURE FOLLOWING LOSS OF FEEDWATER

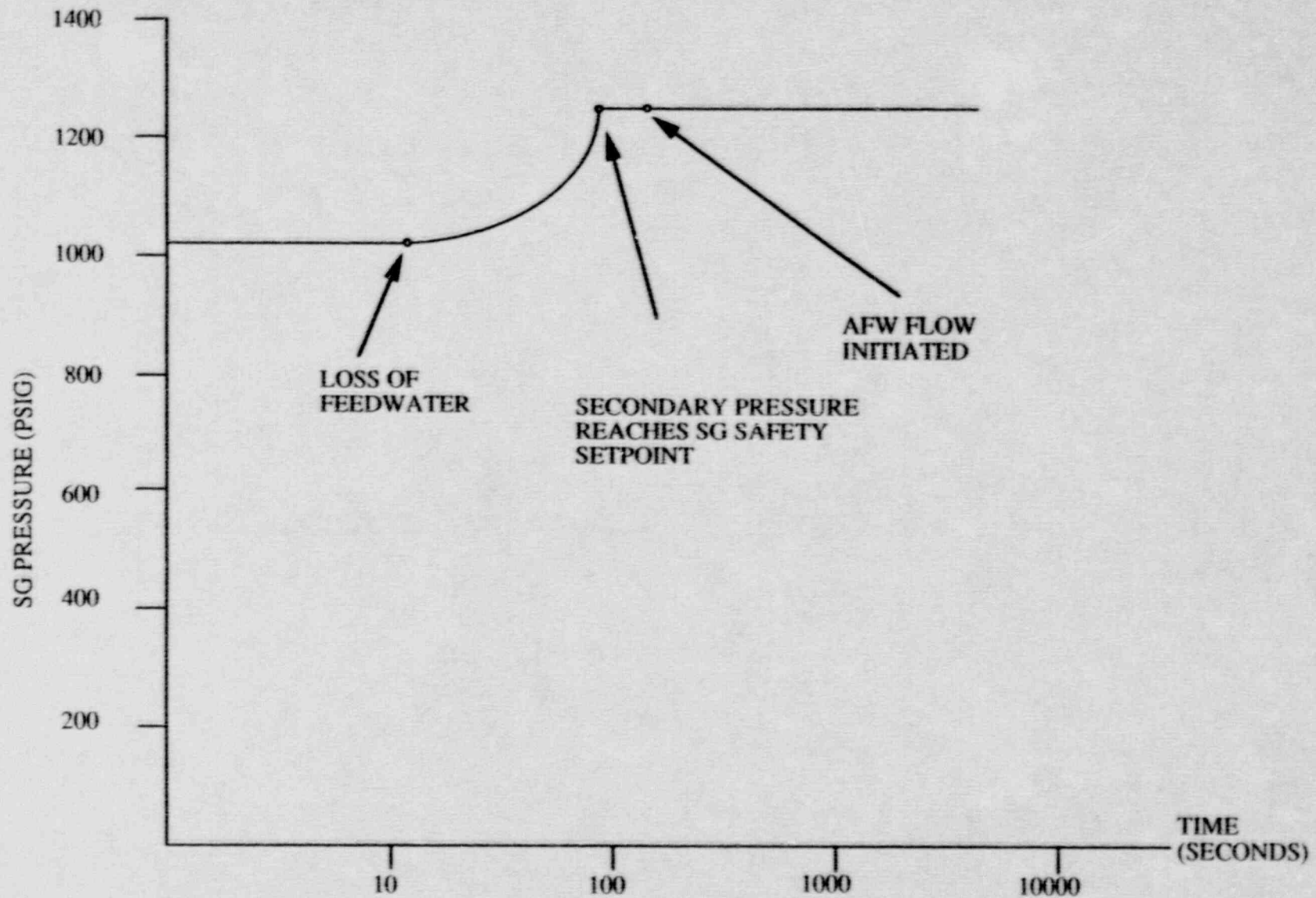


FIGURE 2.7 RCS PRESSURE RESPONSE TO FEED LINE BREAK

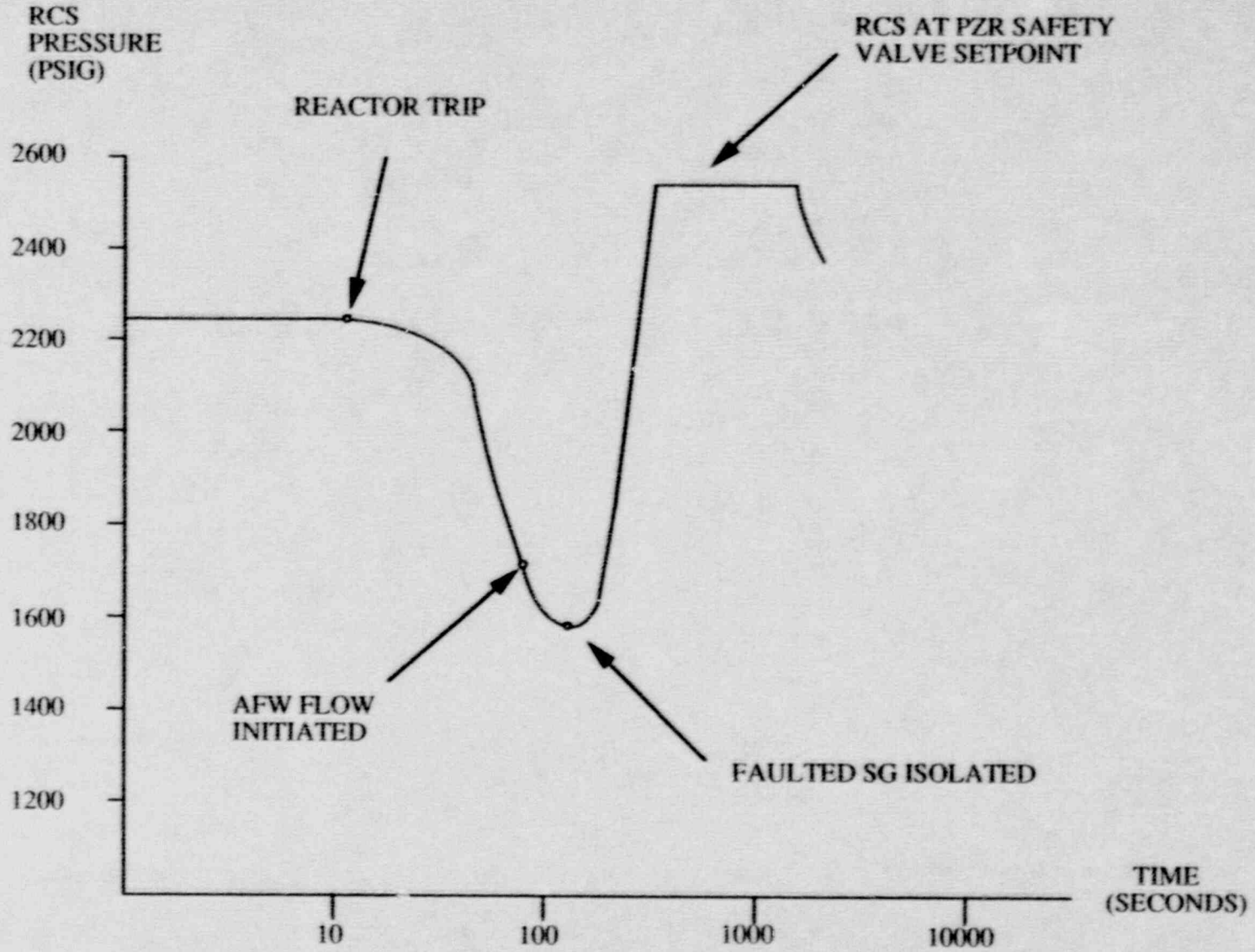
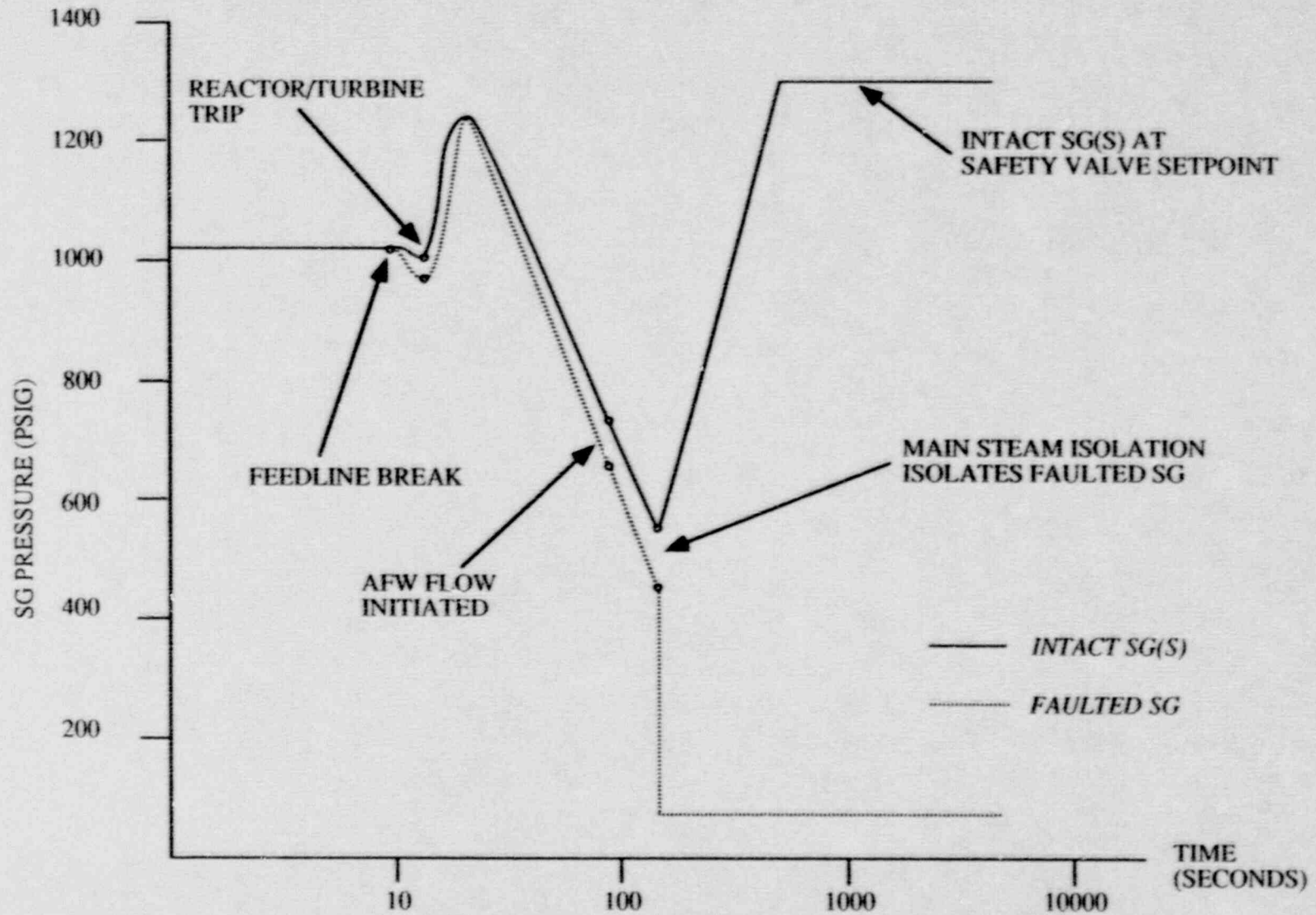


FIGURE 2.8 STEAM GENERATOR PRESSURE FOLLOWING FEED LINE BREAK



CHAPTER 3 REFERENCE PLANT DETAILED DESIGN

3.0. INTRODUCTION

A cooperating utility allowed ORNL to review the details of the AFW design at an operating plant, along with associated operating, surveillance, and maintenance procedures. Further reference to this plant will be as "Plant A". The design of the Plant A AFW system will be discussed in Section 3.1. Section 3.2 provides additional information on Plant A procedural practices.

A simplified system flow diagram of the Plant A AFW system is provided in Figure 3.1. The design requirements and actual design features of each of the major system components will be discussed in detail. The major configuration and design features of the system are:

- Two motor driven pumps, each capable of delivering flow to two SGs
- One turbine driven pump, capable of delivering flow to all four SGs
- The AFW discharge lines connect with the Main Feed headers
- Steam can be supplied to the AFW turbine from either SG A or D
- The normal supply of water is the Condensate Storage Tank, with Emergency Service Water acting as a backup source

There are several AFW automatic start signals. The motor driven pumps (MDP) start on:

- Safety Injection
- Low-Low Level in one SG
- Trip of either Main Feed Pump at $\geq 80\%$ power
- Trip of both Main Feed Pumps (at any power)
- Station Blackout signal

The turbine driven pump (TDP) starts on the same signals, except that Low-Low Level in two SGs must exist for TDP start.

In addition to the pumps starting automatically, other AFW System features are automatically actuated. These will be discussed in detail for each of the specific components.

3.1. COMPONENT DESIGN FUNCTIONS, CONTROLS, AND INDICATION

3.1.1. Pump Suction Check Valves (SCV): C-3, 4, 5

3.1.1.1. Component Function and Design Features

The SCV opens on pump start to allow water from the Condensate Storage Tank (CST) to reach the pump suction. In the event that the CST is depleted, or for other reason a low suction pressure condition exists, the motor operated ESW to AFW pump suction isolation valves open to admit water to the pump suction. When this occurs, the pump SCV closes to prevent backflow of ESW to the CST.

The motor driven pump SCVs are 8-inch swing check valves. The turbine driven pump SCV is a 10-inch swing check valve.

The general arrangement of the pump suction check valves, including approximate distances from the nearest upstream elbow, are shown in Figure 3.2. Note that there are 3-4 nominal pipe diameters between the elbow and the SCVs for the motor driven pumps, while there is about 1 pipe diameter between the elbow and the SCV for the turbine driven pump.

Under the design basis flow conditions of 465 gpm for the motor driven pumps and 920 gpm for the turbine driven pump, the average approach velocities to the SCVs are roughly 3 and 4 ft/sec, respectively. Under test alignment conditions where the pumps are on recirculation flow only, the velocities for both type pumps' SCVs are less than $\frac{1}{4}$ ft/sec. During startup/shutdown support, when the motor driven pumps are run on a continuous basis, the motor driven pump SCVs' would see varying flow conditions, with the bulk of the time on recirculation only, but occasional "batching" flow rates of 165 gpm, which would correspond to a velocity of about 1 ft/sec.

3.1.2. Emergency Service Water (ESW) to Motor Driven Pump Suction Isolation Valves: MOV-1, 2, 3, 4

3.1.2.1. Component Function and Design Features

ESW is the safety grade supply of water for the AFW pumps; the Condensate Storage Tank is the normal supply source, but is non-safety, non-seismic class. The switchover must occur quickly enough so that the pumps are not damaged or air bound due to loss of required suction head. At the same time, inadvertent switchovers should be avoided to prevent the introduction of lake water into the AFW system.

The ESW Supply Valves to the motor driven pumps are normally closed 8-inch gate valves with 480 VAC motor operators (LIMITORQUE SMB-000). The permissives required for the valves to open are: a) Low suction pressure sensed by 2/3 pressure switches in the pump suction header, and b) The associated pump is running. The pump running permissive is provided by pump breaker auxiliary contacts (52S/a).

The suction pressure switches for each of the motor driven pumps are upstream of the manual suction isolation valves (locked open valves) and the suction check valve. A main control board alarm annunciates if any suction pressure switch is "made". There is no time delay associated with the alarm. The relays which energize on the 2/3 low suction pressure logic have a built in 4 second time delay before they provide their part of the permissive to open the valves.

The open coil for the valve motor is deenergized by limit switch (no torque switch in the open coil circuit). The close coil circuit includes a torque switch which is bypassed by a limit switch except for the final 2-3 % of stroke. Thermal overload heaters for the valves have been removed and replaced with jumpers.

Due to the fact that there are few or no occasions when significant flow is delivered through the piping sections between the upstream isolation valves and the ESW headers, the potential for accumulation of Asiatic Clams in the stagnant piping exists. To combat this potential, the plant provides for chlorination (0.2 to 2.0 ppm) of the piping sections whenever the intake temperature exceeds 60 °F. Chlorination on a year round basis is also required for microbiologically induced corrosion control, provided that chlorine discharge limits are not exceeded.

3.1.2.2. Controls

-Main Control Board handswitches (HS-1/2A and HS-3/4A) with "OPEN", "CLOSE", and "AUTO" positions (the CLOSE and OPEN positions spring return to AUTO). Note that MOV-1 and MOV-2 are controlled from a single handswitch, as are MOV-3 and MOV-4.

-Motor Control Center (MCC) handswitches (HS-1/2C and HS-3/4C) with "OPEN", "CLOSE", and "AUTO" positions (the CLOSE and OPEN positions spring return to AUTO).

-Transfer switches at the MCCs with "AUX" and "NOR" positions (XS-3/4 and XS-1/2). The Main Control Board controls are enabled in "NOR" and the MCC controls are enabled in "AUX". The automatic transfer circuit is enabled with the transfer switches in either position.

-Local control panel with "OPEN", "CLOSE", and "STOP" pushbuttons. These controls are not affected by the transfer switch position; however, the STOP pushbutton provides contacts (which are "made" as long as the pushbutton is not depressed) that enable the valve open and close coil seal-in circuits for Main Control Board or MCC control.

3.1.2.3. Indication/Alarms

- Valve position indicating lights at main control board, motor control centers, local control panel
- Main control board annunciation of low suction pressure condition (1/3 logic). Note that the alarm that is lit is labeled "PS-3A COND STG TANK HDR TO AUX FWPS PRESS LOW". The alarm actually comes in if a low suction pressure condition is sensed by 2/3 instruments for any of the three pumps, including the PS-1, PS-2, or PS-3 set.
- Input to the "TRANSFER SWITCH IN AUX MODE" common annunciator
- Status Monitoring System (a system which provides operators, via control room monitor, indication of off-normal conditions for a large number of plant components)
inputs: Valve open; No power to valve operator

3.1.3. ESW to Turbine Driven Pump Suction Isolation Valves: MOV-5, 6, 7, 8

3.1.3.1. Component Function and Design Features

The ESW Supply Valves to the turbine driven pump are normally closed 10 inch gate valves with 480 VAC motor operators (LIMITORQUE SMB-00). The automatic open permissives are : a) Low suction pressure sensed by 2/3 pressure switches in the pump suction header, and b) The turbine driven pump is starting.

The pump starting portion of the permissive originates from a T & T valve stem limit switch which closes when the T & T valve is half open. If a low suction pressure condition exists after the turbine trip and throttle valve has reached the midpoint of its open stroke, a 5.5 second time delay relay (AAA) energizes. Energization of the AAA relay, in turn, closes contacts which cause two other relays (BBB and AAB) to energize. (Note that the AAB relay has another 5.5 second time delay before energization).

The BBB relay causes contacts in the MOV-7 & MOV-8 open coil to close, resulting in the valves starting to stroke open. If the low suction pressure condition clears in the 5.5 seconds between energization of the BBB relay and the energization of the AAB relay, all the relays will deenergize, MOV-7 & MOV-8 will continue to open (due to a seal-in for the open coil), and MOV-5 & MOV-6 will not be affected.

If, however, the low suction pressure condition has not cleared within the 5.5 seconds, the AAB relay will energize, resulting in contact closure which energizes relay CCC, which in turn causes contacts in the MOV-5 & MOV-6 open coils to close, and the valves will then stroke open. In addition, the AAB relay closes a contact which energizes relay BBA, which closes contacts in the MOV-7 & MOV-8 close coil circuit. When the MOV-7 & MOV-8 valves have fully opened, their open coils deenergize, their close coils energize, and the valves stroke back to the shut position. (A similar auto-closure circuit does not exist for MOV-5 & MOV-6.)

The intended result of the sequence is that if the low suction pressure condition does not clear within the 5.5 second period following the start of the opening of MOV-7 & MOV-8, the MOV-5 & MOV-6 valves will open and the MOV-7 & MOV-8 valves will stroke back to the shut position, thereby avoiding cross-train connection while providing the safety grade suction source to the turbine driven pump.

The open coil for each valve motor is deenergized by a limit switch (no torque switch in the open coil circuit). The close coil circuit includes a torque switch which is bypassed by a limit switch except for the final 2-3 % of stroke. Thermal overload heaters for the

valves have been removed and replaced with jumpers.

3.1.3.2. Controls

- Main Control Board handswitches (HS-7/8A and HS-5/6A) with "OPEN", "CLOSE", and "AUTO" positions (the CLOSE and OPEN positions spring return to AUTO). Note that MOV-5 and MOV-6 are controlled from a single handswitch, as are MOV-7 and MOV-8.
- Motor Control Center (MCC) handswitches (HS-7/8C and HS-5/6C) with "OPEN", "CLOSE", and "AUTO" positions (the CLOSE and OPEN positions spring return to AUTO).
- Transfer switches at the MCCs with "AUX" and "NOR" positions (XS-7/8 and XS-5/6). The Main Control Board controls are enabled in "NOR" and the MCC controls are enabled in "AUX". The automatic transfer circuit is enabled with the transfer switches in either position.
- Local control panel with "OPEN", "CLOSE", and "STOP" pushbuttons. These controls are not affected by the transfer switch position; however, the STOP pushbutton provides contacts (which are "made" as long as the pushbutton is not depressed) that enable the valve open and close coil seal-in circuits for Main Control Board or MCC control.

3.1.3.3. Indication/Alarms

- Valve position indicating lights at main control board, motor control centers, local control panel
- Main control board annunciation of low suction pressure condition (1/3 logic). Note that the alarm that is lit is labeled "PS-3A COND STG TANK HDR TO AUX FWPS PRESS LOW". The alarm actually comes in if a low suction pressure condition is sensed by 2/3 instruments for any of the three pumps, including the PS-1, PS-2, or PS-3 set.
- Input to the "TRANSFER SWITCH IN AUX MODE" common annunciator
- Status Monitoring System inputs: Valve open; No power to valve operator

3.1.4. Motor Driven AFW Pumps

3.1.4.1. Component Function and Design Features

Each motor driven AFW pump must start in response to automatic or manual start signals and provide a flow rate of ≥ 440 gpm to two SGs with the SGs at 1085 psig (lowest safety valve setpoint pressure plus 2% accumulation). The flow requirement is based upon accident analysis assumptions.

The motor driven AFW pumps are Ingersoll-Rand nine stage (3HMTA-9) pumps which are provided with three-phase, 6600 volt, 500 hp motors.

The motor breaker closes on the following signals:

- Safety Injection (SI)
- Low-Low Level in one SG
- Trip of either Main Feed Pump at $\geq 80\%$ power
- Trip of both Main Feed Pumps (at any power)
- "Station Blackout" (SB)
- Manual (from the main control board, the pump breaker cubicle, or a local panel)
- Anticipated Transient Without Scram Mitigating System Actuation Circuit (AMSAC)

If proper supply bus voltage is available when an automatic start signal occurs, the AFW pumps will be immediately started. There is a sequencing time delay built into the SB

start signal, which is actually not initiated by a "Station Blackout" (total loss of on-site AC power), but rather by a temporary emergency bus undervoltage condition (commonly referred to as loss of offsite power). In order for the pumps to start, the undervoltage condition must first exist (for at least five seconds), and then clear (when the diesel generator output breaker is closed). There is a time delay of approximately 30 seconds from undervoltage condition initiation until pump starting in the SB portion of the AFW pump starting circuit. The 30 seconds consists of about 10 seconds for the associated emergency diesel-generator to achieve rated speed and reenergize the emergency bus plus a 20 second time delay in the AFW pump breaker closing circuit as a part of diesel load sequencing. Should an SI signal occur during the 20 seconds associated with the AFW timers, the timing sequence will be reinitiated (the other automatic start signals, such as Low-Low SG level, do not affect load sequencing).

It should be noted that either an SI start signal or an SB signal blocks the signals related to Low-Low SG level and Main Feed Pump trip. In the event that control has been switched from the Main Control Board to auxiliary control (6.9 kV switchgear), all automatic start signals, except for SB, are disabled.

In the event that an AFW pump is running (due to either a manual or automatic start signal) at the time that an undervoltage condition occurs, the pump is tripped, and then subsequently automatically sequenced on to the emergency bus, as described above. During the time period while an undervoltage condition exists on the emergency bus, manual pump start is blocked; however, once the bus is reenergized, manual start capability is restored.

The pump motors are provided with electrical fault protection by time and instantaneous overcurrent relays, as well as neutral overcurrent relays.

Minimum flow protection is provided by a recirculation line with a flow restricting orifice. The design flow through the recirculation line is 25 gpm (per pump). Reference flows (for pump inservice testing) are 34.2 and 31.5 gpm for the A and B pump, respectively.

Design runout protection for each pump is provided by a cavitating venturi. The venturi is sized to limit flow through it to 650 gpm (limiting total pump flow to approximately 675 gpm, including recirculation flow).

Based on pump and system head curves (from design calculations), the motor driven pumps are capable of delivering 462 gpm to the SGs with the SGs at 1085 psig (Note that the 462 gpm to the SGs includes an allowance for 25 gpm recirculation flow). Thus, the pumps have a 5% nominal design flow margin relative to safety analysis requirements.

Pump NPSH protection is offered by an automatic switchover from the normal suction source, the Condensate Storage Tank, which is a non-safety, non-seismic source, to the safety grade, seismically qualified Emergency Service Water System. The automatic transfer scheme requires that a low suction pressure condition (2 psig) be detected by 2/3 pressure switches, and that the associated pump be running (as indicated by the closure of pump breaker auxiliary contacts 52S/a). There is a 4 second time delay built into the automatic transfer circuit to avoid spurious transfer. The valves that are automatically opened for the suction transfer are 480 VAC motor operated valves which are powered off of the same train as the associated pump.

The pump motor includes auxiliary breaker contacts which provide inputs to various

indication and control functions:

- Each of the associated motor driven pump level control and bypass level control valve circuits have two sets of contacts that are affected. One set opens on pump start (52S/b) to deenergize the level control valve solenoid, thereby allowing the valve to modulate; the other set closes on pump start (52S/a) to provide a portion of the logic necessary to accomplish the automatic transfer from level control valve control to bypass level control valve control (the other portion of the logic is made up by a pressure switch).
- An auxiliary contact (52S/b) opens on pump start to provide a closure signal to the SG blowdown isolation valves
- Each alternate suction supply isolation valve open circuit has a pump motor auxiliary contact which closes on pump start (52S/a) to provide a portion of the logic necessary to accomplish the automatic opening of the valve (the other portion of the logic is made up by operation of 2/3 of the associated suction pressure switches).
- An auxiliary contact opens on pump start (52S/b) to deenergize a relay (1X) which in turn blocks a continuing closure signal to the breaker.
- Pump status lights and monitoring system inputs receive inputs from other auxiliary contacts.

3.1.4.2. Controls

The Main Control Board control switches for the AFW motor driven pumps have the following positions:

- START (With spring return to AUTO)
- STOP (With spring return to AUTO)
- AUTO
- PULL TO LOCK

Pump start and stop controls are also provided at the pump motor switchgear cubicle and at a local control panel. A transfer switch is provided at the switchgear cubicle to allow transfer from Main Control Board control to auxiliary control. With the transfer switch in the Normal position, the pump control at the Main Control Board is enabled; in the Auxiliary position, control at the pump switchgear cubicle is enabled. The local control panel controls are always enabled, regardless of transfer switch position.

3.1.4.3. Indication/Alarms

- Motor ammeters located at Main Control Board and at motor switchgear cubicle
- Overcurrent Annunciator
- Pump motor breaker indicating lights at Main Control Board and motor switchgear cubicle:
 - Green: Breaker open (Pump off)
 - Red: Breaker closed (Pump running)
- White light at Main Control Board to indicate either an overcurrent condition or motor starting lockout logic failure
- Input to the "TRANSFER SWITCH IN AUX MODE" common annunciator
- Pump discharge pressure
- Individual SG header flow (note that the flow being monitored includes flow from the turbine driven pump, but is labeled as "MOTOR AFWP FLOW")
- Status Monitoring System inputs: Pump "RUNNING", Pump handswitch in "PULL TO LOCK", Pump "PWR OFF" (Indicates no control power to pump breaker or breaker in racked out position)

3.1.5. Turbine Driven AFW Pump

3.1.5.1. Component Function and Design Features

The Turbine Driven (TD) AFW pump provides a diverse means of delivering AFW to the SGs with no reliance on AC power (with the exception of 120 VAC instrument busses which are energized by DC busses through an inverter). The turbine is started by opening of the Trip and Throttle (T&T) valve, which occurs in response to several automatic signals:

- Safety Injection *
- Station Blackout Signal (from two relays on either Train A or Train B)*
- Lo-Lo Steam Generator Level in 2/4 Steam Generators *
- Trip of both Main Feed Pumps at any power level
- Trip of either Main Feed Pump at > 80% power
- Anticipated Transient Without Scram Mitigating System Actuation Circuit (AMSAC)

*Safety Related start signals

The turbine driven AFW pump is an Ingersoll-Rand five stage (3HMTA-5) pump which is driven by a non-condensing turbine (Terry Turbine, type GS-2) at a nominal operating speed of 3970 RPM. Included as an integral part of the turbine drive are the DC motor operated T&T valve, a hydraulic governor valve and associated governor control circuitry.

The T&T valve can be used, as its name implies, for both throttling and overspeed protection purposes. However, it is not normally used for throttling.

The T&T valve automatically closes for the following conditions:

- Electronic Overspeed Trip (4300 RPM)
- Mechanical Overspeed Trip (4900 RPM)
- Failure of the turbine driven pump to develop 100 psig discharge pressure within 60 seconds after the T&T valve opens. This closure is provided to allow automatic transfer of the steam supply source from Steam Generator A (normal source) to Steam Generator D (alternate source).

The overspeed tripping not only protects the turbine itself, but provides inherent pump runout and discharge piping overpressurization protection as well. Both the electronic and mechanical overspeed trips are accomplished by unlatching the T&T valve from its operator. In the case of the electronic overspeed trip, the motor operator automatically drives to the closed position following the trip and relatches the valve. If the open signal is still present, the valve will automatically reopen. For the mechanical overspeed trip, the valve motor will also automatically drive shut following the trip, but local manual reset of the mechanical trip lever is required before the valve can be reopened. Both the electronic and the mechanical overspeed trips are annunciated in the main control room.

In the event that the turbine driven pump fails to develop 100 psig discharge pressure within 60 seconds after the T&T valve begins to open, an automatic transfer of steam supply source occurs. The sequence involves driving the T&T valve shut, closing the normal steam supply valve (MOV-11), opening the alternate steam supply valve (MOV-12), and then reopening the T&T valve. This entire sequence is accomplished automatically. See the discussion for MOV-11 and MOV-12 for further details of the automatic steam supply transfer.

The thermal overload switches for the T&T valve motor operator are bypassed if any

automatic open signal is present (note that the switches are bypassed in both the open and close direction, as long as one of the automatic open signals is present).

The torque switch in the open direction is bypassed for the full stroke for all automatic and manual open strokes. The torque switch in the closed direction is bypassed except for the final 2-3% percent of stroke.

T&T valve stem limit switches provide control and indication inputs to several support functions associated with the AFW system:

- Enable the ramping function of the governor valve control circuit
- Provide a start signal to the turbine driven pump room ventilation fan
- Start the 60 second timer for the automatic steam supply transfer circuit
- Enable the automatic closure feature for the valve's motor operator in the event of an overspeed trip
- Provide close signal Steam Generator Blowdown isolation valves
- Provide a permissive signal to allow opening of the ERCW isolation valves in the event of low suction pressure
- Local and main control board indication of valve position

Turbine speed is normally controlled by the turbine governor valve (GV). The governor valve is a 3-inch hydraulically operated plug valve with a Woodward EG governor (Figure 3.4.A provides a simplified schematic of the governor valve control configuration). Varying hydraulic pressure is exerted on the governor valve remote servo piston by the governor's hydraulic actuator. Oil pressure for the actuator is developed by an internal gear driven pump, which is driven off of the turbine shaft (the turbine lube oil pump, which is also shaft driven, supplies oil to the governor actuator). The oil pressure delivered by the actuator to the remote servo is controlled by an electrical input signal to the actuator which comes from the governor's electric control box.

During steady state operation of the turbine, there are three summed signals that make up the net signal delivered to the actuator: 1) a motor operated potentiometer provides a minimum control setpoint (positive input); 2) a ramp generator/signal converter (RGSC) provides a positive input signal which is based upon pump discharge flow; and 3) a negative feedback signal from a turbine speed sensor. The RGSC also provides a mechanism for controlled ascension from idle to normal operating speed by varying its portion of the input. The initial signal output is an idle speed signal. As the T&T valve opens, a limit switch initiates a ramp signal which gradually increases the RGSC output over roughly a 15 second period, allowing the turbine speed to increase accordingly until it can be controlled by the steady state signals (see Figure 3.4.B).

The RGSC has an internal low signal selector which results in its output being based upon the lesser of the ramp signal or the flow signal, which is an input to the RGSC. Thus, during startup, the ramp signal increases to the point where it exceeds the flow based signal, and from that point on, the three steady state signals noted above are controlling. The general process associated with turbine startup from standby to normal operating speed is explained below.

In standby conditions, the GV is normally held in the full open position by springs in the servo-piston/GV linkage. There is no hydraulic pressure, since the source of hydraulic pressure originates from the oil pump, which is driven off of the turbine shaft. When the trip and throttle (T&T) valve begins opening, the turbine begins to roll, and the shaft driven oil pump is able to develop discharge pressure. Since the governor valve repositioning from full open to the control position depends upon the development of the discharge pressure, there is an associated initial lag in speed control development.

This can be seen in Figure 3.4.B. Initially turbine speed increases rapidly until the governor valve actuator develops pressure and starts to close the valve in response to the low positive demand signal associated with the idle speed signal in conjunction with the rapidly increasing negative feedback from turbine speed (Section "A" of Figure 3.4.B). As the governor valve closes, the speed increase is halted and speed is reduced to the idle speed (Section C). As the T&T valve continues to open, the ramp is initiated by a stem actuated limit switch, and the RGSC output signal gradually increases (Section D) to the point where the steady state speed associated with balanced flow and speed signals is reached (Section E).

Normally, turbine speed will be controlled automatically, as described above, following an automatic turbine start. However, turbine speed, and hence total pump flow can be manually controlled by use of a controller at the Main Control Board (MCB). In order for the controller to be used in manual following an automatic start, the MCB control switch must initially be transferred to an "Accident Reset" position, and then pulled to its manual position. It can then be turned to either increase or decrease the signal being sent from the flow controller to the turbine speed control circuit.

An exception to the switch to manual control occurs in the case of automatic pump start upon the loss of either main feed pump with the plant at greater than 80% power. In this case, the turbine driven pump flow control cannot be put in manual (the "Accident Reset" relay is nulled by an open contact in the controller input). However, the open contacts reclose once plant power has decreased to less than 75%, restoring the "Accident Reset" capability. Note that the 80% and 75% power related actions depend upon non-safety related equipment (such as non-safety pressure sensors, electrical contacts, and power supply).

The pump design nominal capacity is 880 gpm, 2600 ft. total developed head with the turbine operating at 3970 RPM and the steam generators at 1085 psig. As pressure in the steam generators is reduced, the turbine driven pump capability decreases until the nominal design capacity is 525 gpm, 325 ft. total developed head with the steam supply source at 125 psig, with turbine speed at 2200 rpm. The flows cited do not include minimum recirculation line flow, which is nominally 40 gpm. It should be noted that manual speed control is required as steam supply pressure is reduced.

Pump NPSH protection is offered by an automatic switchover from the normal suction source, the Condensate Storage Tank, which is a non-safety, non-seismic source, to the safety grade, seismically qualified Emergency Service Water System. The automatic transfer scheme requires that a low suction pressure condition exist (13.9 psig on 2/3 pressure switches), and that the T&T valve has reached at least the half-open point of its stroke. There is a 5.5 second time delay built into the automatic transfer circuit to avoid spurious transfer. See the discussion for MOV-5, 6, 7, and 8 for further details of the automatic suction source transfer.

3.1.5.2. Controls

- Main Control Board valve control handswitch with "CLOSE", "OPEN", and "NOR" (Normal), with a spring return to "NOR". With the switch in "NOR", this switch has no impact on the valve automatic function.
- Main Control Board valve trip pushbutton with "TRIP" and "NOR" (Normal) positions, with spring return to "NOR". Depressing the pushbutton has the same effect as an electronic overspeed trip.
- Main Control Board Controller for turbine driven pump speed/flow control with both Manual and Auto positions (in for Manual, out for Auto). In Manual, turbine speed (and hence pump flow) can be raised or lowered. Accident Reset positions are provided

to allow resumption of manual control following an automatic start of the turbine.

- Transfer switch located at a local control panel with "AUX" and "NOR" positions, which allows transfer of T&T valve control to local. It should be noted that with the control transferred to local, all of the valve automatic open functions, as well as the electronic overspeed trip are blocked.

- Pushbuttons at local control panel to "OPEN", "CLOSE", and "TRIP" the T&T valve (these pushbuttons are only enabled if the transfer switch is in the "AUX" position).

- There is another local control pushbutton, labeled "STOP" which can be used to interrupt T&T valve stroking at any point in the open or close stroke. When this pushbutton is in the normal, released position, it provides contacts which must be "made" for any open or close strokes to occur.

- Motor Operated Potentiometer located near the turbine driven pump which allows some control over turbine speed. This control would normally only be used in setting the governor minimum control setpoint.

3.1.5.3. Indication/Alarms

- T&T valve position indicating lights at main control board and local controls

- Annunciator for electronic overspeed trip

- Annunciator for mechanical overspeed trip

- Status Monitoring System signal for: T&T Valve open; No power to T&T Valve; No power to speed control (this would also indicate no power to automatic suction source transfer relays)

- Turbine driven pump flow controller MANUAL/AUTO indicating lights at main control board

- Turbine driven pump flow indication at main control board and at local controls

- Reference minimum control speed (from Motor Operated Potentiometer input to turbine speed control circuit) at main control board and at local controls

- Turbine speed indication at main control board and at local controls

- Indicating light at Auxiliary Control Room panel for the AMSAC test circuit

3.1.6. Pump Miniflow Check Valves (MCV): C-6, C-8, C-10

3.1.6.1. Component Function and Design Features

The MCVs are 1-1/2 inch swing check valves that open on pump start to allow a portion of the pump discharge flow to be recirculated to the Condensate Storage Tank. The check valves provide train separation for the three pump recirculation lines (the recirculation lines join to form a common recirculation header).

Nominal flow rates for the motor and turbine driven pumps are 25 gpm and 40 gpm, respectively, with flow being primarily limited by breakdown orifices in each recirculation line. At these flow rates, the average flow velocities are about 6 ft/sec for C-6 and C-8 and 9 ft/sec for C-10.

It should be noted that the flow rates provided by the minimum flow lines are substantially less than the continuous flow currently specified by the pump vendor for the pumps (for example, the current specified continuous minimum flow rate for the motor driven pumps is 170 gpm). As is the case for AFW systems at most operating plants, the minimum flow rates allowed by the recirculation orifices are sufficient to prevent overheating, but not sufficient to provide protection against pump degradation from low flow operation.

3.1.7. Common Miniflow Check Valves (CMCV): C-1, C-2

3.1.7.1. Component Function and Design Features

The CMCVs are 3 inch swing check valves that must open on pump start to allow a portion of the pump discharge flow to be recirculated to the Condensate Storage Tanks (CST).

Under most AFW test or operating conditions, the CMCVs see extremely low flow rates, with average flow velocities of about 0.6 ft/sec. Even under the maximum test conditions (associated with "full" stroking of the CMCVs), the flow velocities would be less than 5 ft/sec.

3.1.8. Pump Discharge Check Valves (DCV): C-7, C-9, C-11

3.1.8.1. Component Function and Design Features

The DCVs are 6-inch swing check valves which are normally closed in standby condition. The DCV opens on associated pump start to allow pump discharge flow to proceed through the flowpaths to the SGs. The DCV for a particular pump, along with an additional check valve in the pump discharge flowpath (level control valve check valve), prevents flow reversal from another pump in the event a pump fails to start. The DCVs also prevent, along with other check valves and the normally closed level control valves, backleakage from main feedwater during normal operation.

The layout of the discharge check valves is shown in Figure 3.3. At design flow rates (440 gpm for the motor driven pumps and 880 gpm for the turbine driven pump), the average velocities at the check valves are about 5 ft/sec for C-7 and C-9 and 11 ft/sec for C-11.

3.1.9. Motor Driven AFW Pump Level Control Valves (MDLCV): LCV-1/1A, LCV-3/3A, LCV-5/5A, LCV-7/7A

*Note: Valves with the "A" suffix to the number will be referred to as "BMDLCV" (bypass MDLCV)

3.1.9.2. Component Function and Design Features

The MDLCV's and the BMDLCV's are normally closed, with controls in "AUTO" in standby condition, and open/modulate following associated pump start. Steam Generator level of 33% is automatically maintained by the air operated valves.

If a pressure of less than 400 psia downstream of the valves is sensed with the associated pump running, an automatic transfer from the MDLCV's to the BMDLCV's is initiated. The purpose of the transfer from the 4-inch MDLCV's to the 2-inch BMDLCV's is to prevent excessive pressure drop across the 4-inch valves.

In addition to responding automatically to allow flow to intact SG's following an AFW actuation signal, the operator must be able to regain manual control of the MDLCV's and BMDLCV's following certain design basis accidents (Feedline or Steamline Breaks). This is necessary to ensure that intact SG's can be fed as well as limiting the extent of containment pressurization and Reactor Coolant System Cooldown.

The normally closed MDLCV's fail open on loss of air or control signal power. On loss of solenoid power, the valves modulate, based upon control signal input. Associated

pump breaker auxiliary contacts (52S/b) open when the pump starts and deenergize the MDLCV solenoids, allowing the valves to modulate.

The normally closed BMDLCV's fail closed on loss of air or solenoid power. On a loss of control signal, the BMDLCV's will go full open (if solenoid energized) or full closed (if solenoid deenergized). The automatic transfer from the MDLCV's to the BMDLCV's occurs if a pressure of less than 400 psia downstream of the valves exists (low pressure condition must exist for 15 seconds to enable the automatic transfer).

Steam Generator level can be manually controlled after any accident signal by taking the valve's handswitch first to "Accident Reset", and then to "Manual" or "Manual Bypass". In "Manual", the MDLCV position can be manually controlled from the control room. In "Manual Bypass", the MDLCV's will be closed, but the BMDLCV's will modulate in response to manual adjustment from the control room.

An exception to the switch to manual control occurs in the case of automatic pump start upon the loss of either main feed pump with the plant at greater than 80% power. In this case, the MDLCV's cannot be put in manual (the "Accident Reset" relay is nulled by open contacts in the controller input); however, the switch to "Manual Bypass" can be made with the result of the MDLCV going closed and the BMDLCV responding to manual adjustment from the control room. In addition, the open contacts reclose once plant power has decreased to less than 75%, restoring the "Accident Reset" capability. Note that the 80% and 75% power related actions depend upon non-safety related equipment (such as non-safety pressure sensors, electrical contacts, and power supply).

3.1.9.3. Controls

- Main Control Board switches for the MDLCV's and BMDLCV's (HS-1A, 3A, 5A, 7A) are dual switch sets. The upper switch has the following positions: "MANUAL", "MANUAL BYPASS", and "AUTO (DEPRESS FOR ACC RESET)". The switch depression for accident reset has a spring return to "AUTO". The lower switch, which is enabled when the upper switch is in "MANUAL" or "MANUAL BYPASS" only, has "RAMP OPEN" and "RAMP CLOSE" positions, with spring return to center.
- Transfer switches for each valve set are located at the Auxiliary Control Panel (ACP). Transferring to the ACP has the same effect on the controller as an accident signal, in that the controller will switch from manual to automatic level control.
- A Level Indicating Controller (LIC-1, 3, 5, 7) is provided for each valve set at the ACP. It is via these controllers that the automatic level control setpoint is established.

3.1.9.4. Indication/Alarms

- Valve position indicating lights (for both MDLCV's and BMDLCV's) at main control board
- Valve controller MANUAL or AUTO indicating lights at main control board
- Loop level indication at main control board
- High and low SG level alarms at main control board
- Input to the "TRANSFER SWITCH IN AUX MODE" common annunciator
- Status Monitoring System input to indicate that solenoids are deenergized, allowing MDLCV's to modulate.

3.1.10. Turbine Driven Pump Level Control Valves (TDLCV): LCV-2, 4, 6, 8

3.1.10.1. Component Function and Design Features

The TDLCV's, which are normally closed 3-inch globe valves with controls in "AUTO", open/modulate following pump start. Steam Generator level of 33% is automatically maintained by the air operated valves. Individual TDLCV's automatically close if a pipe break downstream of the pertinent valve is sensed. During normal operation, the TDLCV's, along with in-series check valves, prevent backleakage of main feedwater into the AFW.

The normally closed TDLCV's fail closed on loss of air or control signal power. An accumulator is provided to allow valve modulation in the event of loss of control air. On loss of solenoid power, the valves modulate, based upon control signal input. The TDLCV solenoids are deenergized when turbine driven pump discharge pressure, as sensed by pressure switches PS-10 (for LCV-6 and 8) and PS-11 (for LCV-4 and 2), reaches 100 psig.

In order to provide pipe break protection, two pressure switches are located downstream of each TDLCV (e.g. PS-18 & 19 for LCV-2). If either of the two pressure switches closes (setpoint = 100 psia), the associated TDLCV's solenoid will be energized, resulting in valve closure. Note that a 30 second time delay, beginning with initial solenoid deenergization, is built into the auto-closure circuit. If the TDLCV handswitches are in manual prior to an automatic pump start, the controllers will automatically transfer from manual to automatic. Steam Generator level can be manually controlled after any accident signal by taking the valve's handswitch first to "Accident Reset", and then to "Manual".

An exception to the switch to manual control occurs in the case of automatic pump start upon loss of either main feed pump with the plant at greater than 80% power. In this case, the TDLCV's cannot be put in manual (the "Accident Reset" relay is nulled by open contacts in the controller input). However, once plant power has decreased to less than 75%, the open contacts reclose, allowing restoration of the "Accident Reset" function and the subsequent transfer to manual. Note that the 80% and 75% power related actions depend upon non-safety related equipment (such as non-safety pressure sensors, electrical contacts, and power supply).

3.1.10.2. Controls

-Main Control Board switches for the TDLCV's (HS-2A, 4A, 6A, and 8A) are dual switch sets. The upper switch has the following positions: "MANUAL" and "AUTO (DEPRESS FOR ACC RESET)". The switch depression for accident reset has a spring return to "AUTO".

The lower switch, which is enabled when the upper switch is in "MANUAL" only, has "RAMP OPEN" and "RAMP CLOSE" positions, with spring return to center.

-Transfer switches for each valve are located at the Auxiliary Control Panel (ACP). Transferring to the ACP has the same effect on the controller as an accident signal, in that the controller will switch from manual to automatic level control.

-Level Indicating Controllers (LIC-2, 4, 6, and 8) are provided for each valve set at a local control panel, located just outside of the turbine driven pump room. It is via these controllers that the automatic level control setpoint is established.

3.1.10.3. Indication/Alarms

-Valve position indicating lights at main control board

-Valve controller MANUAL or AUTO indicating lights at main control board

- Pipe break detection indication at main control board
- Loop level indication at main control board
- High and low SG level alarms at main control board
- Input to the "TRANSFER SWITCH IN AUX MODE" common annunciator
- Input to Status Monitoring System to indicate that solenoids are deenergized, allowing valves to modulate

3.1.11. Level Control Valve Check Valves (LCVVCV): C-12, 13, 14, 15, 16, 17, 18, 19

3.1.11.1. Component Function and Design Features

The LCVVCVs are 4-inch swing check valves that open to allow pump discharge flow to reach the SGs. The LCVVCVs, along with pump discharge check valves, prevent flow reversal from another pump in the event a pump fails to start. The LCVVCVs also prevent, along with the level control valves and the pump discharge check valves, backleakage from hot, pressurized main feedwater during normal operation. The LCVVCVs form a pipe class boundary consistent with the latter function; piping downstream of the LCVVCVs has design pressure and temperature ratings of 1085 psig and 600 degrees F, while piping upstream of the LCVVCVs is rated at 1650 psig and 120 degrees F.

Under design basis flow (220 gpm) conditions, the average velocity in the 4-inch piping at the LCVVCV is approximately 6 ft/sec. At the "batching" flow rate used in support of shutdown/startup evolutions of 75 gpm, the velocity is approximately 2 ft/sec.

The turbine driven pump LCVVCVs are located in a run of piping and valves which would greatly contribute to flow turbulence in the vicinity. A simplified schematic of the layout (not to scale) is shown in Figure 3.5. As can be seen, the LCVVCV is located immediately downstream of the LCV, and there are 90 degree elbows in close proximity to isolation valves located just upstream and downstream.

The motor driven LCVVCVs are not symmetric in arrangement. The "A" and "B" motor driven pump LCVVCVs are arranged as indicated in Figure 3.6. As can be seen in the Figure, the "A" pump LCVVCVs would be subject to more turbulence due to the elbow located just (approximately a foot) upstream.

3.1.12. Steam Generator B and C AFW to Main Feed Check Valves (MFCV): C-21, C-22, C-24, and C-25

3.1.12.1. Component Function and Design Features

The MFCVs open to allow pump discharge flow to reach the SGs. The MFCVs (along with the level control valves, level control valve check valves, and the pump discharge check valves) prevent backleakage from hot, pressurized main feedwater during normal operation. The MFCVs are located inside containment. There are no comparable valves in the AFW to SG A and D Main Feed lines (the AFW to Main Feed connection for these SGs is outside of containment).

The MFCVs are 4-inch swing check valves. Under design basis flow (220 gpm) conditions, the average velocity in the 4-inch piping at the MFCVs is approximately 6 ft/sec. At the "batching" flow rate used in support of shutdown/startup evolutions of 75 gpm per SG, the velocity is approximately 2 ft/sec. The piping arrangement for the MFCVs is depicted in Figure 3.7. The upstream MFCV is located immediately

downstream of an elbow, and the second MFCV is located approximately 4 inches downstream.

3.1.13. Main Feedwater Check Valves (FWCV): C-20, 23, 26, and 27

3.1.13.1. Component Function and Design Features

The FWCVs must close in the event of loss of main feedwater flow to ensure that adequate AFW flow is delivered to the steam generators.

The FWCVs are 16-inch swing check valves. The normal, full power flow condition for each FWCV is almost 9000 gpm, with an average velocity of about 18 f/sec. This velocity should be sufficient to maintain the FWCVs in the fully open position, and avoid fluttering, as long as the plant is operated at full power conditions.

3.1.14. Feedwater Isolation Valves (FWIVs): FWIV-1, 2, 3, 4

3.1.14.1. Component Function and Design Features

The FWIVs, which are normally open to allow passage of feedwater to the SGs, close automatically in response to the following signals:

- Any Safety Injection signal
- Hi-Hi Level (on 2/3 channels) in the serviced SG
- Reactor Trip and Low Tavg (2/4 channels)

From the standpoint of the AFW System, the principal purpose of the FWIVs is, along with check valves located downstream of the FWIVs, to provide an isolation between the AFW connections to the main feed lines and the non-safety portion of the Main Feedwater System, thereby assuring that auxiliary feedwater is delivered to the SGs.

The FWIVs are 16-inch gate valves with 480 VAC motor operators (LIMITORQUE SB-4). The thermal overload heaters for the FWIVs have been replaced with jumpers. Motor deenergization during a close stroke, whether initiated manually or automatically, is accomplished by opening of an "ac" limit switch. Motor deenergization during the open stroke (note that all open strokes are manually initiated) is accomplished by opening of a "bo" limit switch. There are no torque switches incorporated into the FWIV control circuits. There is also no thermal overload protection provided for the FWIVs, since the thermal overload heaters have been removed and replaced with jumpers.

It should be noted that the FWIVs do not close automatically for all AFW automatic start signals (for instance, low-low SG level or blackout). In fact, the automatic closure signals are oriented toward avoiding excessive cooldown rates or overfilling of the SGs rather than to support the AFW System functions.

3.1.14.2. Controls

The main control board switches for the FWIVs have "OPEN", "CLOSE", and "AUTO" positions. Both the "OPEN" and "CLOSE" positions are spring return to "AUTO".

Transfer and OPEN/CLOSE control switches are also provided at the motor control centers.

3.1.14.3. Indication/Alarms

- Valve position indicating lights at main control board and motor control centers.
- Input to the "TRANSFER SWITCH IN AUX MODE" common annunciator
- Status Monitoring System inputs: Valve closed; No power to valve operator.

3.1.15. SG Blowdown Isolation Valves (BDIVs): BDV-1, 2, 3, 4

3.1.15.1. Component Function and Design Features

One BDIV is located in each Steam Generator (SG) blowdown line, outside of containment. The BDIVs must close in response to start of any AFW pump in order to ensure that the AFW flow delivered to the SGs can be converted to steam and released through the Main Steam Safeties or PORVs (instead of being drained off as liquid through the blowdown lines), thereby accomplishing the intended heat removal function.

The BDIVs are 2-inch air operated angle valves which fail closed on loss of air or solenoid power and close automatically in response to start of AFW pumps. The BDIVs are train oriented. The BDIVs from SGs A and C close on the start of the B motor driven or the turbine driven AFW pump, and the BDIVs from SGs B and D close on the start of the A motor driven or the turbine driven AFW pump. The pump start indications used by the control circuitry for the BDIVs are:

Motor driven pumps: 52S/b pump breaker auxiliary contacts

Turbine driven pump: T&T valve stem actuated limit switch (bc position).

The BDIVs also receive a close signal on a Containment Phase A Isolation (the only automatic Phase A Isolation comes from a Safety Injection signal). It should be noted that each BDIV is in series with another blowdown isolation valve (e.g., BDV-1A is in series with BDV-1, where BDV-1A is located inside of containment and BDV-1 is outside). The inside containment blowdown isolation valves receive an automatic closure signal on Phase A Isolation, but not on AFW pump start. In order to provide for a single failure proof design, from the containment isolation standpoint, the inside and outside valves receive their closure signals and solenoid power from different trains; for example, BDV-1 receives its Phase A Isolation signal from the B train of the Solid State Protection System, while BDV-1A receives its signal from train A.

There are a couple of noteworthy design features associated with the BDIVs. As noted above, the BDIVs from SGs A and C close on the start of the B motor driven AFW pump (or the turbine driven pump). However, the B motor driven pump feeds SGs C and D. Similarly, the BDIVs from SGs B and D close on start of the A motor driven pump, which feeds SGs A and B. A second notable feature is that while there is valve redundancy provided in the SG Blowdown Isolation System, from a Containment Phase A Isolation standpoint, there is no valve redundancy from the standpoint of closure on AFW starting. There is redundancy, from a closure signal standpoint, since each BDIV receives a closure signal from both the start of a motor driven AFW pump as well as the turbine driven pump (which in turn receives start signals from both trains).

3.1.15.2. Controls

The control switches for the BDIVs are ganged switches, with a single handswitch controlling both BDV-1 and BDV-1A. Individual transfer switches are provided for each valve (including separate switches for the inside containment valves) in the Auxiliary Control Room. Repositioning the transfer switches from "NOR" (Main Control Board Control) to "AUX" results in deenergization of the valve solenoid, thereby closing the valve. There is no other control switch for the BDIVs.

The BDIVs can be reopened from the Main Control Board by the operator following closure in response to an AFW pump start (even if the AFW pump is still running) by taking the handswitch to the open position (and holding it in the open position until full open).

3.1.15.3. Indication/Alarms

- Valve position indicating lights at main control board.
- Input to the "TRANSFER SWITCH IN AUX MODE" common annunciator

3.1.16. AFW Turbine Steam Supply Valves: MOV-11, MOV-12

3.1.16.1. Component Function and Design Features

The AFW turbine is supplied with a normal steam supply source, SG A, via normally open MOV-11. In the event that SG A is unavailable to supply steam to the turbine (for example in the event of a feedline break to SG A), an alternate steam supply is automatically provided from SG D, via normally closed MOV-12.

The steam supply valves (SSVs) are 4-inch gate valves. They are equipped with 480 VAC motor operators (LIMITORQUE SMB-00) which are powered off of two separate safety related busses.

In the event that the turbine driven AFW pump discharge pressure has not reached 100 psia within 60 seconds after the T&T valve has begun to open, the control circuit for the SSVs is designed to automatically transfer steam supply sources for the turbine (See Figure 3.8). There are three permissives necessary for the transfer to initiate:

1. The T&T valve has started to open (note that this portion of the permissive seals in until either the required pump discharge pressure is reached or until MOV-12 is full open)
2. MOV-12 is not full open ("bo" contacts are closed)
3. The turbine driven pump discharge pressure, as sensed by PS-10, has not reached 100 psia.

If these permissives are met for 60 seconds, a relay energizes which causes the T&T valve to reclose and MOV-11 to close. Once MOV-11 is closed, MOV-12 will start to open. The T&T valve will start to reopen as soon as it has closed. If MOV-12 reaches full open before the T&T valve, both valves will stay open. However, if the T&T valve reaches full open before MOV-12, it will cycle closed and open again (and will continue to cycle closed/open until MOV-12 is full open).

MOV-11 motor operator rotor actuated limit switches are used for the following purposes in MOV-12:

- "bc" contacts provide the permissive to allow the MOV-12 open coil to energize in conjunction with the automatic steam supply transfer
- "ac" contacts cause MOV-12 to close if it is opened with MOV-11 not closed

Both valves have seal-in circuits for their open and close coils.

The SSVs include thermal overload contacts, which are not bypassed, in both the open and close coil circuits. The open coil for each valve motor is deenergized by a limit switch (no torque switches are provided in the open coil circuits). The close coil circuit includes a torque switch which is bypassed by a limit switch except for the final 2-3% of stroke.

3.1.16.2. Controls

- Main Control Board valve handswitches (HS-11A and HS-12A) with "CLOSE", "OPEN", and "AUTO". Both "CLOSE" and "OPEN" are spring return to "AUTO".
- Motor Control Center (MCC) Open/Close switches (HS-11C and HS-12C)
- Transfer switches located at the MCCs, with "NOR" and "AUX" positions (XS-11 and XS-12). In "NOR", the Main Control Board controls are enabled, and in "AUX", the MCC switches are enabled. The automatic functions of the valves are enabled with the transfer switches in either position.

3.1.16.3. Indication/Alarms

- Valve position indicating lights at main control board and motor control center
- Input to the "TRANSFER SWITCH IN AUX MODE" common annunciator
- Status Monitoring System inputs: Valve closed; No power to valve operator

3.1.17. AFW Turbine Steam Supply Isolation Valves: MOV-9, MOV-16

3.1.17.1. Component Function and Design Features

The steam supply isolation valves (SSIVs) provide automatic isolation of the common steam supply header from the AFW turbine in the event that a high temperature condition (148°F) is detected in the turbine driven pump room.

The SSIVs are 4-inch gate valves. They are equipped with 480 VAC motor operators (LIMITORQUE SMB-00) which are powered off of two separate safety related busses.

When a high temperature condition is sensed, the close coil is energized to drive the valve shut. There are two temperature switches which are wired in series that must sense a high temperature condition in order for a valve to close (there are two temperature switches dedicated to each valve).

The SSIVs include thermal overload contacts, which are not bypassed, in both the open and close coil circuits. The open coil for each valve motor is deenergized by a limit switch (no torque switches are provided in the open coil circuits). The close coil circuit includes a torque switch which is bypassed by a limit switch except for the final 2-3 % of stroke.

3.1.17.2. Controls

- Main Control Board and Motor Control Center (MCC) valve handswitches (HS-9 and HS-10), with "PULL AUTO", "IN-MAN", "CLOSE", and "OPEN" positions (the CLOSE and OPEN positions are used with the handswitch pushed in for manual valve operation). The handswitches are spring return to Auto.
- Transfer switches located at the MCCs, with "NOR" and "AUX" positions (XS-9 and XS-10). In "NOR", the Main Control Board controls are enabled, and in "AUX", the MCC switches are enabled. The automatic functions of the valves are enabled with the transfer switches in either position.

3.1.17.3. Indication/Alarms

- Valve position indicating lights at main control board and motor control center
- Input to the "TRANSFER SWITCH IN AUX MODE" common annunciator
- Status Monitoring System inputs: Valve closed; No power to valve operator; Main Control Board valve handswitch not in Auto

3.2. REVIEW OF PROCEDURES RELATING TO AFW COMPONENTS

When plants are originally designed, analyses are performed to verify that safety related systems such as the AFW System will be able to function in such a way as to effectively mitigate the consequences of design basis accidents and transients. These analyses are documented in the Final Safety Analysis Report (typically Chapter 15). Inherent in these safety analyses are assumptions relative to normal alignments, equipment availability and capability, automatic actions, and other characteristics. While changes to the plant design and procedures which control plant and system operation may be made (as long as the constraints dictated in 10 CFR 50.59 are satisfied), it is critical that the plant be maintained within the envelope of assumptions made in the safety analyses.

As a part of the plant operating license, plants are issued a set of Technical Specifications which must be met. Tech Specs specify minimum operating condition requirements for systems and components, referred to as Limiting Conditions for Operation (LCO). The Tech Specs also specify surveillance requirements that designate, in general terms, the scope and frequency of, as well as acceptance criteria for, testing that must be performed in order to verify that the LCO is satisfied. The primary intent of the Tech Specs is to ensure, on a regular basis, the continuing validity of assumptions made in conjunction with safety analyses.

While Tech Specs provide the general skeleton or framework for this continuing validation of safety analysis assumptions, it is the individual plant surveillance procedures, developed specifically to meet the Tech Spec requirements, which are actually used to perform the validation.

There are several Tech Specs for the Plant A which address aspects of the AFW System. The Tech Specs which are listed in Appendix A, while plant specific, are fairly representative of those for most operating plants.

A review of procedures related to the monitoring and operation of the AFW System at Plant A was conducted in order to:

1. Determine the extent to which the various types of failures could be detected by programmatic monitoring or routine operating practices, and
2. Estimate the amount of service associated with testing of the components.

While relevant operating and maintenance procedures were also reviewed, the principal focus of this review was the set of procedures that are used to satisfy AFW related surveillance requirements.

Monitoring practices and operating guidelines relative to each of the component types discussed in the COMPONENT DESIGN FUNCTIONS, CONTROLS, AND INDICATION section above are provided below. The general purpose of each procedure, as it relates to the subject component, estimates of the service associated with testing, and pertinent comments are provided. It should be noted that the frequency of testing related operation tables that are provided for each component may include procedures not discussed for that component. This is due to the fact that the component may be actuated by a test that is not used to demonstrate operability of the component, but which does cause its operation. An example of this would be where a safety injection (SI) signal is simulated to verify that a motor driven pump starts in response to the SI signal. The turbine driven pump would also start (or at least the T&T valve would open) in response to this signal, but the test may not be used to demonstrate operability of the turbine driven pump.

Based upon the review of the surveillance, operating, and maintenance procedures, a compilation of failure sources which would not be detectable by the current monitoring practices was developed. A summary of this compilation is provided in Section 3.3.

It should be noted that at the time that the review of the surveillance, maintenance, and operating practices was being conducted, a number of fairly significant procedural revisions as well as complete rewrites were in process. In fact, some previously non-detectable failure sources were made detectable as a result of changes. In light of the fact that this process was ongoing, it is likely that some of the observations made relative to failure non-detectability will not be valid at the time this report is issued. The observations should be recognized for what they are--a picture of the monitoring/operational practices in place for a specific plant at a particular point in time. It is believed, however, that these observations are reasonable indicators of AFW System monitoring practices as a whole.

3.2.1. Pump Suction Check Valves (SCV): C-3, 4, 5

3.2.1.1. SURVEILLANCE AND MAINTENANCE TESTS/INSPECTIONS

ST-8 and 9 are quarterly tests in which the AFW pumps are run in their recirculation flow path. These tests are performed to meet ASME Section XI testing requirements for the pumps, and are also used to demonstrate partial stroking of the SCVs. The flowrates through the valves during this testing is about 1/10 of the required design flow.

ST-14 is performed quarterly to verify that the SCVs close under reverse pressure/flow conditions. The test is performed by pressurizing the piping downstream of the SCV with demineralized water (using a vent connection on the pump casing) and observing that a reverse pressure differential of ≥ 3 psid exists across the SCV.

ST-15, which is performed during each entry into Hot Standby conditions, demonstrates that the pumps are able to deliver design basis flow to the SGs. The test thereby demonstrates that the SCVs stroke open sufficiently to allow the required flow to pass through them. The total of flow rates to the SGs must be ≥ 440 gpm for the motor driven pumps, and ≥ 880 gpm for the turbine driven pump. Note that flow through the check valves would exceed flow delivered to the SGs by the amount of flow delivered through the recirculation flow path.

ST-28, which is performed on a refueling frequency, calls for the disassembly and inspection of several check valves. It should be noted that this ST does not meet a specific Tech Spec Surveillance Requirement, and is not required by the ASME Section XI program, but is performed as a consequence of the San Onofre water hammer event (see NUREG-1190 and IE Notice 86-09). The valves are organized in groups of four. One valve out of each group is disassembled and inspected each refueling outage, so that each valve will be inspected about every six years. If a valve fails to meet the acceptance criteria (see below), all other valves in the group are to be inspected during the same outage. Only the turbine driven pump SCV is addressed in this procedure.

Acceptance criteria are:

- All internal parts are in place and show no signs of abnormal wear
- All internal locking devices, including tack welds, are in place and in good condition
- All internal surfaces are in good condition and show no signs of abnormal wear

3.2.1.2. FREQUENCY OF TEST OPERATION

The motor driven pump SCVs are stroked per the following procedures:

<u>PROCEDURE</u>	<u>NUMBER OF FULL(F)/PARTIAL(P) STROKES</u>	<u>FREQUENCY</u>
ST-3A	5P	R
ST-6	5P	R
ST-9	1P	Q
ST-15	1F	HOT STANDBY ($\leq Q$) ¹
ST-16	1P	R
MI-2A & B	1P	R ²
MI-3A & B	1P	R ²

1. It is assumed that this test is performed twice per year.
2. The MI tests are performed on an alternating basis; that is, one train is tested per refueling outage

TOTAL ESTIMATED TEST RELATED PARTIAL STROKES PER YEAR: The above test frequency information would yield about 13 partial strokes per year; however, the motor driven pumps are used for protracted periods during startups and shutdowns, with varying flow rates, with the dominant amount of time spent at relatively low flow rates or in recirculation flow only. Thus, the valves are partial stroked much more frequently than indicated by testing.

TOTAL ESTIMATED TEST RELATED FULL STROKES PER YEAR: 2 (The only time the valves would be likely to experience full stroking would be during testing, although there might be some infrequent operational demands that would result in substantial, if not design basis flow rates through the valves.)

The turbine driven pump SCV is stroked per the following procedures:

<u>PROCEDURE</u>	<u>NUMBER OF FULL(F)/PARTIAL(P) STROKES</u>	<u>FREQUENCY</u>
ST-7	3P	R
ST-8	2P	Q
ST-15	2F	HOT STANDBY ($\leq Q$) ¹
ST-27	2P	R

1. It is assumed that this test is performed twice per year

TOTAL ESTIMATED TEST RELATED PARTIAL STROKES PER YEAR: 11. Note that the turbine driven pump would not normally be used to support startups or shutdowns.

TOTAL ESTIMATED TEST RELATED FULL STROKES PER YEAR: 4. The only time the valves would be likely to experience full stroking would be during testing, although there might be some infrequent operational demands that would result in substantial, if not design basis flow rates through the valves. Note that "full strokes"

refers to conditions when the flow rate through the valve is at or near the maximum that occurs, not necessarily a condition where the check valve is fully open.

3.2.1.3. RELEVANT OPERATING INSTRUCTIONS

Since the turbine driven AFW pump would seldom be used to support startup/shutdown evolutions, the normal operating procedures primarily affect the motor driven pump SCVs.

OP-1 includes precautions that state:

"AFW Pumps should continue to run on recirculation to avoid hanger damage and extend motor life. AFW LCV's should be maintained in manual to avoid steady-state low flow conditions that could result in damage to hangers in the Turbine Building, Condensate Transfer Pump damage, and/or intermittent actuation of AFW pump suction pressure switches. Just prior to criticality LCV Controller will be placed in AUTO positions."

"While in a low flow condition or Mode 3, AFW should be 'batched' or 'slugged' at \approx 75 gpm to each steam generator to prevent vibration damage and inadvertent ESW swapover. This flowrate will also ensure that S/G nozzle cracking does not occur."

GOP-1 ("Unit Heatup from Cold Shutdown to Hot Standby") and GOP-2 ("Plant Startup from Hot Standby to Minimum Load") include similar precautionary statements.

3.2.1.4. COMMENTS

A noteworthy feature of the testing program for the SCVs is the fact that the turbine driven pump SCV is included in the periodic disassembly and inspection procedure (ST-28) while the motor driven pump SCVs are not. This is difficult to understand in that the motor driven pump SCVs see considerably more service due to the fact that the motor driven pumps are used to support plant startup and shutdown. It is also important to note that the low suction pressure switches for the motor driven pumps are located upstream of the SCV's; thus, failure of an SCV to fully open, thereby creating low suction pressure conditions at the pump suction (but not upstream of the check valves), could occur and not be detected by the suction pressure switches.

The extremely low velocities that the motor driven pump suction check valves would see, in conjunction with the fact that the layout geometry is not particularly beneficial for flow stability (due to the proximity of the upstream elbow), indicate that the probability of disc oscillation related wear would be relatively high (in comparison to that experienced by the average check valve in a standby system). While the wear rate, as a function of hours of service, would be expected to be relatively high, the wear rate as a function of plant life should be relatively low (since the system is not in service the vast majority of the time).

3.2.2. Emergency Service Water Supply Valves MOV-1, 2, 3, 4

3.2.2.1. SURVEILLANCE AND MAINTENANCE TESTS/INSPECTIONS

ST-6, which is performed every 18 months, is used to satisfy Tech Spec Surveillance Requirement 4.7.1.2.b for the motor driven pump ESW valves. The testing is performed on only one of the two in-series valves at a time in order to avoid intrusion of ESW water (lake water) into the AFW system; therefore, the valves are stroked under low or no flow conditions (there is some minor flow during the MOV-2 and MOV-4 valve tests due to the tell-tale drain valves between the two isolation valves being open). The automatic stroking is initiated by manually closing the associated pump breaker auxiliary contacts to simulate a pump running condition and by depressurizing all three suction pressure switches. The testing sequence for each pump's valve set is to first test each upstream valve (MOV-1/3) and then test the downstream valve (MOV-2/4). The upstream valve (MOV-1/3) is stroked after the breaker for the downstream valve's motor operator is opened. In order to accomplish the testing of the downstream valves (MOV-2/4), the procedure calls for the "thermal overloads" ("thermal overloads" is procedure terminology-note that the thermal overloads for these valves have been removed and replaced by jumpers) to be removed from MOV-1 and MOV-3 after MOV-1 and MOV-3 have been tested. This allows the suction pressure switches to energize the relays that automatically open MOV-2 and MOV-4 without causing MOV-1 and MOV-3 to open (the low suction pressure relays are located in the motor control centers for MOV-1 and MOV-3). MOV-1/3 are not restroked after testing the MOV-2/4.

ST-10, 11, and 13 are used to implement the ASME Section XI valve inservice testing requirements. The testing sequence called for is to first test the "B" valve, and then test the "A" valve, in order to avoid intrusion of lake water into the AFW system. The tell-tale drain is closed during the valve stroking, and reopened following completion of the test. Stroking is performed by use of the main control board switch. The maximum allowable stroke time for each of the four valves is 42 seconds.

ST-25 is a Calibration and Functional Test Procedure which satisfies Tech Spec Surveillance Requirements 4.3.2.1.1.B.6.g (Calibration) and 4.3.2.1.1.C.6.g (Functional Test). The Functional Test is required every 31 days and the Calibration is required every 18 months.

The general testing sequence is as follows:

1. Associated motor driven pump control switch is placed in PULL TO LOCK to prevent inadvertent stroking of either valve (since the pump must be running to complete the open permissive).
2. The "B" valve breaker is opened to prevent it from inadvertently opening
3. The "A" pressure switch is isolated and depressurized, and the associated main control board alarm is verified.
4. Using a test rig, the pressure at the switch is varied and the switch setpoint is checked (and adjusted, if necessary). The test rig is then disconnected, the pressure switch unisolated, and the alarm is verified to have cleared.
5. Similar checks are performed on the "B" and "D" switches, with the exception that following the check on the "D" switch, the "D" switch is left isolated and depressurized. The "B" switch is then isolated and depressurized, and the contacts which must close to cause the "A" and "B" valves to open are verified to be closed.
6. The switches are then restored to normal configuration and their sensing lines refilled.

Note that only the B + D pressure switch coincidence is checked.

There is no distinction made in the procedure between the CHANNEL FUNCTIONAL TEST and the CHANNEL CALIBRATION.

MI-4 is a procedure that provides instructions on the testing of motor operated valves using the MOVATS system, which is used to assess the general mechanical and electrical control conditions of the valves.

MI-5 is a preventive maintenance procedure for LIMITORQUE actuators which is used to maintain equipment qualification. It provides for inspection and cleaning of electrical components; cleaning, inspection, and relubrication of the geared limit switch train; inspection and replacement (if needed) of gaskets; setting of the limit switch positions, per MI-6A; measurement of resistance from each phase to ground from the supply breaker; inspection and replacement (if needed) of the operator lubricant; cleaning and relubrication of the valve stem; lubrication of the sleeve top bearing (if a grease fitting is provided); inspection of the shaft seal for excessive leakage; and inspection of the spring pack for hardened grease.

MI-6A is a corrective maintenance procedure which is used periodically (as invoked by MI-5) to adjust motor operated valve limit and torque switch settings. Limit switch settings, which can be set based either on valve travel measurement or the number of handwheel turns, are set as follows:

Open limit switch: Limit switch set to open at 95-98% of valve travel
 Close limit switch: Limit switch set to open at 97-98% of valve travel

MI-7 is used to verify the time delay relays associated with the automatic transfer from the CST to ESW times out at four seconds. The procedure does not actuate any equipment-it only verifies timing. There is no designated frequency of testing. A commitment to periodically calibrate the timers was made in an LER filed by Plant A.

3.2.2.2. FREQUENCY OF TEST OPERATION

The ESW isolation valves are stroked per the following procedures:

<u>PROCEDURE</u>	<u>NUMBER OF FULL STROKES</u>	<u>FREQUENCY*</u>
ST-6	1	R
ST-10/13	1	Q

*R-REFUELING
 Q-QUARTERLY

TOTAL ESTIMATED TEST RELATED FULL STROKES PER YEAR: 5 (all strokes performed under no flow conditions).

3.2.2.3. RELEVANT OPERATING INSTRUCTIONS

OP-1, which is the AFW system operating procedure, specifies that the ESW isolation valves are to be "Operable-Closed", and the telltale drain valves "Open". The Precautions section states that "If the suction pressure of the motor-driven AFW pumps fall below 2 psig for 4 seconds, the suction will shift from CST to ESW. If suction swaps over, Assistant Unit Operator (AUO) should close telltale valves on all AFW Pumps." The procedure also includes instructions on switching over from the CST to ESW as the suction source in the event that "... pump suction drops to 2 psig and auto swap over does not occur." Manually switching over to ESW requires shift supervisor approval, and is accomplished in the following sequence:

-Close telltale drain valve

- Open the outboard valve (e.g., MOV-1)
- Open the inboard valve (e.g., MOV-2)

It should be noted that the operator does not have remote indication of suction pressure, but there is a local suction pressure gauge for each pump.

There is a single low suction pressure alarm which annunciates when any one of the pressure switches for either of the motor driven pumps or the turbine driven pump closes (total of 9 pressure switches).

OP-3 is the annunciator response procedure for AFW related alarms. The annunciator procedure states that the origin of the annunciator is from PS-1A, 2A, or 3A. (In reality, the B or D switches for each of the sets will also cause annunciation). It also states that if 2/3 pressure switches for a given pump reach their setpoint, the pump will automatically switch over to ESW as the suction source. The "Immediate Action" section of OP-3 has the operator "Verify opening of appropriate ESW suction supply valves".

3.2.2.4. COMMENTS

There are a number of comments relative to the testing of these valves:

1. Since there is no indication of suction pressure in the main control room, when a low suction pressure alarm is received, the operator cannot know whether multiple switches on multiple pumps have "made" due to an actual low suction pressure condition, or only a single switch has closed spuriously. Therefore, the operator cannot know which are the 'appropriate' valves (as designated in OP-3). [It has been observed at another plant that when the motor driven AFW pumps are started up with their discharge valves to the SG's open, a low suction pressure alarm annunciates routinely due to transient pressure conditions. However, when started up on recirculation flow only, the alarm does not come in. Note that this plant has suction pressure indication in the main control room for all AFW pumps, versus no indication for Plant A.]

Given the natural reluctance of an operator to switch over to ESW and the availability of only a single annunciator operated off of multiple switches, along with the operating procedure requirement to secure shift supervisor permission prior to switching over to ESW in the operating procedure (OP-1), there is considerable question as to what the operator response would be to an alarm. It should be noted that there is no time delay associated with the suction pressure alarm (the time delay is built into the automatic valve opening circuit).

2. There is no testing conducted which verifies that the opening of these valves in conjunction with an actual low suction pressure condition and the pumps running will achieve satisfactory results (where "satisfactory results" would include the requirements that a) the pump suction switchover takes place quickly enough to prevent loss of required NPSH for the pumps and b) adequate steady state flow is provided to the pumps to allow the AFW design flow requirements to be met). In light of the water chemistry problems associated with the switchover, there is an understandable desire not to test this feature. However, since ESW is the only safety grade source of water for the pumps, the ability for the transfer to occur satisfactorily is critical.

3. There are manual isolation valves and check valves between the pressure switches and the motor driven pumps. Thus, the pressure switches would not detect and correct for a stuck closed check valve or an improperly positioned manual isolation valve.

4. Since there is no flow delivered through the valves, the capability of the suction flow paths to support required AFW flow is not demonstrated.

5. The A + B and A + D pressure switch logic is not verified to result in valve opening.

6. ST-6 does not verify restoration of operability for MOV-1 and MOV-3 following replacement of the "thermal overloads" (jumpers) after testing MOV-2 and MOV-4. Inasmuch as the part of the control circuit that is needed for valve operation is interrupted for the test, but the valve position indicator lights portion of the control circuit remains intact, the reestablishment of continuity in the valve operation portion of the circuit is not provided.

7. The pipe configuration associated with the ESW suction valves is such that there will be a small amount of lake water intrusion into the AFW system each time the inboard valve is stroked, as the ESW valves are located in a vertical section of pipe. Since this is normally a relatively stagnant section of piping, the potential for Asiatic Clam buildup and/or microbiologically induced corrosion exists. However, the procedure which is implemented to deal with Asiatic Clams (ST-30) opens up bypass treatment lines in the ESW to AFW pump suction piping to ensure that the lines are treated when environmental (temperature) conditions warrant action to minimize Asiatic Clam buildup. It is noteworthy that ST-6, which is performed every 18 months, includes provision for flushing out any ESW water left after the "A" (ESW side) valves are stroked by leaving the drain valves open during the "B" valve stroking. However, this good practice is not adopted in ST-10, which is performed quarterly.

8. The section of piping downstream of each motor driven pump's check valve in the normal suction path from the CST is safety grade, seismically qualified piping, while the piping upstream of the check valve is not. The length of piping downstream of the check valve to the motor driven pump only contains enough water for a couple of seconds of pump operation before air would be drawn into the pump casing should the piping upstream of the check valve fail. It would appear that the time delay before automatic valve opening was initiated, as well as the fact that the valves are fairly slow stroking valves, might create conditions where the motor driven pumps became at least partially air-filled before the transfer was completed. Note that this concern is common with the turbine driven pump

3.2.3. Emergency Service Water to Turbine Driven Pump Suction Isolation Valves MOV-5, 6, 7 & 8

3.2.3.1. SURVEILLANCE AND MAINTENANCE TESTS/INSPECTIONS

ST-7, which is performed every 18 months, is used to satisfy Tech Spec Surveillance Requirement 4.7.1.2.b for the turbine driven pump ESW valves. The testing is performed on only one of the two in-series valves at a time in order to avoid intrusion of ESW water (lake water) into the AFW system; therefore, the valves are stroked under no flow conditions. The automatic stroking is initiated by manually opening the T&T valve (with an upstream steam supply valve closed to prevent a pump start) and by depressurizing all three suction pressure switches. The testing sequence for each pump is to first test the upstream valve, and then test the downstream valve to avoid intrusion of lake water into the AFW system. The test provides evidence that the valve sequencing (MOV-7/8 valve begins to open, followed by MOV-5/6 valve beginning to open, and then the MOV-7/8 valve closes) takes place, although the sequence is not timed. It should be noted that the test, as written, will actually cause the MOV-7/8 valve to stroke open, then shut, and repeat the cycle until either the T&T valve is opened or until two of the three suction pressure switches are repressurized.

ST-10, 11, and 13 are used to implement the ASME Section XI valve inservice testing

requirements. Stroking is performed by use of the main control board switch. The maximum allowable stroke time for each of the four valves is 55 seconds. The tell-tale drain valve is closed during testing and reopened after testing completion.

ST-25 is a Calibration and Functional Test Procedure which satisfies Tech Spec Surveillance Requirements 4.3.2.1.1.B.6.g (Calibration) and 4.3.2.1.1.C.6.g (Functional Test). The Functional Test is required every 31 days and the Calibration is required every 18 months.

With the breakers for MOV-7 & MOV-8 and MOV-5 & MOV-6 open (to prevent valve stroking), the pressure switches (PS-3A, B, and C) are checked, one at a time, to verify that the switch closes at the proper suction pressure (using a pressure source, with the pressure switch isolated from the suction header). The low suction pressure alarm at the main control board is verified to come in and then to clear for each switch.

After the pressure switches are checked/calibrated, a portion of the automatic switchover circuitry is verified as follows:

- Steam supply to turbine isolated by closing MOV-9 and MOV-10

- T&T valve opened (needed to provide permissive)

- Each of the 2/3 pressure switch coincidence logic combinations is checked to verify that relays BBA, BBB, CCC energize.

There is no distinction made in the procedure between the CHANNEL FUNCTIONAL TEST and the CHANNEL CALIBRATION.

MI-4 is a procedure that provides instructions on the testing of motor operated valves using the MOVATS system, which is used to assess the general mechanical and electrical control conditions of the valves.

MI-5 is a preventive maintenance procedure for LIMITORQUE actuators which is used to maintain equipment qualification. It provides for inspection and cleaning of electrical components; cleaning, inspection, and relubrication of the geared limit switch train; inspection and replacement (if needed) of gaskets; setting of the limit switch positions, per MI-6A; measurement of resistance from each phase to ground from the supply breaker; inspection and replacement (if needed) of the operator lubricant; cleaning and relubrication of the valve stem; lubrication of the sleeve top bearing (if a grease fitting is provided); inspection of the shaft seal for excessive leakage; and inspection of the spring pack for hardened grease.

MI-6A is a corrective maintenance procedure which is used periodically (as invoked by MI-5) to adjust motor operated valve limit and torque switch settings. Limit switch settings, which can be set based either on valve travel measurement or the number of handwheel turns, are set as follows:

Open limit switch: Limit switch set to open at 95-98% of valve travel

Close limit switch: Limit switch set to open at 97-98% of valve travel

MI-7 is used to verify the time delay relays associated with the automatic transfer from the CST to ESW times out at 5.5 seconds. The procedure does not actuate any equipment-it only verifies timing. There is no designated frequency of testing. A commitment to periodically calibrate the timers was made in an LER filed by Plant A.

3.2.4. Motor Driven AFW Pumps

3.2.4.1. SURVEILLANCE AND MAINTENANCE TESTS/INSPECTIONS

ST-3A & B (3A is for "A" train, and 3B is for "B" train), which are performed on an 18 month frequency, are titled "Loss of Offsite Power with SI DG A/2B-B Containment Isolation Test". Note that both trains are tested every 18 months. The testing for a single train is discussed below.

There are several AFW pump related functions which are checked in this test:

- a. The motor driven AFW pump is verified to be stripped from its bus following deenergization of the bus (note that diesel-generator start due to bus undervoltage is inhibited during bus deenergization).
- b. With the bus still deenergized, an SI signal is initiated. This causes the diesel to start and loads (including the associated AFW pump) to sequence on.
- c. After resetting the SB and SI signals, restoring normal power to the bus, and securing the diesel, another SI signal is generated. Both motor driven AFW pumps are verified to start on the SI signal.
- d. After resetting the SI signal and performing testing that is not directly related to AFW, the associated AFW pump bus is deenergized, and the automatic diesel-generator start associated with undervoltage is unblocked, allowing the diesel to start and reenergize the bus. The associated AFW pump is verified to start.

Note that the testing sequence in items a and b result in AFW pump start from an SI signal with a pre-existing Station Blackout signal, the testing sequence in item c results in pump start from SI only, and the item d sequence starts the pump from Station Blackout only. All starts of the AFW pumps are performed with the system aligned for recirculation flow only.

ST-6, which is performed on an 18 month frequency, is titled "Motor-Driven Auxiliary Feedwater Pump and Valve Automatic Actuation". The following test sequences are included in ST-6:

- a. An SI signal is simulated by manually pushing the SI Slave Relay, and the motor driven AFW pumps are verified to start.
- b. A Low-Low SG Level in one SG is simulated by tripping 2/3 level bistables for a single SG and the motor driven pumps are verified to start.
- c. A trip of the "A" Main Feed Pump in coincidence with simulated plant power at > 80% is verified to start both motor driven AFW pumps.
- d. A trip of the "B" Main Feed Pump in coincidence with simulated plant power at > 80% is verified to start both motor driven AFW pumps.
- e. A trip of both Main Feed Pumps is verified to start both motor driven AFW pumps.

The pumps are not verified to start on an SB signal, as the procedure takes credit for the SB starts in ST-3A & B. All ST-6 starts of the AFW pumps are performed with the system aligned for recirculation flow only.

ST-9, which is a quarterly test, is titled "Motor Driven Auxiliary Feedwater Pumps". Each pump is started and run with the system aligned for recirculation flow only. The conditions monitored are flow, suction and discharge pressure, and vibration, per ASME Section XI (which is invoked by Tech Spec 4.0.5) requirements. Flow through the pump miniflow line is measured using temporary ultrasonic flowmeters. Pump suction and discharge pressure are also monitored using test pressure gauges. Vertical and horizontal vibration of the pump inboard bearing is also monitored. Acceptance criteria are:

<u>Parameter</u>	Motor Driven Pump "A"		<u>Required Action Range</u>
	<u>Acceptable Range</u>	<u>Alert Range</u>	
Suction Pressure, psig	≥ 11	NA	<11
Pump Delta-P, psid	1524 to 1661.5	(no low range) 1661.5 to 1677.8	<1524 and >1677.8
Flow Rate, gpm	29.4 to 45.1	26.0 to 29.4 and 45.1 to 47.2	<26.0 and >47.2
Horizontal Vibration, mils	0 to 1.0	1.0 to 1.5	>1.5
Vertical Vibration, mils	0 to 1.0	1.0 to 1.5	>1.5
<u>Parameter</u>	Motor Driven Pump "B"		<u>Required Action Range</u>
	<u>Acceptable Range</u>	<u>Alert Range</u>	
Suction Pressure, psig	≥ 11	NA	<11
Pump Delta-P, psid	1464 to 1565.4	(no low range) 1565.4 to 1580.7	<1464 and >1580.7
Flow Rate, gpm	27.1 to 41.6	23.9 to 27.1 and 41.6 to 43.5	<23.9 and >43.5
Horizontal Vibration, mils	0 to 1.0	1.0 to 1.5	>1.5
Vertical Vibration, mils	0 to 1.0	1.0 to 1.5	>1.5

ST-15, which is performed for each entry into Mode 3 (but not to exceed quarterly), is titled "AFW Check Valve Opening Test During Hot Standby and Hot Shutdown". While the purpose of the test is to demonstrate stroking of check valves in the lines between the pump discharge and the SGs, it is also the only test that demonstrates anything other than recirculation flow from the pumps. The acceptance criteria for the test are that each pump is able to deliver ≥ 220 gpm simultaneously to each of the SGs serviced by the pump. Other than specifying that the testing is to be conducted in Mode 3 or 4, there are no prerequisites relative to system conditions (such as SG pressure).

ST-19, which is performed on an 18 month frequency, is titled "Automatic Load Sequence Timer Functional Test". The test verifies that the AFW motor driven pump sequencing timer time delays are set at 20 seconds nominal (19 to 21 seconds is the acceptable range).

ST-20, which is performed on an 18 month frequency, is titled "Response Time Test of Auxiliary Feedwater System Auto-Start Relays". It is performed in conjunction with ST-6, and in fact only specifies response time test points to be monitored during the performance of ST-6. The only AFW Pump related response times measured are those

associated with trip of the Main Feed Pumps. The times measured are from trip of the Main Feed Pumps until energization of relays which cause the AFW Pumps to start. The times are used in ST-22 to determine system response time.

ST-22, which is performed on an 18 month frequency, is titled "Engineered Safety Feature Response Time Verification". No equipment is actuated by the test; rather, the test compiles response time measurements from several other Surveillance Instructions, including ST-20 and ST-21, as well as from several response time tests for portions of channels performed in several MI tests.

For each of the automatic AFW Actuation signals, total channel response time is calculated. Four response times are calculated for each start signal:

- Turbine driven pump response time
- Turbine driven pump LCV response time
- Motor driven pump response time
- Motor driven pump LCV response time

The greatest time of these four is taken as the total actuation response time.

Each of the four response times is calculated by adding several components which together make up (or simulate) the time from process change until the actuated equipment has reached its safety function condition (pumps have developed required discharge pressure or valves have reached the full open position). The maximum allowable response time specified in the procedure is 59.1 seconds (1.5 % less than the Tech Spec value of 60 seconds to provide for recorder chart speed accuracy).

Since the motor driven pumps, under SB conditions, would not be sequentially loaded onto the diesel until about 30 seconds after an undervoltage condition occurred, the motor driven pumps or the motor driven pump LCVs response times should be greater than the turbine driven pump and turbine driven pump LCVs response times. Note that the turbine driven pump and the level control valves are not dependent upon diesel starting, since their power and control circuits are dependent upon 125 VDC and 120 VAC Vital power.

The SB response time inputs to ST-22 from MI-3A & B are based upon a combined SI/SB signal, and the response times measured are from the diesel start signal (instead of the undervoltage condition, which must exist for 1.5 seconds before the diesel start signal is generated) until the motor driven pumps have reached full discharge pressure. Note that fixed "Response Time Factors" are added to the time inputs from MI-3A & B (as well as those from MI-2A & B) to account for the difference in pressure development time for recirculation conditions, under which the test is conducted, and full flow conditions. The response time factors are variable, and range from 3.32 seconds ("A" pump factor in MI-2A) to 4.96 seconds ("B" pump factor in MI-3B).

It should also be noted that the response times calculated for the motor driven pumps do not include any time associated with the automatic realignment of pump suction from the non-safety related source (CST) to the safety related ESW source. A low suction pressure condition must exist for 4 seconds after pump start to initiate the automatic suction source transfer. The motor operated valves which open to provide the alternate suction source have maximum allowable stroke times of 42 seconds specified in the ST-10, 11, 12, and 13 series of tests.

3.2.4.2. FREQUENCY OF TEST OPERATION

The motor driven pumps are operated per the following test procedures:

<u>PROCEDURE</u>	<u>NUMBER OF PUMP STARTS³</u>	<u>FREQUENCY*</u>
ST-3	5	R
ST-6	5	R
ST-9	1	Q
ST-15	1	HOT STANDBY ($\leq Q$) ¹
ST-16	1	R
MI-2A & B	1	2R ²
MI-3A & B	1	2R ²

*R-REFUELING
Q-QUARTERLY
M-MONTHLY

1. It is assumed that this test is performed twice per year.
2. The MI tests are performed on an alternating basis; that is, one train is tested per refueling outage.
3. It should be noted that all of the above starts, with the exception of ST-15, are performed under recirculation flow only, and even in ST-15, the flow rate to the SGs is manually changed from a relatively low flow to ≥ 220 gpm per SG by manual control.

TOTAL ESTIMATED TEST RELATED STARTS PER YEAR: The above test frequency information would yield about 14 pump starts per year for testing purposes. Most of the testing would involve a brief time of pump operation (few minutes). If the average pump run duration per test was 15 minutes, the average annual run time would be about 3¹/₂ hours. However, the motor driven pumps would be used for protracted periods during startups and shutdowns at varying flow rates, with the dominant amount of time spent at relatively low flow rates or in recirculation flow only. Occasional pump starts could be expected in conjunction with reactor trips or other unplanned events. Thus, while the number of test related starts may exceed the number of unplanned and non-test starts, the amount of time spent running for test purposes is expected to be small, relative to the amount of run time in support of normal plant evolutions.

3.2.4.3. RELEVANT OPERATING PROCEDURES

OP-1 is the AFW system operating procedure. There are several procedural requirements affecting motor driven pump operation included in the OP:

-A precaution states that the AFW Pumps should be run on recirculation flow (as opposed to stopping and starting the pumps) during conditions when SG demand is low in order to avoid hanger damage and extend motor life. Another precaution stipulates that AFW should be batched at ≈ 75 gpm (under manual LCV control) to each SG to prevent vibration damage and inadvertent swapper from the CST to ESW suction as well as to prevent SG nozzle cracking.

-If time permits, the level control valves are taken under manual control and closed prior to starting a motor driven pump.

-Following pump start, the pumps are inspected locally (no specific direction provided for

the inspection)

-For purposes of placing the AFW system in its standby condition, the motor driven pump control switches are specified to be in AUTO.

-Precautions that the pump discharge lines should be $\leq 125^{\circ}\text{F}$. This precaution is included to ensure against backleakage binding of the pumps. It should be noted that Plant A is probably less susceptible to backleakage than many other plants since its level control valves are normally closed (some plants have only check valves between the pumps and the SGs or main feed lines).

-The procedure recommends that operation of the motor driven pumps at flow rates in excess of 525 gpm be avoided when the steam generator pressure is between 385 psig and approximately 865 psig. The stated purpose is to avoid high levels of vibration around the cavitating venturi when the flow rate is high enough to result in cavitation. (Below 385 psig the bypass level control valves should provide sufficient backpressure to prevent cavitation).

GOP-1 (Plant Startup from Cold Shutdown to Hot Standby), GOP-2 (Plant Startup from Hot Standby to Minimum Load), and GOP-3 (Plant Shutdown from Minimum Load to Cold Shutdown) include some of the same precautions relative to operation of the motor driven pumps. GOP-2 specifies that the AFW pumps be used to maintain SG level until the main feed pumps are maintaining SG level. GOP-2 specifies that the main feed pumps should be started at about 1% reactor power.

While not part of a formal procedure (rather based on an operations group instruction letter), auxiliary operators check the temperatures of the pump discharge lines once per shift for evidence of backleakage of main feedwater. This monitoring is performed in response to IE Bulletin 85-01 and Generic Letter 88-03.

3.2.4.4. COMMENTS

The flow testing of the motor driven pumps is performed under recirculation flow (roughly 25 gpm) conditions. This testing is done to satisfy Tech Spec 4.7.1.2 as well as ASME Section XI testing requirements. While the testing satisfies regulatory requirements, it does little in the way of demonstrating pump capability. In fact, the best evidence of pump capability provided by any testing is from ST-15, which verifies that each motor driven pump is capable of delivering at least 440 gpm to the two SGs served, although pressure conditions are not specified.

The operating procedures include precautions to minimize adverse effects upon the pump motors, piping hangers and other system equipment. However, the actions taken to accomplish those ends are deleterious to the pumps. The pumps, during startup and shutdown periods when relatively low flow rates are required, are run continuously in recirculation. As discussed in NUREG/CR-4557, "Aging and Service Wear of Auxiliary Feedwater Pumps for PWR Nuclear Plants", operating pumps for long periods of time at low flow conditions can result in accelerated pump degradation. IE Bulletin 88-04 discussed this problem and required utility response. It does not appear, based upon the operating guidance offered by Plant A procedures, that this issue has been thoroughly addressed.

All of the automatic start signals for the motor driven AFW pumps are adequately verified by testing to result in pump starting. The pumps are also verified to be stripped from their

buses in the event that an undervoltage condition occurs with the pumps already running. All automatic start signal testing is done with the pumps aligned for recirculation flow only. One of the tests in which automatic loading is verified is ST-3A & B. This test is principally oriented toward demonstrating diesel operability, including verification that the automatically connected diesel loads do not exceed its 2000 hour rating. It should be noted that, as conducted, the test doesn't accurately simulate demand condition loads, since the AFW pumps (as well as other pumps) are operating under recirculation flow only, and the power demanded under recirculation would be substantially less than that at full flow (roughly half).

The ability for the pumps to successfully negotiate the transition from their normal source of water (CST) to their safety related source (ESW) is not demonstrated. Actual delivery of lake water into the AFW system is clearly not desirable, from a chemistry perspective. However, the time requirement for sensing a low suction pressure condition, timing out of the time delay relay, and opening of the ESW valves sufficiently to meet pump flow requirements appears to be marginal from the standpoint of ensuring that a pump would not become vapor bound.

The pump auxiliary contacts, which provide control signals to the level control valves, the alternate suction source valves, and steam generator blowdown valves are not verified to function properly.

The response times measured for the motor driven pumps include an allowance for the time required to reach the required flow rate (as an adder to the time required to reach steady state pressure in the recirculation condition), but do not include an allowance for the time that would be required for the automatic transfer of the suction source from the CST to ESW. If the motor driven pump response time were defined to include the maximum allowable stroke time for the alternate suction source valves, the pumps would not be able to satisfy the 60 second response time identified in Tech Specs. The 60 seconds is a somewhat arbitrary, generic Tech Spec time. Some accident/transient analyses do take credit for AFW start at 1 minute (for instance Loss of Normal Feedwater). However, the relatively small amount of time for transfer to the safety related ESW as the suction source, provided the transfer occurs satisfactorily, should have minimal or no observable impact upon the results. It should be noted that the analysis for a feedline break does not assume flow initiation until 10 minutes (due to the fact that operator action must be relied upon to isolate the faulted SG).

3.2.5. Turbine Driven AFW Pump

3.2.5.1. SURVEILLANCE AND MAINTENANCE TESTS/INSPECTIONS

ST-7, which is conducted on an 18 month frequency, verifies that the T&T valve opens, with steam supply isolated by an upstream valve, in response to each automatic open signal (with the exception that the blackout signal is tested on only one train). The turbine is also actually started (steam supply is unisolated) three times by ST-7, with the pump discharge lined up for recirculation flow only. The three starts are for trip of the A Main Feed pump, trip of the B Main Feed pump, and trip of both Main Feed pumps.

ST-8 is a quarterly test of the AFW turbine driven pump. The test is conducted with the pump discharge lined up for recirculation flow only. This test is conducted to fulfill the requirements of Tech Spec Surveillance Requirements 4.0.5 and 4.7.1.2.a.2. Temporary ultrasonic flow meters are used to measure flow through the pump miniflow line (there is no permanent miniflow line flow instrumentation). The T&T valve is opened to start the turbine by operation of the valve's control switch at the Main Control Board, and the

pump is run with only its recirculation flowpath available. Pump speed for the test is the normal operating speed of 3970 rpm. The established pump related acceptance criteria for this test are:

<u>Parameter</u>	<u>Acceptable Range</u>	<u>Alert Range</u>	<u>Required Action Range</u>
Suction Pressure, psia	≥ 11	NA	< 11
Pump Delta-P, psid	1194.6 to 1310.2	1183 to 1194.6 and 1310.2 to 1323.0	< 1183 and > 1323
Flow Rate, gpm	47.1 to 62.3	39.3 to 47.1 and 62.3 to 66.2	< 39.3 and > 66.2
Horizontal Vibration, mils	0 to 1.44	1.44 to 2.16	≥ 2.16
Vertical Vibration, mils	0 to 1	1.0 to 1.5	≥ 1.5

ST-10, 11, and 13 are surveillance procedures which implement valve stroke time and remote position indication requirements of the ASME Section XI Pump and Valve ISI program. Valve stroke time for the T&T valve, based on remote (main control board) indication, is measured quarterly. The test is conducted with steam isolated (MOV-9 closed). Stroke time is measured from closed to open by holding the valve handswitch to OPEN. The maximum allowable stroke time for the T&T valve is 19 seconds.

ST-15 is conducted at shutdown, as a part of the Pump and Valve ISI program. Its intent is to full stroke several check valves, including turbine driven pump discharge check valves and steam supply check valves. Full stroking is demonstrated by verifying ≥ 220 GPM to each steam generator with the turbine driven pump only running. This also provides an indication of turbine driven pump performance, since the procedure requires delivery of ≥ 220 GPM to each steam generator simultaneously, but total pump flow and developed head are not recorded. SG pressure is not recorded, but the procedure specifies that the turbine driven pump related check valves be stroked with steam pressure greater than 842 psig.

ST-21 is an Engineered Safety Features Response Time test in which the response times for the turbine driven pump following Main Feed Pump trip signals (performed in ST-7) are tabulated. A reference response time from signal initiation until the T&T valve begins to open (valve stem limit switch "ac" contacts close) is also determined.

ST-22 is an Engineered Safety Features Response Time test in which response times determined from numerous supporting tests are compiled and compared to allowable values. The response times for starting the turbine driven pump following a Safety Injection signal, Low-Low Steam Generator Level signal, Station Blackout signal, and the Main Feed Pump Trip signals are tabulated. The time interval measured is the time from start signal generation until the pump discharge pressure stabilizes.

It should be noted that the turbine driven pump is actually started, for response time measurement purposes, only in response to the Main Feed Pump Trip signals (see discussion under ST-7 and ST-21). Response times for various portions of the automatic initiation circuits are recorded in procedures MI-2 and 3 and ST-21, and are coordinated in ST-22 to determine total channel response times. It should also be noted that the T&T valve is not opened, nor verified to open for the Low-Low Steam Generator and Station

Blackout signals.

ST-27 is a calibration procedure for the AFW turbine controls, and is conducted on a refueling frequency. The test performs the following T&T valve related checks:

- The mechanical trip is manually actuated using the local trip lever. The open coil circuit of the valve is verified to be interrupted. The mechanical trip is manually reset, and restoration of the open coil circuit is verified.
- The stem actuated limit switch which provides initiation of the governor control ramping function is verified to close when the valve is 1/8 to 1/4 open. Total stroke length is also verified.
- A calibration of the speed sensor which is used for indication and for the electronic overspeed trip is performed. A signal generator is used in order to allow the calibration to be performed without the turbine operating. The electronic overspeed trip point is verified (using the signal generator).

The test also performs a number of checks related to the governor and governor control circuit, including the following:

- Resistance of the electromagnetic speed pickups for the turbine are checked
- A full governor control loop calibration is performed. This calibration includes the control speed sensor, ramp generator/signal converter, and the speed setting potentiometer. Most aspects of the calibration are performed with the turbine idle.
- An actual start of the turbine is conducted to verify that the turbine comes up to 2200 rpm with the minimal flow demand signal, and then controls at 3970 rpm at the full flow demand signal. It should be noted that the speed feedback portion of the circuitry is deleted for this portion of the test. With the turbine operating, the turbine is manually tripped using the mechanical trip lever.
- Following resetting of the turbine trip device and reconnecting of the lifted speed feedback leads, the turbine is verified to "quick start" and come up to normal operating speed (3970 rpm) in 15 +2/-1 seconds.

It should be noted that the starts of the turbine for ST-27 are done with only the miniflow recirculation flow path available.

MI-2 and 3 are a series of Instrument Maintenance Instruction procedures which determine response times for most Reactor Protection and Engineered Safety Features circuits, including portions of the turbine driven pump actuation circuits. The various portions of the Engineered Safety Features (ESF) response time for the T&T valve are determined. The times are compiled in ST-22.

MI-4 is a procedure which provides instructions on the testing of motor operated valves using the MOVATS system, which is used to assess the general mechanical and electrical control conditions of the valves.

MI-5 is a preventive maintenance procedure for LIMITORQUE actuators which is used to maintain equipment qualification. It provides for inspection and cleaning of electrical components; cleaning, inspection, and relubrication of the geared limit switch train; inspection and replacement (if needed) of gaskets; setting of the limit switch positions, per the MI-11.2 series; measurement of resistance to ground from the supply breaker; inspection and replacement (if needed) of the operator lubricant; cleaning and relubrication of the valve stem; lubrication of the sleeve top bearing (if a grease fitting is provided); inspection of the shaft seal for excessive leakage; and inspection of the spring pack for hardened grease.

MI-6 is a corrective maintenance procedure which is used periodically (as invoked by MI-5) to adjust motor operated valve limit and torque switch settings. Limit switch settings, which can be set based either on valve travel measurement or the number of handwheel turns, are set as follows:

Open limit switch: Set to allow valve to open to within 98-99% of full travel (the open limit switch is initially set at approximately 90% of full travel, then the valve is stroked electrically and valve travel measured, and the open limit switch setting is modified as necessary to achieve the 98-99% travel)

Close limit switch: Set to allow valve to close to within 99-100% of full travel (but with the limit switch set to open at no greater than 98% of full travel)

3.2.5.2. FREQUENCY OF TEST OPERATION

The T&T valve is stroked per the following test procedures. Note that the turbine is not started by all tests since upstream steam supply valves are closed prior to stroking the T&T valve.

<u>PROCEDURE</u>	<u>NUMBER OF T&T FULL STROKES/PUMP STARTS</u>	<u>FREQUENCY*</u>
ST-3	4 ³ /0	R
ST-6	1/0	R
ST-7	11/3	R
ST-8	2/2	Q
ST-11/13	1/0	Q
ST-15	2/2	HOT STANDBY ($\leq Q$) ²
ST-25	1/0	M
ST-27	4/2	R
MI-2A & B	1/0	R ¹
MI-3A & B	1/0	R ¹

*R-REFUELING

Q-QUARTERLY

M-MONTHLY

1. The MI tests are performed on an alternating basis; that is, one train is tested per refueling outage

2. It is assumed that this test is performed twice per year.

3. Estimated; the procedure does not identify any stroking, but multiple signals which cause valve opening are created.

TOTAL ESTIMATED TEST RELATED T&T FULL STROKES PER YEAR: 43

TOTAL ESTIMATED TEST RELATED TURBINE STARTS PER YEAR: 15

3.2.5.3. RELEVANT OPERATING INSTRUCTIONS

OP-1 is the AFW System operating procedure. It includes the following guidance:

-A precaution states that the AFW Pumps should be run on recirculation flow (as opposed to stopping and starting the pumps) during conditions when SG demand is low in order to avoid hanger damage and extend motor life. Another precaution stipulates that AFW should be batched at ≈ 75 gpm (under manual LCV control) to each SG to prevent vibration damage and inadvertent swapper from the CST to ESW suction as well as to

prevent SG nozzle cracking.

-Following pump start, the pump is inspected locally (no specific direction provided for the inspection)

-Precautions not to operate the turbine driven pump at less than 2200 RPM (the turbine idles speed). Although not specified in the procedure, the rationale behind this limitation is to prevent the rotational speed from approaching the turbine driven pump's first critical speed, calculated by the vendor to be 1900 RPM.

-Precautions that the pump discharge lines should be $\leq 125^{\circ}\text{F}$. This precaution is included to ensure against backleakage binding of the pumps. It should be noted that Plant A is probably less susceptible to backleakage than many other plants since its level control valves are normally closed (some plants have only check valves between the pumps and the SGs or main feed lines).

-Precautions that when admitting steam to a cold line, the steam supply valve should be cracked manually to warm the line slowly to prevent hammering the line.

OP-1 also provides valve and breaker lineup and control information for system operations. The valve checklist specifies that the T&T valve is to be "Closed and Operable", and that it is latched and the mechanical overspeed trip is reset. The procedure provides directions on starting up the turbine driven pump from the main control room and locally. It includes notes that the turbine speed can be controlled by manually operating the T&T valve, and specifies that it should be positioned to maintain discharge pressure 100 psi greater than SG pressure if so operated.

The procedure includes a note that an auxiliary power supply to the T&T valve is available, but does not include directions on how to place it into service, nor does it include normal position for the manual transfer switch.

The flow controller for the governor valve control circuit is specified to be in "AUTO", with its setpoint at 100% (provides a flow demand signal to the governor Ramp Generator/Signal Converter that is equivalent to 880 gpm).

OP-1 includes a section on starting and operating the turbine driven pump locally, and notes that the governor valve will fail open on loss of control power. It advises that the turbine speed can be controlled by manually operating the T&T valve and maintaining discharge pressure at 100 psi greater than steam supply pressure.

Another section of the OP advises that if the turbine trips on overspeed because of the flow controller failing to control flow automatically, that the controller should be placed in manual and the output set at 20% before restarting.

GOP-1 (Plant Startup from Cold Shutdown to Hot Standby), GOP-2 (Plant Startup from Hot Standby to Minimum Load), and GOP-3 (Plant Shutdown from Minimum Load to Cold Shutdown) include some of the same precautions relative to operation of the turbine driven pump.

While not part of a formal procedure (rather based on an operations group instruction letter), auxiliary operators check the temperatures of the pump discharge lines once per shift for evidence of backleakage of main feedwater. This monitoring is performed in response to IE Bulletin 85-01 and Generic Letter 88-03.

3.2.5.4. COMMENTS

1). There are several accident demand conditions, as well as support functions associated with the T&T valve which are not verified by periodic testing:

a). Bypassing of the valve thermal overload switches (the system design causes the thermal overload switches for the T&T valve to be bypassed by contacts which are actuated by all safety related starts of the turbine driven pump) is not verified.

b). The automatic steam supply transfer, which is built into the design in order to allow the turbine to operate in the event that its normal steam supply source is unavailable, is not verified by testing. This automatic transfer includes an auto-closure and a subsequent auto-open of the T&T valve. There are several tests in which the automatic steam supply transfer should occur (although steam is isolated from the T&T valve by MOV-9 and MOV-10 during the tests), for example, ST-3A & B and ST-7. However, there is no note or precaution in the procedures that the automatic transfer will occur, nor is there verification that the transfer does, in fact, occur. There are several potential sources of failure that are not checked in conjunction with the steam supply transfer. In addition, some components that are checked, for instance the T&T valve motor, are more seriously challenged by the back-to-back stroking that is required.

c). Proper setting and functioning of the following stem position limit switches are not verified by surveillance testing:

1) the switch which results in automatic closure of Steam Generator blowdown isolation valves and provides the permissive to allow automatic transfer to the alternate steam supply source (also note that there are several relays which must energize to cause these functions to occur which are likewise not checked)

2) the switch which causes the turbine driven pump room ventilation fan to start

3) the switch which causes the T&T valve operator to automatically drive to the shut position following an electronic overspeed trip

2). The T&T valve is not included in the Tech Spec list of valves for which verification of thermal overload protection operability is required (and therefore the settings of its thermal overload heaters/switches are not checked by a Surveillance Test). Note that, per Comment 1a, the bypassing of the thermal overload switches is also not verified for the T&T valve. If the bypassing of the thermal overload switches was verified, the thermal overload setting would be of less significance.

3). Automatic operation of the T&T valve closing coil to drive the motor to shut, thereby relatching the motor to the valve (and allowing the valve to automatically reopen, if the open signal is still present), following an electronic overspeed trip is not verified.

4). The electronic overspeed trip setpoint is tested under non-operating conditions (turbine not running). While the ability to trip the turbine using the mechanical trip lever is performed in ST-27, the mechanical trip setpoint is not tested periodically. Therefore, there is no test which verifies that the electronic overspeed trip will precede, and thereby avoid, the mechanical overspeed trip. (Note that an electronic overspeed trip is preferred, from an operational standpoint, since the mechanical overspeed trip requires local resetting.)

5). Only one train of the Blackout Signal is verified to cause opening of the T&T valve in ST-7. The test that is conducted is performed by jumpering contacts, as opposed to simulating the signal (for example, by deenergizing both sets of initiating relays). The train to be tested is left to operator discretion. Although both trains of Station Blackout relays (the relays which cause closure of the contacts noted to be jumpered above) are tested as a part of response time testing for the motor driven AFW pumps (in ST-3A & B), the T&T

valve is not verified to open.

6). With the exception of the testing of discharge check valves which is performed in ST-15, the test related runs of the turbine driven pump are performed with only the miniflow recirculation flow path available. There is no monitoring of the pump/turbine capability other than with minimum flow, plus the incomplete (only flow is recorded) indication provided by ST-15.

7). The tests for the turbine driven pump, as allowed by Tech Specs, are not required unless the steam supply pressure is greater than 842 psig (see Tech Spec Surveillance Requirement 4.7.1.2.a.2). However, as indicated in the Basis section for Tech Spec 3/4.7.1.2, the AFW System is depended upon to provide flow to the SGs until the Reactor Coolant System (RCS) reaches 350°F. Assuming no temperature differential between the RCS and the secondary side of the SGs, the corresponding saturation steam pressure would be about 120 psig. There is no testing of the turbine driven pump's ability to operate properly at reduced steam supply pressures.

3.2.6. Pump Miniflow Check Valves (MCV): C-8 , C-6 , C-10

3.2.6.1. SURVEILLANCE AND MAINTENANCE TESTS/INSPECTIONS

ST-8 and 9 are quarterly tests in which the AFW pumps are run in recirculation only. The MCVs are deemed to be operable in these procedures if recirculation flow, as measured by the use of a strap-on ultrasonic flowmeter, is at least 47 (minimum of the acceptable range) gpm for the turbine driven pump and 29/27 gpm for Motor Driven Pumps A/B.

3.2.6.2. FREQUENCY OF TEST OPERATION

The motor driven pump MCVs are stroked per the following procedures:

<u>PROCEDURE</u>	<u>NUMBER OF FULL STROKES</u>	<u>FREQUENCY*</u>
ST-3A & B	5	R
ST-6	5	R
ST-9	1	Q
ST-15	1	HOT STANDBY ($\leq Q$) ¹
ST-16	1	R
MI-2A & B	1	2R ²
MI-3A & B	1	2R ²

*R-REFUELING
Q-QUARTERLY
M-MONTHLY

1. It is assumed that this test is performed twice per year.
2. The RT tests are performed on an alternating basis; that is, one train is tested per refueling outage.

TOTAL ESTIMATED TEST RELATED FULL STROKES PER YEAR: The above test frequency information would yield about 14 full strokes per year; however, the motor driven pumps are used for protracted periods during startups and shutdowns, with

varying flow rates, with the dominant amount of time spent at relatively low flow rates or in recirculation flow only. Thus, the valves are stroked much more frequently than indicated by testing. Note that "full strokes" refers to conditions when the flow rate through the valves is at or near the maximum that occurs, not necessarily a condition where the check valve is fully open.

The turbine driven pump MCV is stroked per the following procedures:

<u>PROCEDURE</u>	<u>NUMBER OF FULL STROKES</u>	<u>FREQUENCY</u>
ST-7	3	R
ST-8	2	Q
ST-15	2	HOT STANDBY ($\leq Q$) ¹
ST-27	2	R

*R-REFUELING
Q-QUARTERLY
M-MONTHLY

1. It is assumed that this test is performed twice per year. Also note that the turbine driven pump is not assumed to already be operating when ST-15 is performed, as are the motor driven pumps.

TOTAL ESTIMATED TEST RELATED FULL STROKES PER YEAR: 15. The only time the valves would be likely to experience full stroking would be during testing, although there might be some infrequent operational demands that would result in substantial, if not design basis flow rates through the valves. Note that "full strokes" refers to conditions when the flow rate through the valve is at or near the maximum that occurs, not necessarily a condition where the check valve is fully open.

3.2.6.3. COMMENTS

The flow rates through the minimum flow lines are substantially less than current vendor recommended minimum flow for both the motor and turbine driven pumps. At the minimum acceptable flow rates through the miniflow lines of 29/27 gpm for the motor driven pumps and 47 gpm for the turbine driven pump, the line velocities are 6 and 11 ft/sec, respectively. Under these conditions, and particularly in light of the fact that the miniflow orifice is immediately upstream of the MCVs, disc oscillation would be expected.

The measurement of flow through the lines is by a strap-on ultrasonic flow meter. The test procedures do not specify exactly where to place the flow meter. The repeatability and accuracy of the ultrasonic flow meter indication, in light of the lack of specification of location as well as inherent instrumentation inaccuracy, would be expected to be relatively poor.

3.2.7. Common Miniflow Check Valves (CMCV): C-1, C-2

3.2.7.1. SURVEILLANCE AND MAINTENANCE TESTS/INSPECTIONS

ST-9 is a quarterly test in which the motor driven AFW pumps are run in recirculation only. The CMCVs are deemed to have been partially stroked in this procedure if recirculation flow, as measured by the use of a strap-on ultrasonic flowmeter, is at least 27 (Motor Driven Pump B)gpm.

ST-16 is performed once every two years for the specific purpose of demonstrating operability of the CMCVs. The test is performed by operating both motor driven pumps and the turbine driven pump with only the recirculation flow path to one CST available. Flow rates are not recorded.

3.2.7.2. FREQUENCY OF TEST OPERATION

The CMCVs are stroked per the following procedures:

<u>PROCEDURE</u>	<u>NUMBER OF FULL/PARTIAL STROKES</u>	<u>FREQUENCY*</u>
ST-3A & B	10P	R
ST-6	10P	R
ST-7	3P	R
ST-8	2P	Q
ST-9	2P	Q
ST-15	3P	HOT STANDBY ($\leq Q$) ¹
ST-16	1F	R
ST-27	2P	R
MI-2A & B	1P	2R ²
MI-3A & B	1P	2R ²

*R-REFUELING
Q-QUARTERLY
M-MONTHLY

1. This test is assumed to be performed twice per year.
2. The MI tests are performed on an alternating basis; that is, one train is tested per refueling outage.

TOTAL ESTIMATED TEST RELATED STROKES PER YEAR: The above test frequency information would yield about 39 partial strokes and 1 full stroke per year; however, the motor driven pumps are used for protracted periods during startups and shutdowns, with varying flow rates, with the dominant amount of time spent at relatively low flow rates or in recirculation flow only. Thus, the valves are partial stroked much more frequently than indicated by testing. Note that "full strokes" refers to conditions when the flow rate through the valve is at or near the maximum that occurs, not necessarily a condition where the check valve is fully open.

3.2.7.3. RELEVANT OPERATING INSTRUCTIONS

OP-1 includes precautions that state:

"AFW Pumps should continue to run on recirculation to avoid hanger damage and extend motor life. AFW LCV's should be maintained in manual to avoid steady-state low flow conditions that could result in damage to hangers in the Turbine Building, Condensate Transfer Pump damage, and/or intermittent actuation of AFW pump suction pressure switches. Just prior to criticality LCV Controller will be placed in AUTO positions."

"While in a low flow condition or Mode 3, AFW should be 'batched' or 'slugged' at \approx 75 gpm to each steam generator to prevent vibration damage and inadvertent ESW swapover. This flowrate will also ensure that S/G nozzle cracking does not occur."

GOP-1 ("Unit Heatup from Cold Shutdown to Hot Standby") and GOP-2 ("Plant Startup from Hot Standby to Minimum Load") include similar precautionary statements.

3.2.7.4. COMMENTS

Running a number of pumps in recirculation simultaneously, as is done in ST-16, does not provide a reliable indication of operability of the check valves, since flow is not measured. In order to demonstrate required operability, the actual flow of each pump (or at a minimum, the combined flow through the CMCV_s) should be measured.

It should also be noted that the flow velocities through the CMCVs are extremely low, even under conditions where all three AFW pumps are running simultaneously. An estimate of velocity through only one CMCV and through both of the parallel CMCVs for various nominal flow rates are provided below:

<u>FLOW, GPM</u>	<u>NUMBER OF PUMPS RUNNING</u>	<u>VELOCITY (FT/SEC) ONE CMCV OPEN</u>	<u>VELOCITY (FT/SEC) BOTH CMCVs OPEN</u>
25	ONE (MD) PUMP	1	0.6
40	TD PUMP	2	1
90	ALL PUMPS	4	2

The fact that the conditions under which these valves would be stroked from shut to open would normally be at very low velocities (including the ST-16 test, in which "full", or maximum expected flow is passed through the valves) suggests that the valve wear rate, as a function of service hours, would be fairly high.

3.2.8. Pump Discharge Check Valves (DCV): C-7, 9, 11

3.2.8.1. SURVEILLANCE AND MAINTENANCE TESTS/INSPECTIONS

ST-15, which is performed during each entry into Hot Standby conditions, demonstrates that the pumps are able to deliver design basis flow to the SGs. The test thereby demonstrates that the DCVs stroke open sufficiently to allow the required flow to pass through them. The total of flow rates to the SGs must be \geq 440 gpm for the motor driven pumps, and \geq 880 gpm for the turbine driven pump.

ST-28, which is performed on a refueling frequency, calls for the disassembly and inspection of several check valves. It should be noted that this ST does not meet a

specific Tech Spec Surveillance Requirement, and is not required by the ASME Section XI program, but is performed as a consequence of the San Onofre water hammer event (see NUREG-1190 and IE Notice 86-09). The valves are organized in groups of four. One valve out of each group is disassembled and inspected each refueling outage, so that each valve will be inspected about every six years. If a valve fails to meet the acceptance criteria (see below), all other valves in the group are to be inspected during the same outage. The DCVs, along with the turbine driven pump suction check valve, make up one group of valves to be disassembled and inspected in ST-28.

Acceptance criteria are:

- All internal parts are in place and show no signs of abnormal wear
- All internal locking devices, including tack welds, are in place and in good condition
- All internal surfaces are in good condition and show no signs of abnormal wear

3.2.8.2. FREQUENCY OF TEST OPERATION

The motor driven pump DCVs are stroked per the following procedures:

<u>PROCEDURE</u>	<u>NUMBER OF FULL STROKES</u>	<u>FREQUENCY</u>
ST-15	1	HOT STANDBY ($\leq Q$) ¹

1. It is assumed that this test is performed twice per year.

TOTAL ESTIMATED TEST RELATED FULL STROKES PER YEAR: 2. The only time the valves would be likely to experience full stroking would be during testing, although there might be some operational demands, such as total or partial loss of feedwater that would result in substantial, if not design basis flow rates through the valves. It should be noted that since the motor driven pumps are used during startup and shutdown periods, their DCVs would be partially stroked frequently as the pumps are used to maintain SG level.

The turbine driven pump DCV is stroked per the following procedures:

<u>PROCEDURE</u>	<u>NUMBER OF FULL STROKES</u>	<u>FREQUENCY</u>
ST-15	2	HOT STANDBY ($\leq Q$) ¹

1. It is assumed that this test is performed twice per year

TOTAL ESTIMATED TEST RELATED FULL STROKES PER YEAR: 4. The only time the valves would be likely to experience full stroking would be during testing, although there might be some infrequent operational demands that would result in substantial, if not design basis flow rates through the valves.

3.2.8.3. RELEVANT OPERATING INSTRUCTIONS

Since the turbine driven AFW pump would seldom be used to support startup/shutdown evolutions, the normal operating procedures primarily affect the motor driven pump DCVs.

OP-1 includes precautions that state:

"AFW Pumps should continue to run on recirculation to avoid hanger damage and extend motor life. AFW LCV's should be maintained in manual to avoid steady-state low flow conditions that could result in damage to hangers in the Turbine Building,

Condensate Transfer Pump damage, and/or intermittent actuation of AFW pump suction pressure switches. Just prior to criticality LCV Controller will be placed in AUTO positions."

"While in a low flow condition or Mode 3, AFW should be 'batched' or 'slugged' at \approx 75 gpm to each steam generator to prevent vibration damage and inadvertent ESW swapover. This flowrate will also ensure that S/G nozzle cracking does not occur." GOP-1 ("Unit Heatup from Cold Shutdown to Hot Standby") and GOP-2 ("Plant Startup from Hot Standby to Minimum Load") include similar precautionary statements.

While not part of a formal procedure (rather based on an operations group instruction letter), auxiliary operators check the temperatures of the pump discharge lines once per shift for evidence of backleakage of main feedwater. This monitoring is performed in response to IE Bulletin 85-01 and Generic Letter 88-03.

3.2.8.4. COMMENTS

The function of preventing reverse flow from either a parallel AFW pump or from main feedwater is accomplished by several valves, including the DCVs. The disassembly and inspection performed, as well as the full flow testing that is performed, help ensure that the valve strokes open freely. The disassembly and inspection also provides some level of assurance that the valve will not allow an extreme amount of reverse flow. There is no testing which attempts to verify that each specific valve keeps reverse flow to less than some acceptable value. However, as long as the series of valves, including, for example, a closed level control valve and its downstream check valve as well as the DCV, are demonstrated to prevent reverse flow, it is not viewed as particularly critical that the leak tightness of a specific valve be known.

At the maximum flow required for test conditions (220 gpm per SG in ST-15), the velocity through the motor driven pump DCVs is approximately 6 ft/sec. At the flow rate associated with "batching" the SGs during shutdown periods (75 gpm per SG, or 150 gpm total, per OP-1 and GOP-1 and -2), the velocity is approximately 2 ft/sec. These velocities are very low, especially considering the location of the DCVs (see Figure 3.3), and disc oscillation would be expected.

3.2.9. Motor Driven AFW Pump Level Control Valves (MDLCV): LCV-1/1A, LCV-3/3A, LCV-5/5A, LCV-7/7A

3.2.9.1. SURVEILLANCE AND MAINTENANCE TESTS/INSPECTIONS

ST-4, which is conducted on an 18 month frequency, is a channel calibration procedure. The procedure performs a loop calibration on the SG level instrument loops, from the level transmitters all the way through to the valves themselves. The procedure verifies valve position as a function of demand throughout the demand range. It verifies that the air supply pressures for the valve operators and the valve I/P converters are correct. It also verifies that the setpoints for the pressure switches which cause the control to transfer from the MDLCV's to the BMDLCV'S (PS-1, 3, 5, and 7) are proper. The check of the pressure switch setpoints is redundant to a check performed in ST-18.

ST-6, which is performed every 18 months, verifies that the MDLCV and BMDLCV controllers switch from manual to automatic, and that the automatic controllers cause the valves to open/close in response to steam generator level below/above setpoint, in response to simulation of each automatic AFW actuation signal. The test is performed with valves downstream of the level control valves closed, thereby preventing delivery of

flow to the steam generators. The portion of the test which simulates a station blackout does so by jumpering two sets of contacts (operated by the two undervoltage relays) which are normally open, but go closed when the associated 6.9 KV bus experiences an undervoltage condition. (Note that the relays which deenergize to cause the contacts to close are verified to cause the motor driven AFW pumps to start in MI-3; but the specific contacts which affect the MDLCV's and BMDLCV's are not verified to operate when the relays deenergize.)

ST's-10, 11, and 13 are surveillance procedures which implement valve stroke time and remote position indication requirements of the ASME Section XI Pump and Valve ISI program. Valve stroke times for the MDLCV's and the BMDLCV's are checked, using remote (main control board) position indication, on a quarterly basis. Valve stroke times, based on local observation of valve stem movement, are checked every two years and compared to stroke times recorded remotely. Local position is verified to agree with remote position indication every two years. The maximum allowable stroke times identified for the MDLCV's and the BMDLCV's are:

<u>MCLCV</u>	<u>MAXIMUM STROKE TIME</u>	<u>BMCLCV</u>	<u>MAXIMUM STROKE TIME</u>
LCV-1	14.4 SECONDS	LCV-1A	25.2 SECONDS
LCV-3	11.2 SECONDS	LCV-3A	25.3 SECONDS
LCV-5	15.6 SECONDS	LCV-5A	14.0 SECONDS
LCV-7	10.2 SECONDS	LCV-7A	15.6 SECONDS

The stroke times of an MDLCV is checked by first putting the valve handswitch in MANUAL BYPASS, and ramping the BMDLCV to full open (under these conditions, the MDLCV solenoid is energized, keeping it closed, while its controller, which is used for both the MDLCV and the BMDLCV, provides a maximum open signal). The handswitch is then placed to the MANUAL position, which deenergizes the MDLCV solenoid, causing the MDLCV to open. Stroke time is measured during this open stroke. A similar sequence is used for stroke time testing the BMDLCV's, except the handswitch is transferred from MANUAL to MANUAL BYPASS to initiate the stroke.

ST-20 is a test in which the response times of various portions of the AFW actuation circuitry is checked. This test measures the times in conjunction with actual equipment operations which occur when ST-6 is conducted. The times which are applicable to the MDLCV's and BMDLCV's are the times from main feed pump trip until energization of relays which result in the transfer of the valve controllers from manual to automatic.

ST-22 is an Engineered Safety Features (ESF) Response Time test in which the response times for the MDLCV's are measured. The times are measured from a simulated low level signal input to the level controller from level transmitter (note that this is not the same as the Lo-Lo SG level signal which causes AFW actuations to occur) until the MDLCV's are full open. The times are actually measured in MI-2, and in ST-22, the valve stroke response times from MI-2 are added to the relay response times and to other portions of the channel response time (logic and master relay response time) to calculate the total response time of the MDLCV's. The total response times for each of the MDLCV's, as well as the TDLCV's, the motor driven pumps and the turbine driven pump are compared, and the maximum time associated with any of these components is designated as the ESF Response Time for Auxiliary Feedwater.

ST-24, which is performed ever 31 days, verifies that the controllers for the MDLCV's and BMDLCV's respond appropriately to level deviation signals. If the test is performed during a time when the applicable pump is being used to maintain SG level (during

shutdown), the test will use both valve position change and observed flow to verify stroking. If the applicable pump is not in service to maintain SG level, the pumps are simulated to be running, and valve operability is based upon indicated position change in response to level deviation signals. The latter (pump not in service for level maintenance) will be the normal test condition.

It should be noted that this test verifies that the controller responds to transfer of the MCB switches from MANUAL to AUTO (with a pre-established level deviation), and also verifies controller response to adjustment of the automatic control setpoint at the ACP.

MI-2 is a response time procedure, performed once per refueling outage (one train is performed each outage) in which the time required for each MDLCV to stroke from closed to open in response to a simulated low SG level signal input to the valve controller is measured. The time is used in ST-22 to determine total AFW actuation response time. MI-2 also checks the response time for relays which result in the transfer of the valve controllers from manual to automatic.

MI-7 is used to verify the time delay relay associated with the automatic transfer from the MDLCV's to the BMDLCV's times out at fifteen seconds. The procedure does not actuate any equipment-it only verifies relay timing. There is no designated frequency of testing.

3.2.9.2. FREQUENCY OF TEST OPERATION

The MDLCV's are stroked per the following procedures:

<u>PROCEDURE</u>	<u>NUMBER OF FULL STROKES</u>	<u>FREQUENCY</u>
ST-4	1	R
ST-6	6	R
ST-10/13	1	Q
ST-15	1 ^{1,4}	HOT STANDBY ($\leq Q$) ²
ST-24	1	M
MI-2A & B	1 ¹	R X 2 ³

1. Only the MDLCV's are stroked (the BMDLCV's are not).
2. It is assumed that this test is performed twice per year.
3. Each MDLCV is stroked once every other refueling outage.
4. This is the only test in which the valves open to allow flow.

TOTAL ESTIMATED TEST RELATED FULL STROKES PER YEAR: The above test frequency information would yield about 23 full strokes per year for the MDLCV's and 21 for the BMDLCV's; however, both the MDLCV's and the BMDLCV's would be used routinely to support normal plant operation during startup and shutdown periods. Multiple partial or full strokes would occur during these evolutions.

3.2.9.3. RELEVANT OPERATING INSTRUCTIONS

OP-1 is the AFW system operating instruction. The procedure specifies that (as a Condition for Operation) the level controllers at the ACP be set for 33%.

The procedure also includes the following practices or requirements related to the MDLCV's and BMDLCV's.

- For start up of a motor driven pump, the procedure advises the operator to close all

LCV's, if time permits, and to control S/G level by manually throttling the associated LCV's

- For MDLCV manual local operation, the procedure provides directions as to the physical location of the valves, cautions the operator to maintain flow from a motor driven pump to less than 200 gpm in mode 5 or 6, and has the operator maintain level by throttling either the upstream or downstream isolation (gate) valves. A note is provided advising the operator that the MDLCVs fail open and the BMDLCVs fail closed on loss of power or air.

- A precaution stipulates that AFW should be batched at ≈ 75 gpm (under manual LCV control) to each SG to prevent vibration damage and inadvertent swapper from the CST to ESW suction as well as to prevent SG nozzle cracking.

3.2.9.4. COMMENTS

All testing is performed with the MDLCV control switches in MANUAL/MANUAL BYPASS. The normal, standby switch position is AUTO. With the switches in MANUAL, the LCV solenoids will be continuously deenergized, and therefore valve position will be controlled by the controller only. In normal system configuration, the LCV solenoids are energized (and the LCV's are therefore closed), and deenergize when the associated pump starts, thereby allowing the LCV's to modulate. The circuit change which causes the solenoids to transfer from the energized to the deenergized state (opening of pump breaker auxiliary contacts 52S/b) is not demonstrated.

The simulation of blackout signal to verify responses of the MDLCV's and BMDLCV's is done by jumpering the blackout contacts which are normally open, but close in response to loss of bus voltage conditions. The contacts which are jumpered are the contacts which cause the turbine driven pump to start as well as enabling the TDLCV's, MDLCV's, and BMDLCV's to perform their required automatic level control functions. Although the blackout relays are verified to deenergize to cause other contact operations (associated with the start of the motor driven pumps) in other procedures, the contacts which are jumpered for testing simulation purposes are not verified to operate properly (close when the relays deenergize).

The automatic transfer from MDLCV to BMDLCV control is not demonstrated. The pressure switches which initiate the transfer are verified to close at the correct setpoint (in ST-4), but the pump breaker contacts (52S/a) which provide another portion of the auto transfer permissive, as well as the relay and associated contacts which effect the transfer, are not verified to operate. The principal significance of not testing these components is that in the event of a faulted SG, failure of the faulted SG's MDLCV to transfer over to BMDLCV would result in continuing flow through the larger valve to the faulted SG.

The ability of the ACCIDENT RESET switch position to transfer the controller back to manual control in the presence of an accident signal is not demonstrated. Although the ACCIDENT RESET switch position is used several times in the ST's, the simulated accident signal is always removed first, thereby rendering the transfer to ACCIDENT RESET meaningless. The primary importance of being able to transfer to manual control is to provide the operator with the capability of dealing with either a situation where the controller(s) malfunctions in AUTO, or where a faulted SG condition exists, and flow to the faulted SG needs to be isolated (which would not occur automatically, since a low SG level condition would exist). Note that automatic transfer from MDLCV to BMDLCV control should occur when the downstream pressure is less than 400 psig; however, this is also not demonstrated to occur.

In addition to the fact that the ACCIDENT RESET switch is not demonstrated, there

exists a design condition for which neither the MDLCV's nor the TDLCV's can be reset to manual control. When the plant has been operating at > 80% load, a main feed pump trip will result in automatic start of the AFW pumps. Even for automatic starts of the AFW pumps from other sources (such as Safety Injection) which occur first, the feed pump trip start signal would also be generated. There is a single contact, operated by a non-safety grade pressure switch which senses HP turbine impulse pressure, which, in the event that it sticks closed (it is set to open at < 75% power), would prevent transfer of any of the MDLCV or TDLCV controllers from automatic to manual without additional operator intervention (such as the lifting of leads). The ability to reset the controls to manual and isolate a faulted SG within 10 minutes is taken credit for in the feedline and steamline accident analyses.

None of the surveillance tests which officially demonstrate the OPERABILITY of the MDLCV's put any flow through the valves; however, ST-15, which is used to demonstrate full stroking of various check valves, does demonstrate that the valves can be opened (using the manual controls) to allow ≥ 220 GPM to each SG.

3.2.10. Turbine Driven Pump Level Control Valves (TDLCV): LCV-2, LCV-4, LCV-6, LCV-8

3.2.10.1. SURVEILLANCE AND MAINTENANCE TESTS/INSPECTIONS

ST-4, which is conducted on an 18 month frequency, is a channel calibration procedure. The procedure performs a loop calibration on the SG level instrument loops, from the level transmitters all the way through to the valves themselves. The procedure verifies valve position as a function of demand throughout the demand range. It also verifies that the air supply pressures for the valve operators and the valve I/P converters are correct.

ST-7, which is conducted on an 18 month frequency, verifies that the TDLCV's controllers switch from manual to automatic and then open/close the valves in response to level below/above control setpoint, in response to each automatic turbine driven pump start signal (except that the blackout signal is tested on only one train). There is no flow delivered in this test, since downstream isolation valves are closed. All tests are conducted with the valve switches in "MANUAL" (the normal position is "AUTO")

ST-10, 11, and 13 are used to implement the ASME Section XI valve inservice testing requirements. The TDLCV's are stroked once per quarter under these procedures for remote stroke time measurement. Every two years, the valve are stroked for verification of consistency between local and remote stroke time measurement and position indication. There is no flow delivered to the SG's in this test. The maximum allowable stroke times for the TDLCV's, as identified in ST-10, are:

LCV-2: 102.6 SECONDS
LCV-4: 132.0 SECONDS
LCV-6: 126.0 SECONDS
LCV-8: 112.0 SECONDS

The valves are stroked, per ST-10, by placing the valve handswitch in MANUAL and then ramping open the valve using the manual controls.

ST-22 is an Engineered Safety Features (ESF) Response Time test in which the response times for the TDLCV's are measured. The times are measured from a simulated low level signal input to the level controller from level transmitter (note that

this is not the same as the Lo-Lo SG level signal which causes AFW actuations to occur) until the TDLCV's are full open. (The times are actually measured in MI-2). In ST-22, the response times for the TDLCV's, as well as those for the MDLCV's, the TDP, and the MDP's are compiled. The maximum time associated with any of these components is designated as the ESF Response Time.

ST-24 is a monthly test by which the proper responses of the automatic controller to above/below setpoint deviation signals are verified. It should be noted that this test verifies that the controller responds to transfer of the MCB switches from MANUAL to AUTO (with a pre-established level deviation), and also verifies controller response to adjustment of the automatic control setpoint at the ACP.

MI-2 and 3 are a series of procedures which determine response times for most Reactor Protection and Engineered Safety Features circuits, including portions of the turbine driven pump actuation circuits. The various portions of the Engineered Safety Features (ESF) response time for the TDLCV's are determined. The times are compiled in ST-22.

3.2.10.2. FREQUENCY OF TEST OPERATION

The TDLCV's are stroked per the following procedures:

<u>PROCEDURE</u>	<u>NUMBER OF FULL STROKES</u>	<u>FREQUENCY*</u>
ST-4	1	R
ST-7	7	R
ST-10/13	1	Q
ST-15	2 ³	HOT STANDBY ($\leq Q$) ¹
ST-24	1	M
MI-2A & B	1	R ²

*R-REFUELING
Q-QUARTERLY
M-MONTHLY

1. It is assumed that this test is performed twice per year.
2. The RT tests are performed on an alternating basis; that is, one train is tested per refueling outage.
3. This is the only test in which flow through the TDLCV's is exhibited (the TDLCV's are opened after the turbine driven pump is started, and ≥ 220 GPM to each SG is verified).

TOTAL ESTIMATED TEST RELATED FULL STROKES PER YEAR: 26

3.2.10.3. RELEVANT OPERATING INSTRUCTIONS

See the discussion for the motor driven pump level control valves (MDLCV's) under item G above. The comments also apply to the TDLCV's.

3.2.10.4. COMMENTS

A check valve is provided in the control air line upstream of the accumulator connection.

The function of the check valve is to ensure that in the event of control air loss, the air in the accumulator will be available for valve stroking. This check valve is not tested, nor is the ability of the accumulator (in the absence of continuing control air supply) to stroke the LCV demonstrated periodically.

The maximum allowable stroke times for the TDLCV's established in ST-10 appear to be very high, and inconsistent with the allowable ESF Response Time for AFW (60 seconds). Also, the response time for the TDLCV's is measured under no flow conditions. Since these are fail closed valves, stroke times under flow conditions (versus no flow) would be expected to increase.

The automatic pipe break detection function, which isolates the TDLCV to a faulted SG, is not tested. Two sets of pressure switches (turbine driven pump pressure switches PS-10 and 11 and the pressure switches downstream of the TDLCV's: PS-14 and 15, PS-16 and 17, PS-18 and 19, and PS-12 and 13), along with relays and contacts which must change state in response to pressure switch closure are required to operate properly in order for the automatic isolation to occur. Although both sets of pressure switches are checked to verify that the switches close at the proper pressure, the relays and associated contacts that actually cause isolation are not verified. It should be noted that even though the TDLCV's close by design, this is not a Tech Spec required function for Plant A (faulted SG isolation is a Tech Spec requirement for some other plants).

The ability of the ACCIDENT RESET switch position to transfer the TDLCV controller back to manual control in the presence of an accident signal is not demonstrated. Although the ACCIDENT RESET switch position is used several times in the ST's, the simulated accident signal is always removed first, thereby rendering the transfer to ACCIDENT RESET meaningless. The primary importance of being able to transfer to manual control is to provide the operator with the capability of dealing with either a situation where the controller(s) malfunctions in AUTO, or where a faulted SG condition exists, and flow to the faulted SG is not automatically isolated (note that the automatic isolation feature is not verified).

In addition to the fact that the ACCIDENT RESET switch is not demonstrated, there exists a design condition for which neither the MDLCV's nor the TDLCV's can be reset to manual control. When the plant has been operating at > 80% load, a main feed pump trip will result in automatic start of the AFW pumps. Even for automatic starts of the AFW pumps from other sources (such as Safety Injection) which occur first, the feed pump trip start signal would also be generated. There is a single contact, operated by a non-safety grade pressure switch which senses HP turbine impulse pressure, which, in the event that it sticks closed (it is set to open at < 75% power), would prevent transfer of any of the MDLCV or TDLCV controllers from automatic to manual without unusual additional operator intervention (such as the lifting of control wiring leads). The ability to reset the controls to manual and isolate a faulted SG within 10 minutes is taken credit for in the feedline and steamline accident analyses.

There is no testing conducted in which the TDLCV's are verified to open/close automatically with their control switches in AUTO, which is the normal condition. All testing in which the valves are stroked, whether manually, or by the automatic controller, is done with the valve control switch in MANUAL. The contacts which would open to deenergize the valves' solenoids with the switches in AUTO are therefore never demonstrated. (Note that the relays which operate the contacts are also not verified to operate)

None of the surveillance tests which officially demonstrate the OPERABILITY of the

TDLCV's put any flow through the valves; however, ST-15, which is used to demonstrate full stroking of various check valves, does demonstrate that the valves can be opened (using the manual controls) to allow ≥ 220 GPM to each SG.

3.2.11. Level Control Valve Check Valves (LCVCV): C-12, 13, 14, 15, 16, 17, 18, 19

3.2.11.1. SURVEILLANCE AND MAINTENANCE TESTS/INSPECTIONS

ST-15, which is performed during each entry into Hot Standby conditions, demonstrates that the pumps are able to deliver design basis flow to the SGs. The test thereby demonstrates that the LCVCVs stroke open sufficiently to allow the required flow to pass through them. The total of flow rates to the SGs must be ≥ 440 gpm for the motor driven pumps, and ≥ 880 gpm for the turbine driven pump.

ST-28, which is performed on a refueling frequency, calls for the disassembly and inspection of several check valves. It should be noted that this ST does not meet a specific Tech Spec Surveillance Requirement, and is not required by the ASME Section XI program, but is performed as a consequence of the San Onofre water hammer event (see NUREG-1190 and IE Notice 86-09). The valves are organized in groups of four. One valve out of each group is disassembled and inspected each refueling outage, so that each valve will be inspected about every six years. If a valve fails to meet the acceptance criteria (see below), all other valves in the group are to be inspected during the same outage. The motor driven pump LCVCVs (C-13, C-15, C-17, C-19) make up one group and the turbine driven pump LCVCVs (C-12, C-14, C-16, C-18) make up another group of valves which are disassembled and inspected in ST-28.

Acceptance criteria are:

- All internal parts are in place and show no signs of abnormal wear
- All internal locking devices, including tack welds, are in place and in good condition
- All internal surfaces are in good condition and show no signs of abnormal wear

3.2.11.2. FREQUENCY OF TEST OPERATION

The motor driven pump LCVCVs are stroked per the following procedures:

<u>PROCEDURE</u>	<u>NUMBER OF FULL STROKES</u>	<u>FREQUENCY</u>
ST-15	1	HOT STANDBY ($\leq Q$) ¹

1. It is assumed that this test is performed twice per year.

TOTAL ESTIMATED TEST RELATED FULL STROKES PER YEAR: 2. The only time the valves would be likely to experience full stroking would be during testing, although there might be some operational demands, such as total or partial loss of feedwater that would result in substantial, if not design basis flow rates through the valves. It should be noted that since the motor driven pumps are used during startup and shutdown periods, their LCVCVs would be partially stroked (in manual) frequently as the pumps are used to maintain SG level. Note that "full strokes" refers to conditions when the flow rate through the valves is at or near the maximum that occurs, not necessarily a condition where the check valve is fully open.

The turbine driven pump LCVCVs are stroked per the following procedures:

<u>PROCEDURE</u>	<u>NUMBER OF FULL STROKES</u>	<u>FREQUENCY</u>
ST-15	2	HOT STANDBY ($\leq Q$) ¹

1. It is assumed that this test is performed twice per year

TOTAL ESTIMATED TEST RELATED FULL STROKES PER YEAR: 4. The only time the valves would be likely to experience full stroking would be during testing, although there might be some occasional operational demands, such as total or partial loss of normal feedwater, that would result in substantial, if not design basis flow rates through the valves. Note that "full strokes" refers to conditions when the flow rate through the valves is at or near the maximum that occurs, not necessarily a condition where the check valve is fully open.

3.2.11.3. RELEVANT OPERATING INSTRUCTIONS

Since the turbine driven AFW pump would seldom be used to support startup/shutdown evolutions, the normal operating procedures primarily affect the motor driven pump LCVCVs.

OP-1 includes precautions that state:

"AFW Pumps should continue to run on recirculation to avoid hanger damage and extend motor life. AFW LCV's should be maintained in manual to avoid steady-state low flow conditions that could result in damage to hangers in the Turbine Building, Condensate Transfer Pump damage, and/or intermittent actuation of AFW pump suction pressure switches. Just prior to criticality LCV Controller will be placed in AUTO positions."

"While in a low flow condition or Mode 3, AFW should be 'batched' or 'slugged' at ≈ 75 gpm to each steam generator to prevent vibration damage and inadvertent ESW swapover. This flowrate will also ensure that S/G nozzle cracking does not occur."

GOP-1 ("Unit Heatup from Cold Shutdown to Hot Standby") and GOP-2 ("Plant Startup from Hot Standby to Minimum Load") include similar precautionary statements.

3.2.11.4. COMMENTS

The batch flow rate which is specified by the operating procedures for the AFW lines to the SGs during startup/shutdown (75 gpm) corresponds to a flow velocity of 2 ft/sec. This low flow rate (and complicated by the piping configuration for the "A" pump lines-see Figure 3.6) would be expected to contribute to disc oscillation and wear.

The function of preventing reverse flow from either a parallel AFW pump or from main feedwater is accomplished by several valves, including the LCVCVs. The disassembly and inspection performed, as well as the full flow testing that is performed, help ensure that the valve strokes open freely. The disassembly and inspection also provides some level of assurance that the valve will not allow an extreme amount of reverse flow. There is no testing which attempts to verify that each specific valve keeps reverse flow to less than some acceptable value. However, as long as the series of valves, including, for example, the combination of a closed level control valve, the associated LCVCV and the pump discharge check valve, are demonstrated to prevent reverse flow, it is not

particularly critical that the leak tightness of a specific valve be known.

The requirement to inspect the turbine driven pump LCVCVs at the same frequency as the motor driven pump LCVCVs does not appear supportable from the standpoint of susceptibility to operationally induced wear. It would appear that less emphasis on the turbine driven pump LCVCVs would be reasonable (perhaps only disassemble and inspect one valve every other refueling outage).

3.2.12. Steam Generator B and C AFW to Main Feed Check Valves (MFCV): C-21, C-22, C-24, and C-25

3.2.12.1. SURVEILLANCE AND MAINTENANCE TESTS/INSPECTIONS

ST-15, which is performed during each entry into Hot Standby conditions, demonstrates that the pumps are able to deliver design basis flow to the SGs. The test thereby demonstrates that the MFCVs stroke open sufficiently to allow the required flow to pass through them. The total of flow rates to the SGs must be ≥ 440 gpm for the motor driven pumps, and ≥ 880 gpm for the turbine driven pump.

ST-28, which is performed on a refueling frequency, calls for the disassembly and inspection of several check valves. It should be noted that this ST does not meet a specific Tech Spec Surveillance Requirement, and is not required by the ASME Section XI program, but is performed as a consequence of the San Onofre water hammer event (see NUREG-1190 and IE Notice 86-09). The valves are organized in groups of four. One valve out of each group is disassembled and inspected each refueling outage, so that each valve will be inspected about every six years. If a valve fails to meet the acceptance criteria (see below), all other valves in the group are to be inspected during the same outage. The MFCVs make up one group of valves which are disassembled and inspected in ST-28.

Acceptance criteria are:

- All internal parts are in place and show no signs of abnormal wear
- All internal locking devices, including tack welds, are in place and in good condition
- All internal surfaces are in good condition and show no signs of abnormal wear

3.2.12.2. FREQUENCY OF TEST OPERATION

The MFCVs are stroked per the following procedures:

<u>PROCEDURE</u>	<u>NUMBER OF FULL STROKES</u>	<u>FREQUENCY</u>
ST-15	3	HOT STANDBY ($\leq Q$) ¹

1. It is assumed that this test is performed twice per year.

TOTAL ESTIMATED TEST RELATED FULL STROKES PER YEAR: 6 (The only time the valves would be likely to experience full stroking would be during testing, although there might be some operational demands, such as total or partial loss of feedwater that would result in substantial, if not design basis flow rates through the valves.) It should be noted that since the motor driven pumps are used during startup and shutdown periods, the MFCVs would be partially stroked frequently as the pumps are used to maintain SG level.

3.2.12.3. RELEVANT OPERATING INSTRUCTIONS

OP-1 includes precautions that state:

"AFW Pumps should continue to run on recirculation to avoid hanger damage and extend motor life. AFW LCV's should be maintained in manual to avoid steady-state low flow conditions that could result in damage to hangers in the Turbine Building, Condensate Transfer Pump damage, and/or intermittent actuation of AFW pump suction pressure switches. Just prior to criticality LCV Controller will be placed in AUTO positions."

"While in a low flow condition or Mode 3, AFW should be 'batched' or 'slugged' at ≈ 75 gpm to each steam generator to prevent vibration damage and inadvertent ESW swapover. This flowrate will also ensure that S/G nozzle cracking does not occur."

GOP-1 ("Unit Heatup from Cold Shutdown to Hot Standby") and GOP-2 ("Plant Startup from Hot Standby to Minimum Load") include similar precautionary statements. The MFCVs therefore would be most frequently exposed to flow rates of about 75 gpm.

3.2.12.4. COMMENTS

The velocity at the MFCVs during the "batching" of AFW to the SGs at 75 gpm would be about 2.4 ft/sec, which is less than that required to fully open the the MFCVs. In addition, as noted previously, disc oscillation due to turbulence would be expected in light of the piping configuration. However, the combination of disassembly and inspection and flow monitoring appear to provide a reasonable assurance that degradation of these valves would be detected and corrected.

3.2.13. Main Feedwater Check Valves (FWCV): C-20, 23, 26, 27

3.2.13.1. SURVEILLANCE AND MAINTENANCE TESTS/INSPECTIONS

ST-29, which is performed during cold shutdown with the SGs depressurized, verifies closure of the FWCVs by monitoring the extent of backleakage of water from the SGs. The test acceptance criteria allow a leak rate of about 16 gpm.

ST-28, which is performed on a refueling frequency, calls for the disassembly and inspection of several check valves. It should be noted that this ST does not meet a specific Tech Spec Surveillance Requirement, and is not required by the ASME Section XI program, but is performed as a consequence of the San Onofre water hammer event (see NUREG-1190 and IE Notice 86-09). The valves are organized in groups of four. One valve out of each group is disassembled and inspected each refueling outage, so that each valve will be inspected about every six years. If a valve fails to meet the acceptance criteria (see below), all other valves in the group are to be inspected during the same outage. The FWCVs make up one group of valves to be disassembled and inspected in ST-28.

Acceptance criteria are:

- All internal parts are in place and show no signs of abnormal wear
- All internal locking devices, including tack welds, are in place and in good condition
- All internal surfaces are in good condition and show no signs of abnormal wear

3.2.13.2. FREQUENCY OF TEST RELATED OPERATION

The FWCVs are not stroked for test purposes. The normally open valves would close when normal feedwater flow to the SGs is terminated, either during routine plant shutdown or following certain transients, such as loss of feedwater or or feedwater isolation.

3.2.13.3. COMMENTS

As noted above, the test which checks for backleakage (ST-29) allows up to about 16 gpm seat leakage under depressurized conditions where the only driving force is the elevation head associated with the water level in the SGs.

Assuming that a) the reverse flow rate through the check valve is proportional to the square root of the pressure drop and that b) the valve disk/seat geometry is not affected by the difference between test and demand pressure and temperature conditions, the 16 gpm allowable backleakage under depressurized conditions would correspond to about 130 gpm per SG at the pressure of the lowest SG safety valve. This would appear to be unacceptable.

3.2.14. Feedwater Isolation Valves (FWIVs): FWIV-1, 2, 3, 4

3.2.14.1. SURVEILLANCE AND MAINTENANCE TESTS/INSPECTIONS

ST-10, 11, and 13 are surveillance procedures which implement valve stroke time and remote position indication requirements of the ASME Section XI Pump and Valve ISI program. Valve stroke times for the FWIVs, based on remote (main control board) indication, are measured quarterly. Stroke time is measured by turning the handswitch to closed and measuring the time until the valve open indicating light is off and the closed indicating light is on. The maximum allowable stroke time for the FWIVs is 7.5 seconds.

MI-4 is a procedure which provides instructions on the testing of motor operated valves using the MOVATS system, which is used to assess the general mechanical and electrical control conditions of the valves.

MI-5 is a preventive maintenance procedure for LIMITORQUE actuators which is used to maintain equipment qualification. It provides for inspection and cleaning of electrical components; cleaning, inspection, and relubrication of the geared limit switch train; inspection and replacement (if needed) of gaskets; setting of the limit switch positions, per MI-6B; measurement of resistance from each phase to ground from the supply breaker; inspection and replacement (if needed) of the operator lubricant; cleaning and relubrication of the valve stem; lubrication of the sleeve top bearing (if a grease fitting is provided); inspection of the shaft seal for excessive leakage; and inspection of the spring pack for hardened grease.

MI-6B is a corrective maintenance procedure which is used periodically (as invoked by MI-5) to adjust motor operated valve limit and torque switch settings. Limit switch settings, which can be set based either on valve travel measurement or the number of handwheel turns, are set as follows:

Open limit switch: Set such that the valve will open to within 98-99% of full travel, where "full travel" is the distance from valve to seat contact (closed) to backseat contact (open)

Close limit switch: Set such that the valve will close to within 99-100% of full travel.

3.2.14.2. FREQUENCY OF OPERATION

The FWIV's are stroked per the following procedures:

<u>PROCEDURE</u>	<u>NUMBER OF FULL STROKES</u>	<u>FREQUENCY</u>
ST-3A & B	4	R
ST-10 / 13	1	COLD SHUTDOWN ¹
ST-29	1	COLD SHUTDOWN ¹

1. Assumed to occur once per year (in addition to refueling outages).

TOTAL ESTIMATED TEST RELATED FULL STROKES PER YEAR: 5

3.2.14.3. RELEVANT OPERATING INSTRUCTIONS

From an AFW perspective, the operating procedures of importance are the emergency operating procedures. Emergency procedures require early verification of closure of the MFIV's. The emergency procedure which is initially used for normal post trip purposes, EOP-1, "Reactor Trip or Safety Injection", has the operator verify that the MFIVs (and upstream Main Feed Reg Valves) are closed as one of the early actions (Step 7). Main Feed Isolation is also verified in step 3 of EOP-2, "Reactor Trip Response". EOP-2 would be transitioned into from EOP-1 following a reactor trip without safety injection being required. While the checks in these two procedures are the primary means by which the operator is instructed to ensure that the FWIVs are closed, Main Feed Isolation is also verified in other procedures that may be transitioned into as conditions dictate (for example step 2 of E-2, "Faulted Steam Generator Isolation").

3.2.14.4. COMMENTS

The power supplies for the motor operated FWIVs at Plant A are not strongly tied to the AFW System. For instance, the FWIV to SG B is operated by a motor powered off of a "B" train bus, while SG B is fed by motor driven AFW pump A, which is powered from an "A" train bus. A similar circumstance exists for the SG C FWIV (powered from "A" train) and the AFW pump used to feed SG C ("B" pump). Also, as at most plants, the signals that automatically start the AFW pumps do not provide a close signal to the FWIVs.

From a feedline break perspective, the function of these valves is fairly important. The San Onofre event is a good example of the importance that these valves have in assuring that AFW is actually delivered to the SGs. The FWIVs are not leak-rate checked; however, the fact that they are gate valve should minimize the probability of excessive seat leakage.

3.2.15. SG Blowdown Isolation Valves (BDIVs): BDV-1, 2, 3, 4

3.2.15.1. SURVEILLANCE TESTS

ST-10, 11, and 13 are surveillance procedures which implement valve stroke time and remote position indication requirements of the ASME Section XI Pump and Valve ISI program. Valve stroke times for the BDIVs, based on remote (main control board) indication, are measured quarterly. Stroke time is measured by turning the handswitch to closed and measuring the time until the valve open indicating light is off and the closed indicating light is on. It is noteworthy that the test instructions do not advise the operator to maintain the switch in the "Open" position when reopening the valve (or initially opening it for stroke time measurement), since the BDIV's do not have a seal-in circuit, and require that the operator hold the switch to "Open" until the valve is fully open. (The reason that this is noteworthy is that the stroking procedures for other valves which have the seal-in circuit, such as FCV-1-17 and 18, do advise the operator to hold the switches during stroking).

The maximum allowable Inservice Test stroke times for the BDIVs are:

BDV-1:	7.2 seconds
BDV-2:	10.0 seconds *
BDV-3:	7.4 seconds
BDV-4:	10.0 seconds *

*Based upon Tech Spec limitations.

ST-3A & B are tests which verify automatic operation of plant equipment in response to various simulated conditions, including Safety Injection, Loss of Offsite Power, and Phase A Containment Isolation. These tests are performed on an 18 month frequency, during mode 5 (Cold Shutdown). The BDIVs are verified to close during the Phase A Isolation signal portion of the test. The test does not specifically call for the BDIVs to be reopened following the Phase A sequence. Subsequent test sequences, such as the Safety Injection sequence, result in the generation of a closure signal to the BDIVs (due to the fact that the AFW pumps start on an SI signal as well as the fact that an SI signal causes a Phase A Isolation signal). However, closure is not verified in the test, and in fact it is probable that the BDIVs would not be reopened after the Phase A Isolation test.

3.2.15.2. FREQUENCY OF TEST OPERATION

The BDIV's are stroked per the following procedures:

<u>PROCEDURE</u>	<u>NUMBER OF FULL STROKES²</u>	<u>FREQUENCY</u>
ST-3A & B	2	R
ST-7	1	R
ST-8	1	Q
ST-9	1	Q
ST-10/13	1	Q
ST-15	1	HOT STANDBY (\leq Q) ¹
ST-25	1	M
ST-27	1	R

1. It is assumed that this test is performed twice per year.

2. Stroking of the valves is only called for in ST-10/13 and ST-3A & B; however, valve stroking should occur automatically in the other procedures due to the fact that the AFW

pumps are started. Note that there are other tests conducted during refueling shutdowns which cause AFW pumps to start, and thus cause closure signals to be sent to the BDIVs; however, since SG Blowdown would normally be secured during this time, there is no stroking assumed.

TOTAL ESTIMATED TEST RELATED FULL STROKES PER YEAR: The above test frequency information would yield about 29 full strokes per year; however, the BDIVs would also be stroked open and closed during plant startup and shutdown.

3.2.15.3. RELEVANT OPERATING INSTRUCTIONS

OP-2 is the SG Blowdown operating procedure. It specifies a maximum blowdown flow rate of 75 gpm per SG. Per OP-2, the BDIVs are closed whenever blowdown is secured. However, the procedure specifically instructs that the BDIVs are not to be used to secure blowdown, rather that they are to be closed after blowdown is secured (flow is isolated by a common downstream regulating valve). The procedure also specifies that the BDIVs not be used to place blowdown in service. Blowdown is placed in service by initially opening one SGs' BDIV (and inside isolation valve) to pressurize the piping upstream of the common line isolation valve, then opening the BDIVs from the other SGs, and finally opening the common regulating valve. (One of the intents of this sequence is to minimize water hammer associated with either securing blowdown or placing it in service).

GOP-1, which is the general operating instruction for taking the plant from Cold Shutdown to Hot Standby, specifies that blowdown is to be placed into service when the RCS is around 200 degrees F.

GOP-3, which is the general operating instruction for taking the plant from Minimum Load to Cold Shutdown, specifies that blowdown is to be secured when the RCS is less than 200 degrees F.

The emergency procedures, which are based on generic Westinghouse guidelines, frequently associate the SG blowdown valves with AFW. For example, in EOP-0 (Reactor Trip or Safety Injection Emergency Procedure), the procedural instructions which "Verify AFW Status" include the following conditions for verification:

"AFW Pumps-RUNNING
AFW level control valves in AUTO
If SG level < 33%, then verify AFW flow
SG blowdown valves-CLOSED"

3.2.15.4. COMMENTS

The BDIVs are not verified to close in response to start of the AFW pumps. There is not a specific Tech Spec requirement that specifies that the BDIVs must close in response to an AFW pump start, since the BDIVs are not "in the flow path". However, failure of the BDIVs to close would substantially diminish the effective flow delivery capability of the AFW pumps. The impact that blowdown has on AFW is implicitly confirmed by the inclusion of blowdown isolation verification under the heading of "AFW Status" in the emergency procedures. The impact of unisolated blowdown can, in part, be gathered from the 1985 water hammer event at San Onofre (See NUREG-1190).

The fact that verification of blowdown isolation is included in the emergency procedures under "AFW Status", which is checked at an early point in the procedures, provides some assurance that the valves will be closed following a transient induced reactor trip (whether as a direct result of the AFW pumps starting or as a result of operator action).

The stroke testing of the BDIVs which is done as a part of the ASME Section XI program strokes the valves manually, and does so by use of the ganged switch which controls not only the BDIV but the inside containment isolation valve as well. The flow conditions under which the BDIVs are stroked are not specified. The ability of the BDIVs to close, and the speed with which they would close depends, in part, on the extant flow and pressure conditions. The worst case conditions under which the valves would have to close would be at high pressure and flow, and without the assistance provided by the simultaneous closure of the inside containment isolation valves (since these valves only close on a Phase A Isolation, which in turn, only occurs automatically as the result of a Safety Injection. Note that design basis demand conditions for the BDIVs, and the AFW system, correspond to heat-up conditions which would not necessarily cause a Safety Injection). The testing which demonstrates operability of the BDIVs causes both the BDIVs and the inside containment isolation valves to close, and is performed under nominal pressure/flow conditions.

3.2.16. AFW Turbine Steam Supply Valves (SSVs): MOV-11, MOV-12

3.2.16.1. SURVEILLANCE AND MAINTENANCE TESTS/INSPECTIONS

ST-10, 11, and 13 are surveillance procedures which implement valve stroke time and remote position indication requirements of the ASME Section XI Pump and Valve ISI program. Valve stroke times for MOV-11 and MOV-12, based on remote (main control board) indication, are measured quarterly. MOV-11 is stroke time tested from open to closed by turning the valve handswitch to the CLOSE position, and holding the switch in CLOSE until the valve open indicating light is off and the closed indicating light is on. MOV-12 testing is similar, except that it is stroke timed from closed to open. It is noteworthy that by keeping the valve handswitches in the CLOSE or OPEN position until valve travel is complete, the seal-in features of the valve open and close coils are not demonstrated. Valve stroke times, based on local observation of valve stem movement, are checked every two years and compared to stroke times recorded remotely. Local position is verified to agree with remote position indication every two years.

The maximum allowable stroke times for the SSVs is:

MOV-11: 15.9 SECONDS

MOV-12: 20.0 SECONDS

ST-23, which is performed every 18 months, verifies that the thermal overload heaters are operating properly. The thermal overload trip time at rated full load current is demonstrated to be greater than twice the maximum allowable stroke time, and the trip time at locked rotor current is demonstrated to be between 10 and 15 seconds.

MI-4 is a procedure which provides instructions on the testing of motor operated valves using the MOVATS system, which is used to assess the general mechanical and electrical control conditions of the valves.

MI-5 is a preventive maintenance procedure for LIMITORQUE actuators which is used to maintain equipment qualification. It provides for inspection and cleaning of electrical components; cleaning, inspection, and relubrication of the geared limit switch train; inspection and replacement (if needed) of gaskets; setting of the limit switch positions, per MI-6A; measurement of resistance from each phase to ground from the supply breaker; inspection and replacement (if needed) of the operator lubricant; cleaning and relubrication of the valve stem; lubrication of the sleeve top bearing (if a grease fitting is

provided); inspection of the shaft seal for excessive leakage; and inspection of the spring pack for hardened grease.

MI-6A is a corrective maintenance procedure which is used periodically (as invoked by MI-5) to adjust motor operated valve limit and torque switch settings. Limit switch settings, which can be set based either on valve travel measurement or the number of handwheel turns, are set as follows:

Open limit switch: Limit switch set to open at 95-98% of valve travel
 Close limit switch: Limit switch set to open at 97-98% of valve travel

MI-8 is used to verify the time delay relay associated with the automatic steam supply transfer times out at sixty seconds. The procedure does not actuate any equipment-it only verifies timing. There is no designated frequency of testing. A commitment to periodically calibrate the timers was made in an LER filed by Plant A.

3.2.16.2. FREQUENCY OF TEST OPERATION

The SSVs are stroked per the following procedures:

<u>PROCEDURE</u>	<u>NUMBER OF FULL STROKES²</u>	<u>FREQUENCY</u>
ST-6	1	R
ST-7	1	R
ST-8	1	Q
ST-10/13	1	Q
ST-15	1	HOT STANDBY ($\leq Q$) ¹
ST-25	1	M
ST-27	1	R
MI-2A & B	1	R
MI-3A & B	1	R

1. It is assumed that this test is performed twice per year.
2. Stroking of the valves is only called for in ST-10/13 and MI-2A & B; however, valve stroking should occur automatically in the other procedures due to the fact that the T&T valve will open, but the turbine won't roll.

TOTAL ESTIMATED TEST RELATED FULL STROKES PER YEAR: 25

3.2.16.3. RELEVANT OPERATING INSTRUCTIONS

OP-1 is the AFW operating procedure. In the valve checklist portion of the procedure, the "Required Position" for MOV-11 and MOV-12 is listed as "Operable", with a footnote that states: "If steam supply is aligned from S/G A, MOV-11 will be open and MOV-12 will be closed. If steam supply is aligned from S/G D, MOV-12 will be open and MOV-11 will be closed."

The procedure does not provide direction for the steam supply transfer sequence. The knowledge that both steam supply valves cannot be open simultaneously may be considered "skill of the craft"; however, it would appear prudent to either include provision for accomplishing the transfer in the procedure or a precaution noting the existence of the interlock.

3.2.16.4. COMMENTS

The normal AFW operating procedure (OP-1) allows for a normal standby condition where SG D is the steam supply source to the AFW turbine. If the plant were operated in this condition, it would be susceptible to credible accident conditions outside of the analyzed bounds*. For example:

-Feedline break in SG D with a single failure of loss of "A" train AC (or loss of DC, which would also cause loss of AC) power.

This would result in only the "B" AFW pump available for service, and with only one intact SG (SG C) serviced by the "B" pump. The loss of AC power would prevent the "A" pump from operating and would also prevent remote switchover from SG D to SG A as the steam supply for the turbine driven pump (steam supply valves are powered from the "A" train).

*This problem was independently identified by utility personnel after the completion of ORNL's review of procedures. OP-1 now specifies that an LCO must be entered if the AFW System alignment is configured with SG D as the available steam supply source for the turbine.

There is no testing which demonstrates the automatic steam supply transfer function. As a result, there are three relays and numerous contacts associated with the automatic transfer function that are not verified to operate properly. The apparent basis for not testing the automatic transfer is that it is assumed that operator action switches over to the alternate supply source. However, there are no specific steps in any normal, abnormal, or emergency procedure to so direct. It could possibly be argued that this is "skill of the craft" knowledge. In light of the fact that the interlock that prevents both valves from being open simultaneously is not mentioned in any operating procedure, as well as the fact that the automatic transfer is not even mentioned in the FSAR, this would appear to be a somewhat debatable proposition.

Although not used to demonstrate operability of MOV-11 and MOV-12, ST-15 demonstrates that each steam supply line provides sufficient steam to the turbine to allow the turbine driven pump to deliver ≥ 220 gpm to each SG (the test is run to prove full-open stroking of check valves C-28 and C-29). It should be noted that the procedure includes the following directives relative to transferring the turbine steam supply source from SG A to SG D:

- "Manually close T&T using HS-T&T located on M-3
- Close MOV-11 and verify MOV-12 automatically opens"

The closure of the T&T valve will most likely prevent the automatic transfer from occurring (depending upon the relationship of discharge pressure and T&T valve position--if the T&T valve "bc" contacts close before discharge pressure drops below 100 psia, the automatic transfer will not occur; alternatively, if discharge pressure drops below 100 psia before the T&T valve "bc" contacts close, then the automatic transfer should occur).

It should be noted that the Plant A FSAR does not discuss the automatic steam supply transfer design. The FSAR does take credit for operator action, in a general sense, such that following a feedline break with the following comment:

"...auxiliary feedwater is assumed to be initiated 10 minutes after the trip with the feed rate of 440 gpm.."

The specific operator actions that are required are not identified.

As a general comment on the design configuration, it is noted that this is not a normal arrangement for AFW turbine steam supply systems. At most plants, either both valves would be normally open, and the T&T valve shut, or the T&T valve would be open and both steam supply valves shut. In the latter case, the normal design would call for both steam supply valves to open on an automatic start signal. There are advantages to each design. The Plant A design provides protection against blowing down two SG's in the event of a secondary system pipe or valve failure by ensuring that both AFW turbine steam supply valves are not open simultaneously. Other designs depend solely upon the check valves that are in series with the isolation valves to provide automatic protection against the possibility of blowing down two SG's. On the other hand, the Plant A design effectively lacks redundancy of steam supply sources, since the ability to open MOV-12 is dependent upon MOV-11 being closed.

3.2.17. AFW Turbine Steam Supply Isolation Valves (SSIVs): MOV-9, MOV-10

3.2.17.1. SURVEILLANCE AND MAINTENANCE TESTS/INSPECTIONS

ST-10, 11, and 13 are surveillance procedures which implement valve stroke time and remote position indication requirements of the ASME Section XI Pump and Valve ISI program. Valve stroke times for MOV-9 and MOV-10, based on remote (main control board) indication, are measured each time the plant is put in cold shutdown. The valves are stroke time tested from open to closed by turning the valve handswitch to the CLOSE position, and holding the switch in CLOSE until the valve open indicating light is off and the closed indicating light is on. It is noteworthy that by keeping the valve handswitches in the CLOSE position until valve travel is complete, the seal-in features of the valve close coils are not demonstrated. Valve stroke times, based on local observation of valve stem movement, are checked every two years and compared to stroke times recorded remotely. Local position is verified to agree with remote position indication every two years.

The maximum allowable stroke times for the SSIVs is 10 seconds (based on design criteria)

ST-23, which is performed every 18 months, verifies that the thermal overload heaters are operating properly. The thermal overload trip time at rated full load current is demonstrated to be greater than twice the maximum allowable stroke time, and the trip time at locked rotor current is demonstrated to be between 10 and 15 seconds.

MI-9 is the calibration procedure by which the temperature switches are calibrated. Each switch is calibrated once per refueling cycle. The calibration only verifies proper setpoints for the switches (automatic valve closure is not verified).

MI-4 is a procedure which provides instructions on the testing of motor operated valves using the MOVATS system, which is used to assess the general mechanical and electrical control conditions of the valves.

MI-5 is a preventive maintenance procedure for LIMITORQUE actuators which is used to maintain equipment qualification. It provides for inspection and cleaning of electrical components; cleaning, inspection, and relubrication of the geared limit switch train; inspection and replacement (if needed) of gaskets; setting of the limit switch positions, per MI-6A; measurement of resistance from each phase to ground from the supply breaker; inspection and replacement (if needed) of the operator lubricant; cleaning and

relubrication of the valve stem; lubrication of the sleeve top bearing (if a grease fitting is provided); inspection of the shaft seal for excessive leakage; and inspection of the spring pack for hardened grease.

MI-6A is a corrective maintenance procedure which is used periodically (as invoked by MI-5) to adjust motor operated valve limit and torque switch settings. Limit switch settings, which can be set based either on valve travel measurement or the number of handwheel turns, are set as follows:

Open limit switch: Set to allow valve to open to within 98-99% of full travel (the open limit switch is initially set at approximately 90% of full travel, then the valve is stroked electrically and valve travel measured, and the open limit switch setting is modified as necessary to achieve the 98-99% travel)

Close limit switch: Set to allow valve to close to within 99-100% of full travel (but with the limit switch set to open at no greater than 98% of full travel)

3.2.17.2. FREQUENCY OF OPERATION

The SSIVs are stroked per the following procedures:

<u>PROCEDURE</u>	<u>NUMBER OF FULL STROKES</u>	<u>FREQUENCY</u>
ST-3A & B	2	R
ST-6	1	R
ST-7	1 ²	R
ST-8	1	Q
ST-10/13	1	COLD SHUTDOWN ¹
ST-10/13 FOR T&T VALVE	1 ³	Q
ST-14	1	Q
ST-25	1	M

1. It is assumed that this test is performed twice per year.
2. Only one of the two valves is designated to be stroked
3. Only MOV-9 is designated to be stroked.

TOTAL ESTIMATED TEST RELATED FULL STROKES PER YEAR: The above test frequency information would yield about 25 full strokes per year for MOV-10 and 29 full strokes per year for MOV-9; however, these valves would likely be stroked more frequently, since they would be probable candidates to isolate steam from the AFW turbine for clearance purposes.

3.2.17.3. RELEVANT OPERATING INSTRUCTIONS

OP-1, 6 (both procedures specify valve and breaker positions)

3.2.17.4. COMMENTS

The automatic isolation feature associated with these valves is not demonstrated.

Although not used to demonstrate operability of MOV-9 and MOV-10, ST-15 demonstrates that the steam supply line provides sufficient steam to the turbine to allow the turbine driven pump to deliver ≥ 220 gpm to each SG.

3.3 FAILURE MODES AND FEATURES THAT ARE NOT DETECTABLE BY CURRENT MONITORING PRACTICES

3.3.1 Pump suction check valves (SCV): C-4 (A motor driven pump), C-3 (B motor driven pump), C-5 (Turbine driven pump)

FAILURE MODE

1. The SCV fails closed, preventing flow from the CST reaching the pump suction.
2. The SCV fails to open sufficiently to allow required flow to the pump suction.
3. The SCV fails to close when the ESW suction valves open to provide flow to the pump suction.

NON-DETECTABILITY

None. Failure to open would be observed during any of the turbine or motor driven pump starts.

This should be observed, to an extent, during the full flow testing of the AFW pumps. It should be noted, however, that degradation could occur without observation, since neither pump flow nor delta-p, which would be rough indicators of the general flow path conditions are not monitored. Rather, the only parameters monitored are flows to the SGs, and even that is not quantified, except that flow to each SG is > 220 gpm.

The motor driven pump SCVs are not included in the periodic disassembly and inspection program (ST-28), even though they would be more subject to wear than the turbine driven pump SCV (which is included in ST-28). In this context, it should also be noted that failure of a motor driven pump SCV to open sufficiently to allow required flow would result in degraded suction pressure conditions at the pump which would not be detected by the suction pressure switches, which are located upstream of the SCVs for the motor driven pumps.

Failure to close would be noted during the quarterly testing which demonstrates closure. However, gradual degradation of the motor driven pump SCVs might not be noticed, since they are not included in the periodic disassembly and inspection program (ST-28).

3.3.2 Emergency Service Water (ESW) to Motor Driven Pumps Supply Valves MOV-1, 2, 3, 4

FAILURE MODE

1. Valve operator fails to open in response to a low pressure condition at the pump suction.

2. With the ESW valves opened, insufficient flow is available.

3. The opening sequence and response time results in pump damage and/or turbine overspeed tripping.

NON-DETECTABILITY

It appears that only one of three possible logic coincidences is verified to result in an open signal. Also, not all conditions which cause low suction pressure (such as improperly positioned or broken manual valves and stuck closed suction check valves) are detectable by the existing design. It is doubtful that operator intervention would be rapid enough to avoid pump cavitation and/or binding, and the potential associated damage, given the existence of only a single annunciator and no other control room indication.

Also, as noted in the discussion for the SCVs (Section 3.3.1), a low pressure condition could exist at a motor driven pump suction without being detected by the suction pressure switches if, for example, the SCV failed to open sufficiently or if the manual suction isolation valve were improperly positioned.

It should also be noted that the upstream valves (MOV-1 and-3) are not restroked after reconnecting the control circuit leads following testing of MOV-2 and-4 in ST-6, thereby creating the potential for improper reconnection going undetected until the next test.

There is no test which verifies flow, which would be a direct indication of adequate valve opening, as well as an indication that the piping is sufficiently clear to allow the required flow (which is of some concern due to the fact that ESW water is lake water, and the piping is therefore subject to Asiatic Clam buildup or the collection of other foreign material). The valve stroking that is done under the ASME Section XI program does check stroke time from closed to open quarterly, and verifies that remote position indication is consistent with local position indication every two years.

Since a switchover to ESW is never actually tested (with good reason), the ability of the switchover to occur smoothly is not demonstrated. While this is probably more a design concern than aging concern, it would appear to be a substantial system challenge to complete the transfer under the most severe, credible circumstances (seismic event) without at least temporary pump loss.

3.3.3 Emergency Service Water (ESW) to Turbine Driven Pump Suction Isolation Valves: MOV-5, 6, 7, 8

FAILURE MODE

1. Valve operator fails to open in response to a low pressure condition at the pump suction.

2. With the ESW valves opened, insufficient flow is available.

3. MOV-7 & MOV-8 fail to close in response to an automatic close signal.

4. The opening sequence and response time results in pump damage and/or turbine overspeed tripping.

NON-DETECTABILITY

None noted.

There is no test which verifies flow, which would be a direct indication of adequate valve opening, as well as an indication that the piping is sufficiently clear to allow the required flow (which is of some concern due to the fact that ESW water is lake water, and the piping is therefore subject to Asiatic Clam buildup or the collection of other foreign material). The valve stroking that is done under the ASME Section XI program does check stroke time from closed to open quarterly, and verifies that remote position indication is consistent with local position indication every two years.

Automatic closure of these valves is not included as an acceptance criterion in any test (ST-7 does include a note that the valves will close after opening; however, it is not an acceptance criterion).

Since a switchover to ESW is never routinely tested (with good reason), the ability of the switchover to occur smoothly is not demonstrated. While this is probably more a design concern than aging concern, it would appear to be a substantial system challenge to complete the transfer under the most severe, credible circumstances (seismic event) without at least temporary pump loss.

3.3.4 Motor Driven AFW Pumps

FAILURE MODE

1. Pump fails to start upon demand.
2. Pump fails to continue to run after starting.
3. Pump fails to load shed upon demand.
4. Pump fails to deliver required flow to the SGs.
5. Pump auxiliary contacts fail to provide required control inputs to other automatically actuated equipment.

NON-DETECTABILITY

None noted.

The ability of the pumps to continue to operate satisfactorily during and following transfer of the suction source to ESW is not demonstrated by surveillance testing.

None noted.

There is apparently no testing which verifies that a motor driven pump can deliver the required flow to its two SGs at the required pressure conditions. ST-15 does verify that each motor driven pump can deliver > 440 gpm total flow to two SGs, but does not monitor actual flow, SG pressure, or developed pump head.

It should also be noted that operating procedure guidance appears to require that the operators leave the motor driven pumps running on recirculation flow when not batching the SGs. This practice would result in accumulated pump wear due to the low flow operation which would not necessarily be detected by the ST-15 testing due to the fact that only flow is monitored.

Auxiliary contacts used to provide control signals to the motor driven pump level control valves, the alternate suction source valves, and SG blowdown valves are apparently not verified to function properly.

3.3.5 Turbine Driven AFW Pump

FAILURE MODE

1. T&T valve operator fails to open in response to an automatic AFW turbine start signal. (Turbine fails to start on demand)
2. T&T valve operator fails to complete the close-open strokes in response to the automatic steam supply transfer signal (i.e., fails to close or fails to reopen).
3. Valve electronic overspeed trip function fails to trip the valve before the mechanical overspeed trip occurs, thereby requiring local resetting (and preventing automatic restart).
4. Pump fails to develop required flow
5. Valve stem operated switches fail to provide input signals to other AFW related equipment or functions.

NON-DETECTABILITY

- a) The thermal overload switch bypassing, which is designed to occur on all safety related starts, does not appear to be verified.
 - b) The thermal overload settings are apparently not verified.
 - c) It is not clear that the station blackout signal generated start of the turbine driven pump is verified. The extent of testing is to verify that the T&T valve will open when contacts from one, undesignated, train are jumpered (as opposed to closing automatically).
- a) The circuit which enables the automatic transfer of steam supply sources does not appear to be tested at all.
 - b) See items a and b under Failure Mode 1 above.
- a) The electronic overspeed trip is tested under simulated, rather than actual operating conditions.
 - b) The automatic operation of the T&T valve closing coil to drive the motor to shut, thereby relatching the motor to the valve, following an electronic overspeed trip does not appear to be verified.
 - c) The mechanical overspeed trip setpoint is apparently not verified under simulated or actual conditions.
- a) Full flow developed during ST-15. However, pump condition is not fully monitored (procedure verifies flow to each SG to be greater than 220 gpm, but does not monitor other pump parameters)
 - b) There is no testing performed in which the ability of the turbine driven pump to deliver required flow at steam supply pressures less than 842 psig is verified. In fact, Tech Specs require testing to be performed with steam pressure ≥ 842 psig.
- There is apparently no verification of proper operation of the following switches:
- a) Switch which results in automatic closure of SG Blowdown isolation valves and provides the permissive to allow the automatic steam supply transfer to occur.
 - b) Switch which causes the T&T valve operator to drive the operator to the shut position following an electronic overspeed trip.
 - c) Switch which starts the turbine driven pump room ventilation fan.

3.3.6 Pump Miniflow Check Valves (MCV): C-6, 8, 10

FAILURE MODE

1. The MCV fails closed, or fails to open sufficiently to allow required recirculation flow.

NON-DETECTABILITY

The quarterly pump testing, using ultrasonic flow instrumentation, provides an indication that the miniflow check valve is stroking open adequately to allow the designated minimum flow. However, the flow rate is so low that the valves would not be fully stroked. Also, it is questionable as to whether the flow rates are adequate to provide pump protection.

3.3.7 Common Miniflow Check Valves (CMCV): C-1, 2

FAILURE MODE

1. A CMCV fails closed, or fails to open sufficiently to allow required recirculation flow.

NON-DETECTABILITY

The performance testing does not demonstrate that each check valve allows at least a given amount of flow to pass, rather, that several pumps can operate simultaneously. Verification that the valves open sufficiently to prevent pump overheating can only be demonstrated by monitoring flow.

NOTE: If flow were monitored in ST-16, some assurance of proper valve functioning would be provided; however, in light of the low flow conditions normally experienced by these valves, it would appear that periodic disassembly and inspection or other monitoring would also be appropriate.

3.3.8 Pump Discharge Check Valves (DCV): C-7, 9, 11

FAILURE MODE

1. The DCV fails closed, or fails to open sufficiently to allow adequate flow to reach the SGs.

NON-DETECTABILITY

In all probability, this would be observed during the ST-15 testing. However, as noted previously, only flow is monitored during the testing. Thus, a DCV could open sufficiently to allow the required flow at test conditions, but limit flow to less than required under different pressure conditions.

2. The DCV fails to close to prevent reverse flow.

There is apparently no testing which demonstrates that the DCV keeps reverse flow below some acceptable value. However, reverse flow protection offered by the combination of valves in the discharge flow path is verified during normal operation (by observation of pump casing and discharge piping temperature).

3.3.9 Motor Driven AFW Pump Level Control Valves (MDLCV):LCV-1/1A, 3/3A, 5/5A, 7/7A

FAILURE MODE

1. MDLCV controller fails to automatically control SG level in response to an AFW motor driven pump start signal.
2. Valve operator does not open or stay open in response to a demand from the controller.
3. Valve fails to open sufficiently to allow adequate flow.
4. Valves fail to close sufficiently to prevent excessive flow to a faulted SG or to prevent feedwater backleakage.
5. Valve cannot be placed in manual control following an AFW actuation signal.

NON-DETECTABILITY

- a) The deenergization of the AFW blackout relays is not demonstrated to result in the energization of relays which must function properly to enable various actions in the MDLCV control circuits, including transfer of the controllers from manual to automatic. This is not judged to be a significant concern, since the valve switches are normally maintained in AUTO.
 - b) The transfer from MDLCV to BMDLCV control, including the accompanying closure of the MDLCV's is apparently not verified by testing. This is primarily a concern from the standpoint of minimizing flow to a faulted SG until the flow can be isolated altogether by manual actions (Note that the ability to transfer from automatic control to manual control in the presence of an accident signal is not demonstrated, per item 5 below). Failure of this transfer to occur should be noted, however, when the motor driven pumps are used to maintain SG inventory during plant shutdown and startup conditions.
- a) The deenergization of the MDLCV solenoids (which allows the valves to open/modulate automatically) due to an automatic pump start does not appear to be demonstrated. All testing is performed with the valve switches in MANUAL (which itself deenergizes the valve solenoid).
- In all probability, this would be observed during the ST-15 testing. However, as noted previously, only flow is monitored during the testing. Thus, a MDLCV could open sufficiently to allow the required flow at test conditions, but limit flow to less than required under different pressure conditions.
- There is apparently no testing which is specifically oriented toward detecting seat leakage. Reverse flow protection offered by the combination of check valves plus the level control valves is observable during normal operation. It is possible that excessive MDLCV or BMDLCV seat leakage might be observed during startup and shutdown evolutions, or possibly during routine pump testing (in recirculation).
- The ability to transfer the control of the MDLCV's from automatic to manual in the presence of an AFW actuation signal does not appear to be demonstrated. Inability to transfer to manual control would prevent the operators from isolating flow to a faulted SG except by additional operator intervention or by stopping the associated pump. The inability to transfer to manual control could also aggravate recovery efforts in the event that there was an automatic controller failure.

3.3.10 Turbine Driven Pump Level Control Valves (TDLCV): LCV-2, 4, 6, 8

FAILURE MODE

1. Valve controller fails to automatically open/close to control SG level in response to an AFW turbine driven pump start signal.

2. Valve operator does not open or stay open in response to a demand from the controller.

3. Valve operator does not drive the valve closed to prevent excessive flow to a faulted SG.

4. Valve does not close sufficiently to prevent excessive flow to a faulted SG or to prevent feedwater backleakage.

5. Valve fails to open sufficiently to allow adequate flow.

6. Valve cannot be placed in manual control following an AFW actuation signal.

NON-DETECTABILITY

None noted.

a) The ability of the accumulator to stroke the valve, and the proper seating of the control air check valve for the accumulator are apparently not demonstrated.

b) The deenergization of the valve solenoids, which allows the TDLCV's to open/modulate, is not demonstrated with the control switches in AUTO. The solenoids are also deenergized by placing the control switches in MANUAL, and all test related deenergization of the solenoids is demonstrated with the control switches in MANUAL.

There is apparently no testing which demonstrates that the valves are driven shut in response to a faulted SG condition. In addition, the ability to transfer from AUTO back to MANUAL in the presence of an accident signal does not appear to be demonstrated (this ability allows the operator to deal with a faulted SG remotely).

There is apparently no testing which is specifically oriented toward detecting seat leakage. Reverse flow protection offered by the combination of check valves plus the level control valves is observable during normal operation. Excessive TDLCV seat leakage might be observed during startup and shutdown evolutions, or possibly during routine pump testing (in recirculation).

In all probability, this would be observed during the ST-15 testing. However, as noted previously, only flow is monitored during the testing. Thus, a TDLCV could open sufficiently to allow the required flow at test conditions, but limit flow to less than required under different pressure conditions.

The ability to transfer the control of the TDLCV's from automatic to manual in the presence of an AFW actuation signal does not appear to be demonstrated. Inability to transfer to manual control would prevent the operators from remotely isolating flow to a faulted SG except by stopping the turbine driven pump. The inability to transfer to manual control could also aggravate recovery efforts in the event that there was an automatic controller failure.

3.3.11 Level Control Valve Check Valves (LCVVCV): C-12, 13, 14, 15, 16, 17, 18, 19

FAILURE MODE

NON-DETECTABILITY

1. The LCVVCV fails closed, or fails to open sufficiently to allow adequate flow to reach the SGs.

In all probability, this would be observed during the ST-15 testing. However, as noted previously, only flow is monitored during the testing. Thus, a LCVVCV could open sufficiently to allow the required flow at test conditions, but limit flow to less than required under different pressure conditions.

2. The LCVVCV fails to close to prevent reverse flow.

There is no testing which demonstrates that the LCVVCV keeps reverse flow below some acceptable value. Reverse flow protection offered by the combination of check valves plus the level control valves is observable during normal operation.

3.3.12 Steam Generator B and C AFW to Main Feed Check Valves (MFCV): C-21, 22, 24, 25

FAILURE MODE

NON-DETECTABILITY

1. The MFCV fails closed, or fails to open sufficiently to allow adequate flow to reach the SGs.

Degradation of these valves should be observed during the periodic inspection performed per ST-28. Also, in all probability, this would be observed during the ST-15 testing. However, as noted previously, only flow is monitored during the testing. Thus, a MFCV could open sufficiently to allow the required flow at test conditions, but limit flow to less than required under different pressure conditions.

3.3.13 Main Feedwater Check Valves (FWCV): C-20, 23, 26, 27

FAILURE MODE

NON-DETECTABILITY

1. The FWCV fails to close sufficiently to ensure that adequate AFW flow is delivered to the SG.

The periodic disassembly and inspection of these valves provides reasonable assurance that the valve internals are in proper operating condition. The leak rate testing, however, allows for leakage which may be substantially in excess of that which can be tolerated while still meeting the system design requirements.

3.3.14 Feedwater Isolation Valves (FWIVs): FWIV-1, 2, 3, 4

FAILURE MODE

1. FWIV fails to close in response to an automatic or manual closure demand signal.
2. FWIV fails to close sufficiently to prevent excessive backleakage from the SG and/or AFW.

NON-DETECTABILITY

None noted. Since manual closure is depended upon, from an AFW system perspective, manual closure performed in conjunction with valve inservice testing adequately simulates the control aspect of closure.

There is apparently no testing which checks for FWIV seat leakage. Since the upstream feed reg valves and the downstream check valves provide some redundancy, and the FWIVs are gate valves, this is not viewed as being a significant concern.

3.3.15 Steam Generator Blowdown Isolation Valves (BDIVs): BDV-1, 2, 3, 4

FAILURE MODE

1. The BDIVs fail to close in response to an automatic closure signal associated with start of an AFW pump.

NON-DETECTABILITY

There does not appear to be any testing which verifies that the BDIVs close in response to any AFW pump start.

The start indication of the turbine driven pump comes from a T&T valve stem mounted limit switch, which also provides a start indication for the automatic steam supply transfer. Proper operation (or operation at all) of these limit switch contacts does not appear to be checked.

The start indications of the motor driven pumps come from 52S/b contacts. These contacts are apparently not verified to operate properly.

The BDIVs are verified to close in response to a Containment Phase A Isolation signal, as well as in response to the control board switch. The only electrical circuit features not verified by this testing are the relay and contact operations associated with pump starts. It should be noted that the test conditions are substantially different than design basis demand conditions, in that the flow rate is relatively low, and an upstream valve is simultaneously closing to isolate flow.

2. The BDIVs fail to close sufficiently to isolate blowdown flow.

There is apparently no testing which checks the extent to which blowdown flow is isolated by the BDIVs. Note that blowdown is normally secured using downstream, non-safety related valves.

3.3.16 AFW Turbine Steam Supply Valves (SSV). MOV-11, 12

FAILURE MODE

1. The automatic transfer sensing circuit fails to initiate an automatic steam supply transfer.

2. MOV-11 fails to close on demand (from either the automatic transfer circuit or from the main control board switch).

3. MOV-12 fails to open on demand (from either the automatic transfer circuit or from the main control board switch).

4. MOV-11 motor operator contacts fail to provide proper permissive to MOV-12.

5. MOV-12 motor operator contacts fail to provide steam supply transfer permissive.

6. SSVs fail to open sufficiently to allow required steam flow.

NON-DETECTABILITY

Other than verifying the setpoint of the turbine driven pump discharge pressure switch, apparently none of the automatic transfer circuit (including various relays and contacts) is tested.

Energization of the close coil by the automatic transfer logic does not appear to be verified by testing. However, the ability to close the valve using the control switch is demonstrated periodically.

Energization of the open coil by the automatic transfer logic is apparently not verified by testing. However, the ability to open the valve using the control switch is demonstrated by various periodic testing.

The ability of MOV-12 to be opened (and stay open) in various tests demonstrates that the MOV-11 "ac" contacts (which are open when MOV-11 is shut) are not causing automatic closure of the valve. There is apparently no testing, however, which demonstrates that closure of the MOV-11 "ac" contacts causes MOV-12 to close. The MOV-11 "bc" contact (closed when the valve is shut) portion of the automatic open circuit also does not appear to be demonstrated by any testing, since all transfers are made manually.

This is apparently not demonstrated since there is no testing which verifies the automatic transfer sequence.

The ability of each steam supply valve to provide the required steam flow is reasonably well demonstrated in ST-15. However, since steam flow is partially dictated by pump power demands, and only pump flow (not delta-p) is monitored, the steam flow demanded during testing may be somewhat less than that required during a demand event. Also, there is no testing at low steam supply pressures.

It should also be noted that the periodic stroking of the SSV is performed by holding the switches in the CLOSE/OPEN positions until the stroke is completed, thus not demonstrating that the seal-in portion of the MOV-12 opening circuit is functioning.

3.3.17 AFW Turbine Steam Supply Isolation Valves (SSIV): MOV-9, MOV-10

FAILURE MODE

1. SSIV closes during a turbine driven pump demand condition without a pipe break existing.
2. SSIV fails to close upon demand.
3. SSIV fails to open sufficiently to allow the required steam flow.
4. SSIV fails to close sufficiently to isolate a leak/break.

NON-DETECTABILITY

There appears to be no testing which requires an extended run period for the turbine driven pump. Since the automatic isolation is based on ambient temperature, it is not clear that stable ambient conditions would be reached in the short time required for pump testing.

There is apparently no testing to verify that automatic closure will occur. Although the temperature switches are individually calibrated, neither the automatic closure of the isolation valves nor even continuity in the automatic closure circuit is verified. It should be noted that failure to close would not constitute an AFW System failure, but could adversely impact other equipment in the vicinity.

The ability of the SSIVs to allow the required steam flow is reasonably well demonstrated in ST-15. However, since steam flow is partially dictated by pump power demands, and only pump flow (not delta-p) is monitored, the steam flow demanded during testing may be somewhat less than that required during a demand event. Also, there is no testing at low steam supply pressures.

There is apparently no testing to verify the extent to which the SSIVs isolate steam flow. However, the SSIVs would be used to isolate steam for clearance and test purposes, and excessive leakage should be detected at that time.

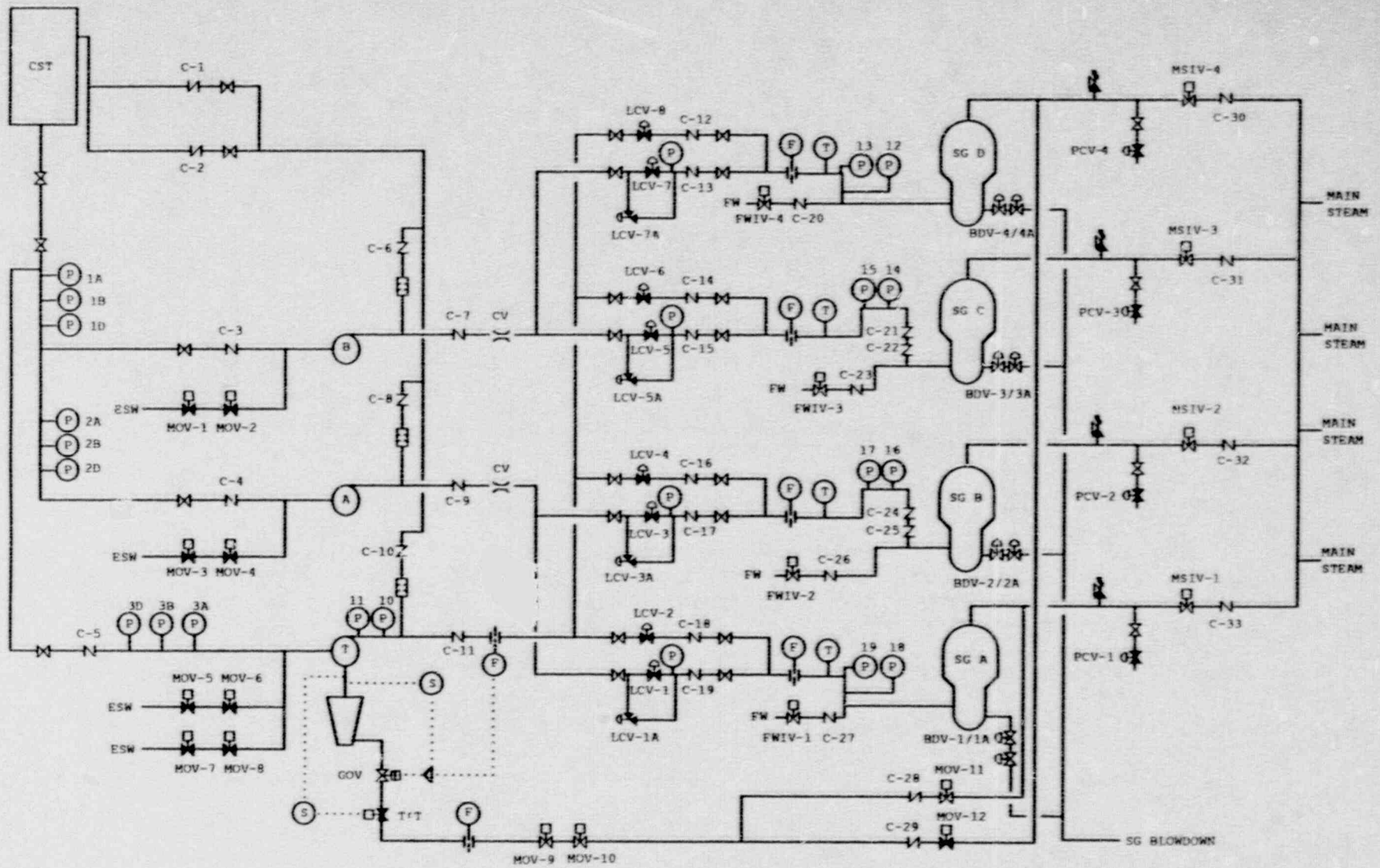


Figure 3.1 REFERENCE PLANT AUXILIARY FEEDWATER SYSTEM

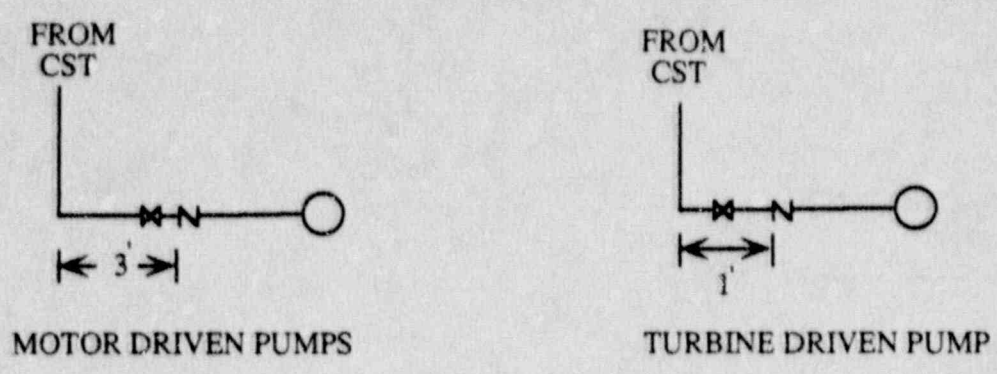


Figure 3.2 Pump Suction Check Valves Configuration

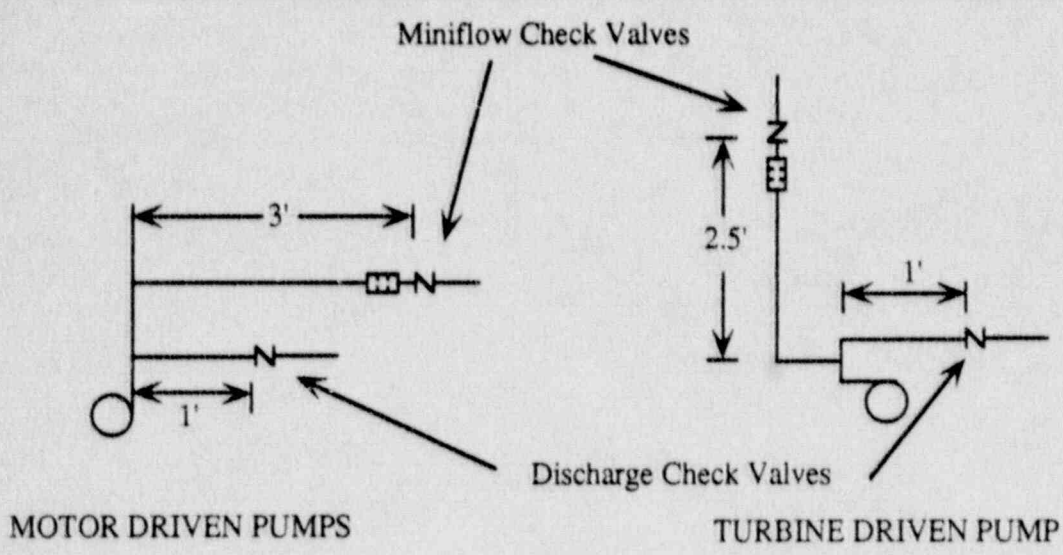


Figure 3.3 Pump Miniflow and Discharge Check Valves Configuration

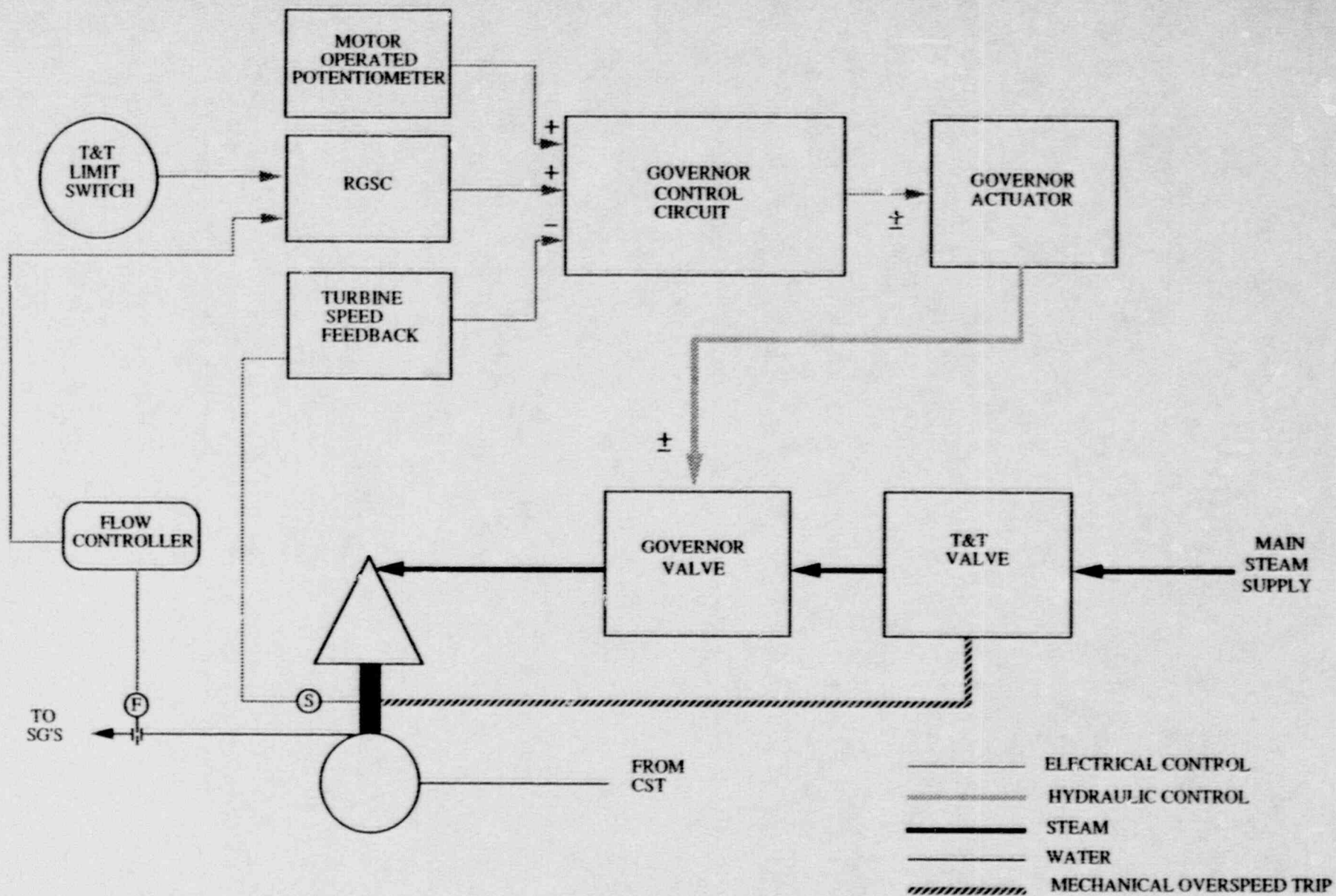
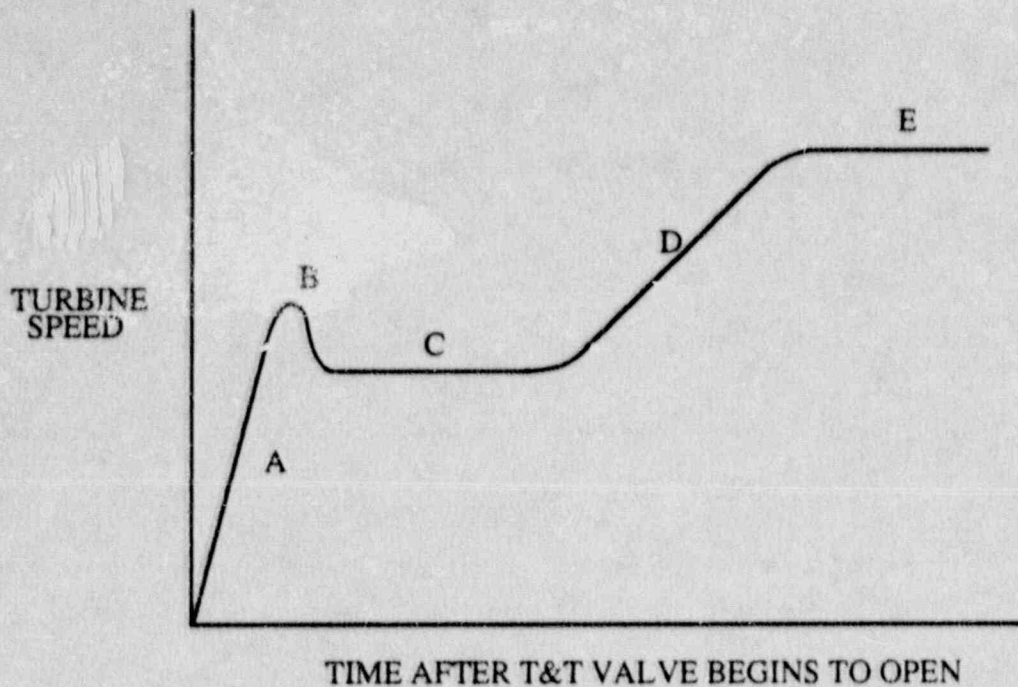


FIGURE 3.4.A AFW TURBINE SPEED CONTROL CIRCUIT



- A. INITIAL ACCELERATION AS T&T VALVE ADMITS STEAM
- B. TURBINE GOVERNOR OIL PRESSURE BUILDS UP AND IS ABLE TO DRIVE GOVERNOR VALVE IN CLOSED DIRECTION
- C. TURBINE AT "IDLE" SPEED
- D. TURBINE SPEED ACCELERATING IN CONJUNCTION WITH RAMP SIGNAL
- E. TURBINE ACHIEVES NORMAL OPERATING SPEED

FIGURE 3.4.B TURBINE SPEED DURING STARTUP

Control valve immediately upstream of check valve

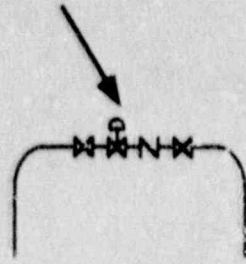
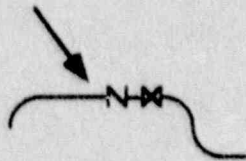


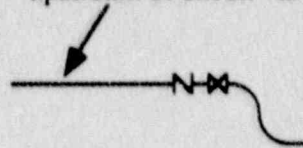
FIGURE 3.5 Turbine Driven Pump Level Control Valve Check Valve Configuration

-1 foot from elbow to valve



"A" Motor Driven Pump

Considerable length of straight pipe upstream of check valve



"B" Motor Driven Pump

FIGURE 3.6 Motor Driven Pump Level Control Valve Check Valve Configurations

~4 inches between valves

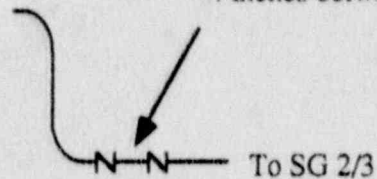


FIGURE 3.7 Main Feedwater Check Valve Configuration

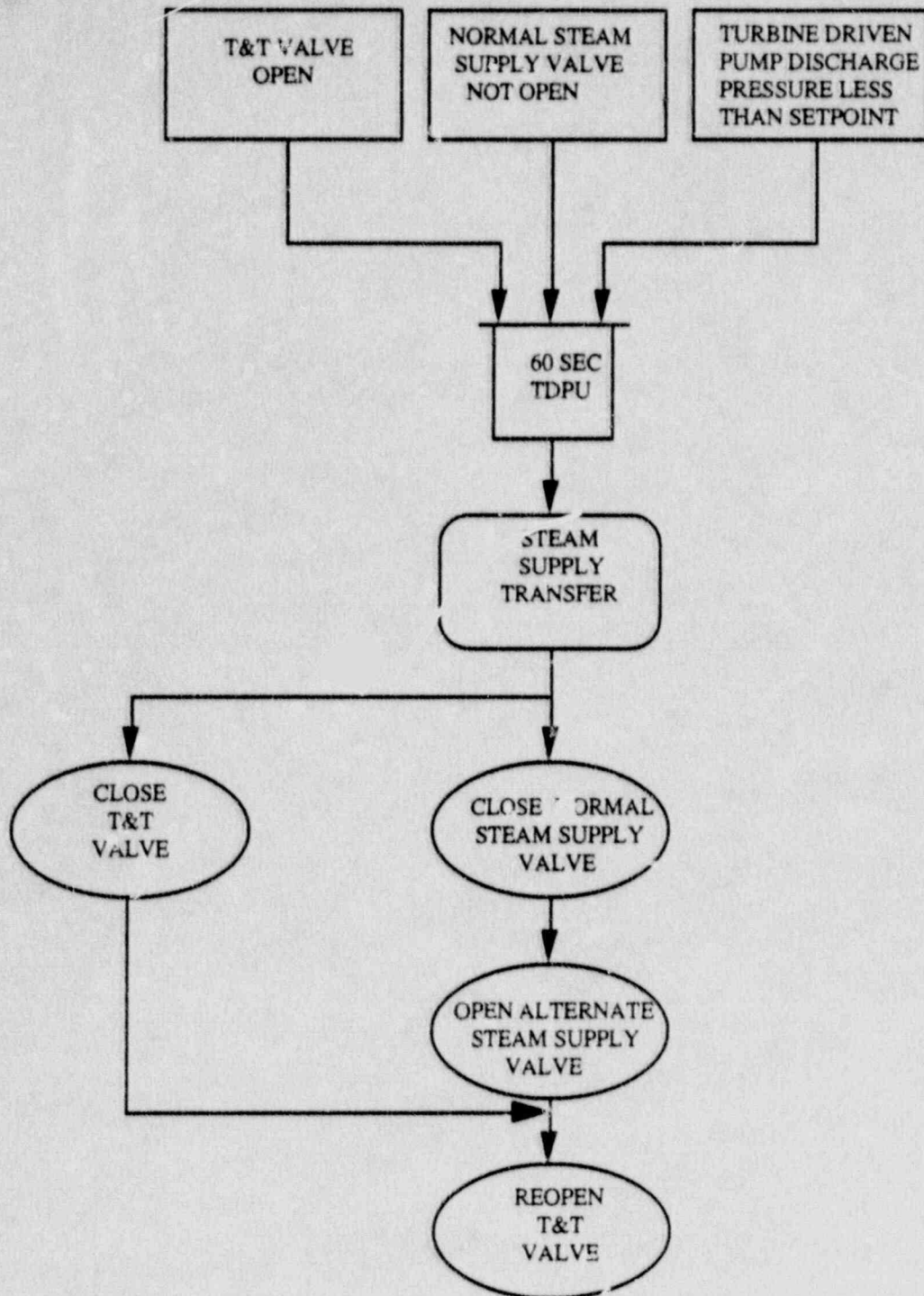


Figure 3.8 Turbine Steam Supply Transfer Sequence

CHAPTER 4

AFW SYSTEM FAILURE DATA REVIEW AND ANALYSIS

4.1. INTRODUCTION

In order to gain some insights into the importance of various AFW System components from an historical failure perspective, reviews of failure data through 1986 for Westinghouse and Babcock & Wilcox plants from INPO's Nuclear Plant Reliability Data System (NPRDS^{*}), the Nuclear Operations Analysis Center's Licensee Event Report (LER), and S. M. Stoller's Nuclear Power Experience (NPE) databases were conducted. The initial intent of reviewing all three databases was to provide an indication of the validity of relying on only the NPRDS data, since it should theoretically be the most comprehensive set of data, and in fact, all failures that would be reported in LERs should also be reported in NPRDS, while NPRDS should also include many failures not reported in LERs. However, it became clear during the initial review of failure data from these databases that a significant fraction of the failure records found in the NPE and LER databases were not found in NPRDS. As a result, each record from all three databases was reviewed and combined to form a single ORNL database, thereby avoiding redundant entries while establishing a more thorough set of failure records.

It was also determined that in order for meaningful results to be gathered from the data review, a single, consistent assignment of several parameters for each failure record was required. This determination was based largely upon the fact that the NPRDS failure records, in particular, assigned the failures to incorrect types of components (for example, a turbine speed control problem that resulted in tripping of the turbine driven AFW pump being designated as a pump failure instead of a turbine/governor failure), attributed single failures to multiple components (for example, where a turbine speed control resulted in tripping of the turbine, a failure record was entered for both the turbine and the turbine driver, pump), and inconsistently ascribed various characteristics to the failures.

A third reason for establishing the ORNL database was to assign the failure records to a level that was meaningful, from a system perspective. This was due to the fact that the component assignment of failure was not structured in such a way to facilitate a system review. This was especially found to be the case relative to instrumentation and control (I&C) components. The importance of a particular type of I&C failure, from a system perspective, depends upon what other components are affected, and therefore it was necessary to assign such failures to the component(s) ultimately affected. An example of such a situation would be where a pressure transmitter fails. Depending upon the transmitter function, the result of the transmitter loss might range from simple loss of indication to loss of speed control for the turbine driven pump.

While the ORNL database is based upon a recreated, more consistent set of failure records, it is extremely important to realize that any conclusions drawn must be made with great care. One feature of the failure records that is particularly noteworthy is that of the change in reporting requirements and practices that occurred in the 1983-1984 time frame. It was during that time that the LER reporting requirements were changed, substantially reducing

* Plant specific information from the NPRDS database is proprietary. Although much of the failure data compilation and evaluation depended upon plant and component identification, the results of the study are presented without identification of individual plants.

the number of failures that were reportable to the NRC in LERs. At the same time, utility NPRDS reporting practices began to improve (in part due to the fact that improved voluntary failure reporting to the NPRDS was used as justification of the relaxation of LER reporting requirements). As a result, the total failure data available from NPRDS is dominated by the data from 1984 and later. Almost three-quarters of the NPRDS failure records for the AFW System comes from the years 1984-1986, and about one-half of the total failure record data (from all three sources) can be found in the NPRDS data for these three years alone. As a result, information such as failure rate as a function of plant age for a particular plant, or even for industry as a whole, can be extremely misleading. Because of this and other complicating factors, any attempt to use the failure record data results or findings included in this report for any purpose other than those which are specifically discussed within the report is strongly discouraged without consultation with the author.

Another aspect of the failure database which should be pointed out is that very few, if any, of the failures are associated with design basis challenges of the AFW System. While there are failures classified as demand related failures, these are primarily failures that occurred when an automatic or manual start of the AFW System occurred during testing or following a "normal" reactor trip (not, for example, following a design basis event such as a feedwater line break). It must be recognized that the challenges presented to various components may be more severe under design basis conditions, and therefore, certain types of failure more likely. Thus, it would be inappropriate to directly extrapolate the failure data associated with the normal AFW System and general plant conditions to those that would exist following design basis events.

A limitation of the failure data that must be discussed relates to the completeness of the data. While there are a significant number of failure records in the ORNL failure database (1767 total), the database clearly does not include a large fraction of known historical failures, based on a review of some plant specific failure data which was available for comparison. However, the three sources of data used to form the ORNL database are reasonably accessible and usable, in contrast to plant specific data (available only from maintenance work requests which normally contain considerably less information than is available from the NPRDS, LER, or NPE databases).

A final observation about the failure data is that even plants that are very thorough in their reporting practices can only report failures when they are known to exist. As discussed in Chapter 3, there are a number of failure types which would not be identifiable by current monitoring practices. For example, the disk for a check valve may have separated and be laying in the bottom of the valve body. If there are no reverse flow closure challenges to the valve, either from testing or from operational circumstances, the failure may go undetected, and hence, unreported for a considerable time. Thus, even full reporting of known failure data would not necessarily be a perfect representation of the distribution of areas of concern.

4.2. ORNL DATABASE FORMATION

Computerized searches of the NPE, LER, and NPRDS databases were conducted. Since the failure data available from the NPRDS included failure records from Westinghouse and B&W plants through most of 1986, the NPE and LER database search records for the same time periods were included. The initial review process consisted of sorting each of the databases by plant, failure date, and component. It was at this time that the ORNL component assignments were made. The three sources of data were then combined to form a single database. This single database was then processed to eliminate multiple entries for the same failure event. The single set of failure records was then reviewed again in order to

evaluate and record the method of discovery, the impact upon the AFW System, and other pertinent information.

For each component type, the numbers of failure counts in the database and the effect upon the system as a whole were tallied. Some explanation of the component categorization and other aspects and limitations of the data presented are necessary:

1. There are a total of five component types designated. The failures ascribed to particular component types include not only failures of the component proper, but failures of auxiliary components or parts which affected the component. As an example, the failure of a contact in the AFW turbine control circuitry which resulted in overspeed tripping of the turbine driven pump would be included under the Pump Driver category. Table 4.1 provides descriptions of the component types and their scope. The more important component types were divided into subgroups for further evaluation. The subgroups will be discussed later.

2. Three parameters are provided for most sortings of the failure database. These are:

- a. Failure Counts - The number of failure records associated with the described parameter.
- b. Average System Effect - The average fraction of the system degraded per failure.
- c. Relative System Degradation - A measure of the overall historical system degradation associated with the described parameter.

3. The Average System Effect was determined for each failure record, based upon the particular plant design and the extent to which the system was affected by the component failure. The effect was measured on a scale from 0 to 1, with 1 representing total system failure and 0 representing no, or insignificant impact upon the system. As an example, if one motor driven pump in a three pump system would not start due to a faulty circuit breaker, a system effect of 0.33 would be assigned for that failure (note that this failure would be included in the Pump Driver category).

4. The Relative System Degradation is a normalized measure of the overall contribution of a component type to total system degradation, taking into account both the number of failures and the significance of each event. The method used to determine the Relative System Degradation is as follows:

$$RSD = FC_i * ASE_i / \sum (FC_i * ASE_i)$$

RSD=Relative System Degradation for a component type
ASE=Average System Effect for a component type
FC=Failure Counts for a component type
i=Individual failure record

This method of assigning the Relative System Degradation (RSD) allows the different sources of AFW System degradation to be compared on an equivalent basis. Where the Relative System Degradation is used in this report, it must be kept in mind that the values cited are in the context of the level of review. To illustrate, Pump Drivers were found to be responsible for 37% of the Relative System Degradation for the AFW System, as a whole (see Table 4.2). Of the three types of pump drivers, the turbine drive was found to be responsible for 73% of the Relative System Degradation associated with Pump Drivers (see Table 4.6). Thus, failures associated with turbine

drives were responsible for $0.73 \times 0.37 = 0.27$, or 27% of the overall AFW Relative System Degradation.

5. The Average System Effect and Relative System Degradation measures cited above do not include an accounting for recoverability; that is, the ability to recover the failed piece of equipment within a short time interval. This is primarily due to the difficulty in ascertaining the extent to which operator action would be able to offset many failures experienced. Thus, two failures of the same component may be given identical consequence ratings, when in fact, one of the failures could be overcome in fairly short order.

6. Each failure record in the database is based upon information from one or more of the information sources (NPE, LER, and NPRDS). Each "failure" record is not necessarily a failure that disables the component. For instance, the valve "failure" records range from packing leaks to broken valve stems. The system effect for these two failure types would clearly differ, but each would contribute one failure count. It is important, therefore, to realize that the failure count information can be particularly misleading in terms of relative significance.

A total of 517 Reactor Years of operating experience for the plants is included in the ORNL failure record database. The plants included were Westinghouse and B&W units which started in or before 1986. These plants have a total of 130 safety related AFW pumps, including 77 motor driven, 51 turbine driven and 2 diesel driven pumps. The accumulated pump operating experience for the time period covered by the database was 808 motor driven pump train-years, 604 turbine driven pump train-years, and 13 diesel driven pump train-years.

4.3. ANALYSIS RESULTS

4.3.1. GENERAL SUMMARY

A total of 1767 Failure Counts, many of which were reported in more than one of the three database sources were reviewed. As can be seen from Figure 4.1 and Table 4.2, Valve Operator (including air, motor, electrohydraulic, and solenoid valve operators) problems resulted in the largest number of Failure Counts, contributing 30% of the total (534 / 1767). Valves and Pump Drivers provided 24% and 23% of the total Failure Counts, respectively.

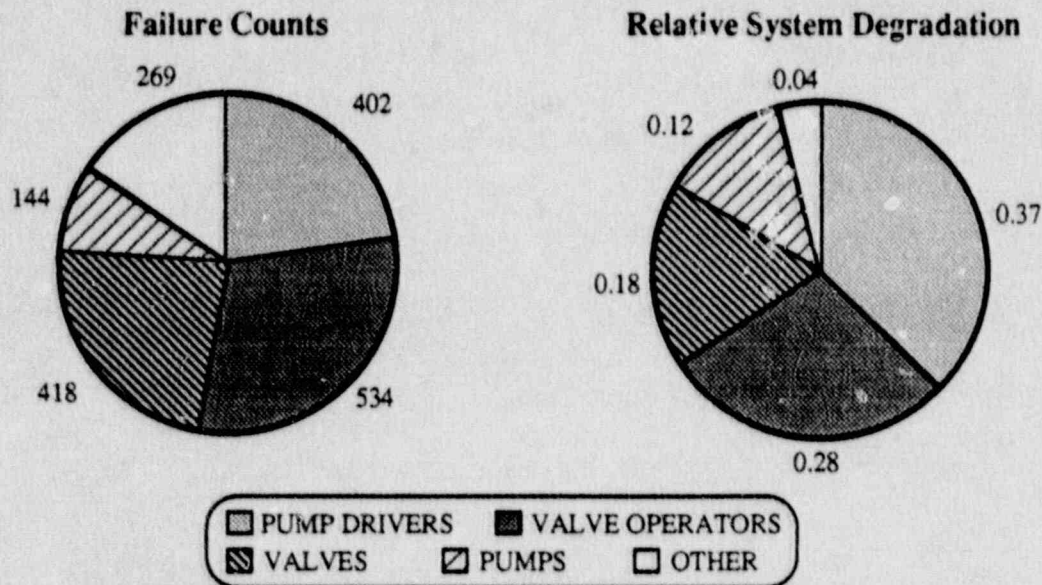


FIGURE 4.1 Failure Count and Relative System Degradation Distributions

The average effects of failures associated with Pump Drivers and Pumps were found to be 0.36 and 0.33, respectively (i.e., the average fraction of system degraded per failure). In contrast, the average effects associated with the Valve Operator and Valve categories were 0.20 and 0.16, respectively. The reason that the average effect of a pump or pump driver failure is greater than a valve or valve operator failure is that a single failure of a pump or pump driver causes the loss of an entire train, while a valve or valve operator failure normally results in only partial loss of a train.

As noted previously, failure count comparisons alone can be misleading. In order to gain a better perspective as to the overall degradation associated with failures of particular components, the Relative System Degradation for each was determined. Even though there were fewer associated Failure Counts for Pump Drivers than for Valve Operators or Valves, Pump Drivers were found to be the leading contributor to AFW Relative System Degradation, accounting for about 37% of the total, while Valve Operators and Valve failures accounted for 28% and 18%, respectively. Pump failures were found to contribute about 12% of the historical Relative System Degradation. The reason that both the Pump Driver and Pump categories were found to cause a higher fraction of Relative System Degradation than the associated fraction of Failure Counts would suggest is that, as noted

above, the average effect of a Pump or Pump Driver failure was substantially greater than that for a failure of a Valve or Valve Operator.

4.3.2. METHOD OF DETECTION SUMMARY

The method of discovery of each failure record was designated during the review process. The Failure Counts, Average Effect, and Relative System Degradation associated with the component types by the method of detection are reported in Tables 4.3.1, 4.3.2, and 4.3.3 and summarized in Figure 4.2. Three methods of detection were ascribed:

- A. Those failures found by programmatic monitoring methods, such as Technical Specification Surveillance testing. This would include failures detected during testing, even if the component that was found to be failed was not specifically being checked by the test.
- B. Those failures found during routine equipment observation, such as by noting valve stem leakage or by unusual indication or alarm at the main control board.
- C. Those failures which were only found during an operational demand, such as failure of a pump to automatically start following a reactor trip with a legitimate start signal present.

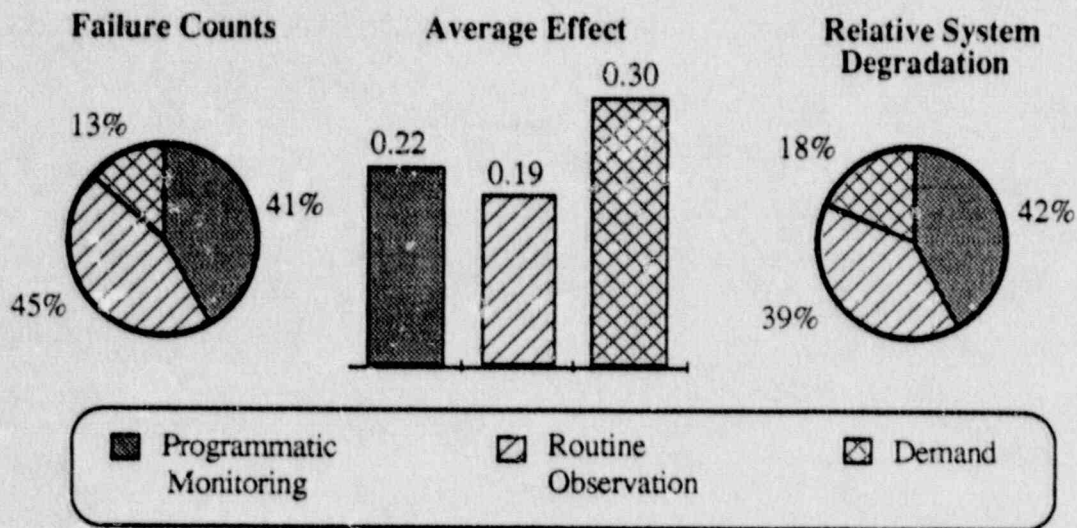


Figure 4.2 Method of Detection Summary

Note that the total Failure Counts included in the three categories is slightly less than the total Failure Counts identified in Table 4.2 (and in some other Tables) due to the fact that some failure detection means were either not clear or did not fit any of the categories.

Overall, 230 of the 1767 (13%) of the Failure Counts, and 18% of the Relative System Degradation were due to failures detected during demand events. There are several features of Figure 4.2 and Tables 4.3.1 through 4.3.3 that are particularly noteworthy:

1. Over one-fourth of the Pump Driver Failure Counts and Pump Driver related Relative System Degradation were associated with on demand failure.
2. Those failures detected during demand were, in general, more severe than those detected otherwise. As an example, the Average Effect of all demand failures was 0.30 compared to 0.22 and 0.19 for all failures detected by Programmatic Monitoring and Routine Observation, respectively.
3. Over one-half of the Relative System Degradation associated with demand failures was due to Pump Driver failures.

4.3.3. SUBSYSTEM REVIEW SUMMARY

One of the designators applied to each failure record was the subsystem affected. Four types of subsystems were designated. Three of the types are related to the type of pump driver, i.e., turbine driven pump (TDP), motor driven pump (MDP), and diesel driven pump (DDP). For those failures associated with components common to two or more trains with different types of pump drivers, the subsystem was designated as "Common". An example of a Common Subsystem component would be a flow control or isolation valve located downstream of the junction of turbine driven pump and motor driven pump discharge lines. Where the affected subsystem was indeterminate, "Unknown" was assigned.

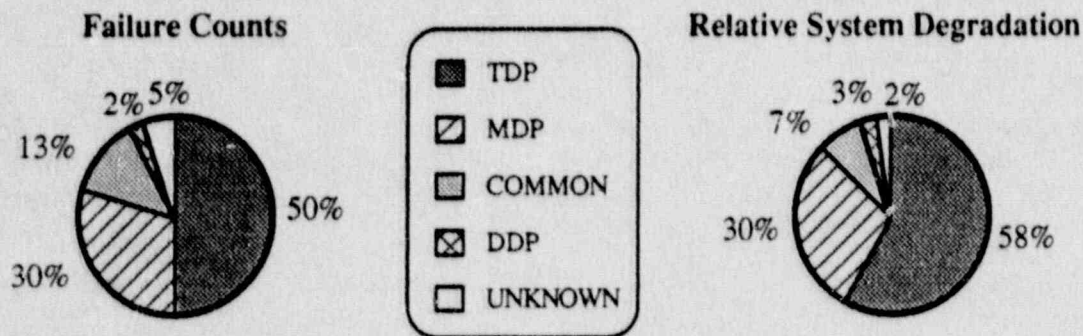


Figure 4.3 Failure by Subsystem Summary

Figure 4.3 and Tables 4.4.1 through 4.4.3 provide failure data sorted by affected subsystem. Failures within the TDP Subsystem were found to have contributed almost half of the total failure counts, and over half (58%) of the Relative System Degradation. MDP Subsystem failures were found to account for about 30% of the Failure Counts and Relative System Degradation. The significance of the TDP Subsystem failure records is amplified by the fact that there are more motor driven pumps than turbine driven pumps (77 motor driven pump subsystems vs. 51 turbine driven pump subsystems, with 808 and 604 Pump-Years cumulative service, respectively, for the units and operating periods included in the ORNL database).

4.3.4. PLANT AGE REVIEW SUMMARY

Failure records were sorted by the age of the plant at the time of component failure, and then divided into 5 year age groups. Because of the diversity of plant ages, normalization of the data was necessary to account for the fact that there have been more reactor years of operation in the lower age groups. The results of the the age-related sorting of the data are presented in Tables 4.5.1 and 4.5.2.

There are some cautions relative to this particular data sort that are extremely important. First, aging trends that may appear to be extant based on Tables E.1 and E.2 may in fact not be present at all. These tables are based upon failure records and reactor years of operation for the life of all plants included in the database. However, the failure record database, as mentioned previously, is heavily influenced by failures reported from 1984-1986 due to improvements in reporting practices (particularly the case for NPRDS) during this time period. For those plants which have operated for some time, therefore, a built in bias toward more apparent failures with age exists. Secondly, the age of the component whose failure is recorded may or may not be the same as the age of the plant. For example, a particular valve's operator may have been replaced or substantially refurbished several times prior to occurrence of a failure which is recorded in the database. Thirdly, reporting practices vary considerably from plant to plant. The reporting practices of older plants in particular can have a substantial impact upon the results of sorting of this nature. As a result, the aging relationship tables (Tables 4.5.1 and 4.5.2) should be viewed as informational data with a great deal of uncertainty.

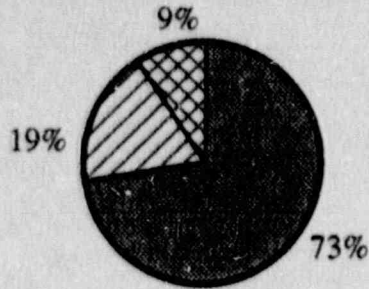
4.3.5. COMPONENT GROUP REVIEW SUMMARY

A more detailed review and characterization of failure records for the components which were found to be major contributors to AFW Relative System Degradation was performed. The component categories reviewed in more detail were Pump Drivers (specifically turbines and motors), Valve Operators, Valves, and Pumps.

4.3.5.1. Pump Drivers

Figure 4.4 and Table 4.6. provide a summary of Pump Driver failure record information from the ORNL database. Turbines accumulated the largest number of Failure Counts of any individual component type (290), and over one-fourth of overall Relative System Degradation was due to turbine related failures. Almost three-fourths of both the Failure Counts and the Relative System Degradation for Pump Drivers was associated with turbine drives. The recorded failure count rate for the turbine drives was more than four times that of the motor drives. Although there are only two diesel driven pumps (out of the total of 130 pumps in the database), failures associated with the diesels contributed 9% of the Pump Driver Relative System Degradation. This is due, in part, to the fact that the average effect at plants with the diesel driven pumps is high (each unit using diesel driven pumps has only two AFW pumps, and therefore a failure of one pump causes a 50% degradation in the system). However, it also appears, based upon the fairly small experience base for the diesel driven pumps (13 diesel driven pump-years) that the diesel driver failure rate may be higher than for the other type drivers.

Relative System Degradation



Failure Counts per Pump Drive Year

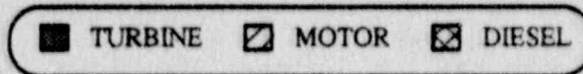
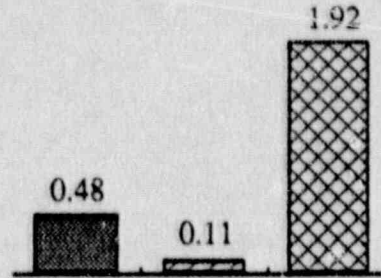


Figure 4.4 Pump Driver Summary

4.3.5.1.1 Turbines

A more detailed review and assignment of the failure sources was undertaken for the pump drivers. Figure 4.5 and Tables 4.7.1, 4.7.2, and 4.7.3 present analysis results for the turbine drives, sorted by subcomponent groupings, and method of discovery. The six subcomponents or failure sources designated for the turbine drives, and the associated scope were as follows:

A. Instrumentation and Control (I&C) / Governor Control

This includes the external control circuitry which would provide start signals to the turbine driven pump (does not include failures of instrumentation used to provide input to safeguards logic circuitry, such as steam generator level instrumentation), as well as the governor speed control circuit.

B. Trip & Throttle (T&T) Valve

Failures of the T&T valve, such as tripping due to worn linkage, or failure to open due to a damaged operator were included in this category. It should be noted that T&T valve and valve operator failures are included here, and not in the Valve or Valve Operator component groups because the T&T valve is typically a part of the turbine package, and is integral with turbine starting and operation.

C. Governor Valve

Failures of the governor valve, such as the valve plug sticking and external leakage, are included in this category.

D. Oil/Bearing

Turbine bearing failures and miscellaneous bearing oil related problems are included.

E. Turbine

Failures of the turbine itself, such as blade failure, are included.

F. Other/Unknown

Includes all other miscellaneous failures and those whose source could not be determined.

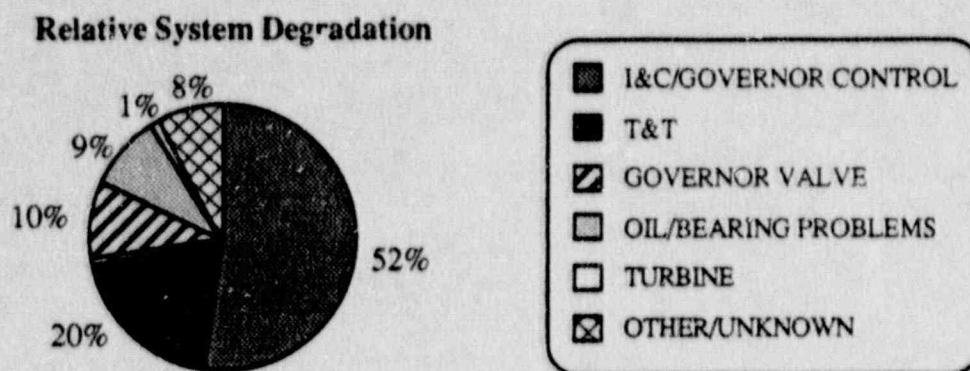


Figure 4.5 Sources of Turbine Drive Failures

Problems associated with I&C/Governor Control circuits were the dominant source of turbine degradation, comprising about half the total turbine related Failure Counts and Relative System Degradation. Trip and Throttle valve problems were responsible for about 1/5 of the Relative System Degradation.

One particularly noteworthy finding was that almost 1/3 of the I&C/Governor Control failures were detected during demand (see Figure 4.6). The I&C/Governor Control failures were responsible for about 70% of the total turbine related demand failures.

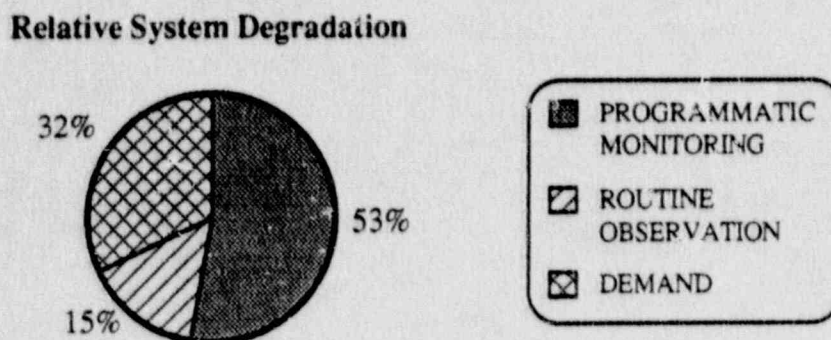


Figure 4.6 Turbine I&C/Governor Failure Summary by Detection Method

4.3.5.1.2 Motors

Tables 4.8.1, 4.8.2, and 4.8.3 provide information for motor drives. Four pump motor subcomponent failure sources were designated:

A. Instrumentation & Control (I&C)

Includes the controls which are used for automatic and manual starting of motor driven pumps (does not include failures of instrumentation used to provide input to safeguards logic circuitry, such as steam generator level instrumentation).

B. Breaker

Includes the breaker itself and breaker auxiliaries.

C. Motor

Includes all motor parts, except for the motor bearings.

D. Motor bearings

Self explanatory.

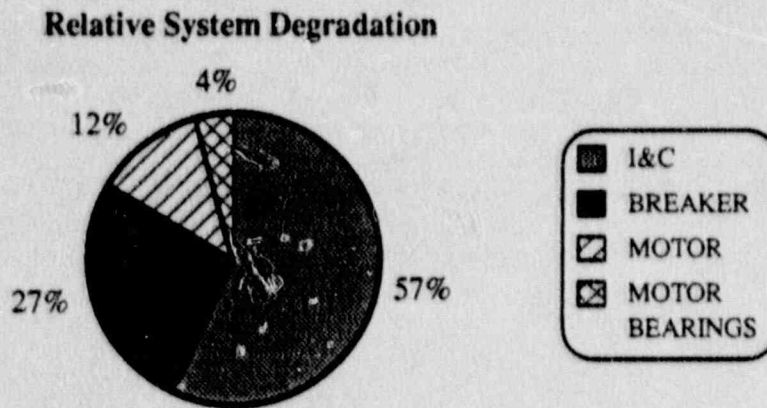


Fig. 4.7 Sources of Pump Motor Drive Failures

As was the case for the turbine drives, I&C related problems were the principal source of motor drive degradation, contributing over 50% of the total motor drive Failure Counts and Relative System Degradation. About one-third of the I&C problems for motor drives were detected during demand conditions. The I&C failures were responsible for about 80% of the total motor drive related demand failures.

4.3.5.1.3. Diesels

Tables 4.9.1, 4.9.2, and 4.9.3 provide failure database information for diesel drives. Three diesel subcomponent failure sources were designated:

A. Instrumentation & Control (I&C)

This includes the external control circuitry which would provide start signals to the diesel driven pump (does not include failures of instrumentation used to provide input to safeguards logic circuitry, such as steam generator level instrumentation), as well as the diesel governor speed control circuit.

B. Mechanical/Support

Includes the diesel itself and non-control diesel supporting auxiliaries, such as fuel oil piping.

C. Other

Self explanatory

As was the case for the turbine and motor drivers, I&C problems were found to be the principal source of diesel drive degradation, with about 80% of the Failure Counts and

Relative System Degradation resulting from I&C failures. One-half of the I&C failures recorded, comprising 40% of the total diesel failure records, occurred on demand.

4.3.5.2. Valve Operators

The Valve Operator group, which was found to have the highest number of Failure Counts, 534, was found responsible for 28% of the overall Relative System Degradation (see Tables 4.3.1 and 4.3.3 and Figure 4.1). Tables 4.10.1, 4.10.2, and 4.10.3 provide a breakdown of failure statistics of the valve operator types, including Air Operators (AOV), Motor Operators (MOV), and Electrohydraulic Operators (EHOV). Figure 4.8 indicates the relative proportions of system degradation attributable to the valve operator types. AOV's and MOV's were found to be roughly equal, in terms of both numbers of failures and Relative System Degradation. Current monitoring practices appear to be better able to detect degradation and failure of valve operators than pump drivers in that about 13% of the Relative System Degradation associated with the Valve Operator group was found during demand conditions (Table 4.10.3), compared to over 25% of the pump driver Relative System Degradation being found during demand.

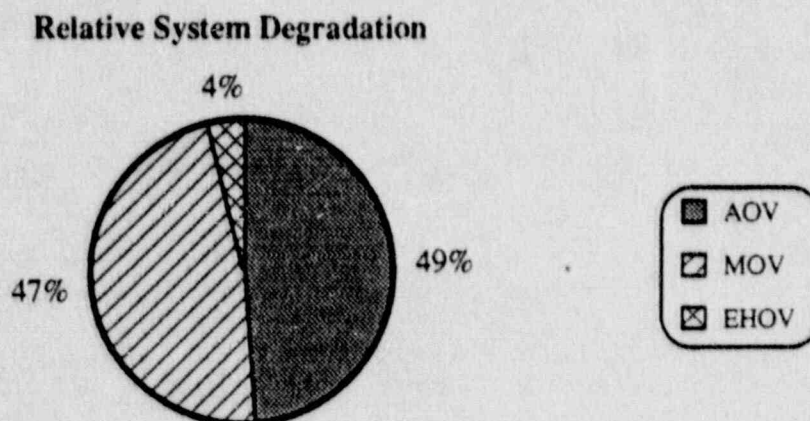


Figure 4.8 Valve Operator Failure Summary

4.3.5.2.1. Air Operated Valves (AOVs) Operators

Tables 4.10.4, 4.10.5, and 4.10.6 provide more detailed information concerning the types of failure sources for AOVs. Figure 4.9 summarizes the results. Five subcomponents or failure sources were designated:

A. Instrumentation and Control (I&C)

Includes the valve controller circuit, as well as relays, contacts, etc. that are external to the controller circuit, but which provide signals to the valve controller circuit.

B. Mechanical

This applies to the valve operator itself, including positioner, limit switches, diaphragm, connections, linkage, etc.

C. Instrument Air

Includes failures in which either instrument air supply components, such as pressure regulators were involved, or where poor instrument air quality was clearly the cause of failure. It should be noted that some other failures, such as some solenoid failures (below)

may have resulted from poor quality air, but these were not ascribed to instrument air unless the failure record description so stated.

D. Solenoids

Includes failures of the solenoid plunger or coil.

E. Unknown/Other

Self explanatory

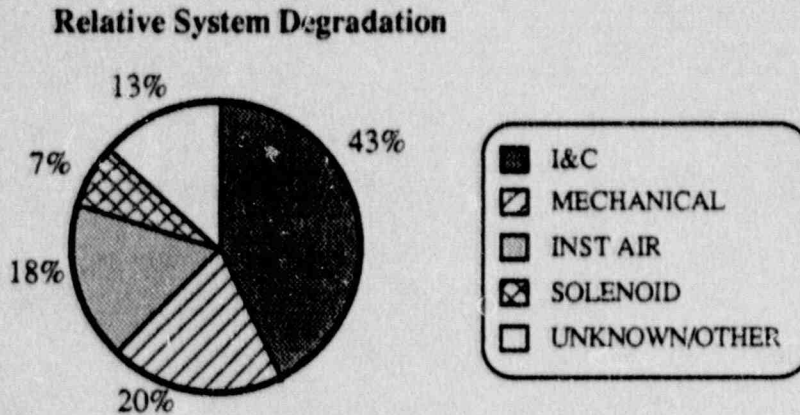


Figure 4.9 Sources of Air Operated Valve Operator Failures

Of the five failure sources for AOVs, I&C problems were the single largest contributor, both in terms of Failure Counts (131 of 289) and AOV related Relative System Degradation. About 12% of the AOV Relative System Degradation was detected during demand conditions. One half of the demand related AOV Relative System Degradation was associated with I&C failures.

4.3.5.2.1. Motor Operated Valves (MOV's) Operators

Tables 4.10.7, 4.10.8, and 4.10.9 provide more detailed information concerning the types of failure sources for MOVs. Figure 4.10 summarizes the results. Three subcomponents or failure sources were designated:

A. Motor, Switches

This category includes the motor operator itself and all local appurtenances, including the motor, torque and limit switches, gearing, etc.

B. Instrumentation and Control (I&C)

This category includes all remote controls, such as fuses, control relays and contacts that operate to control power to the operator motor (primarily located at the motor control center).

C. Other/Unknown

Self explanatory

Relative System Degradation

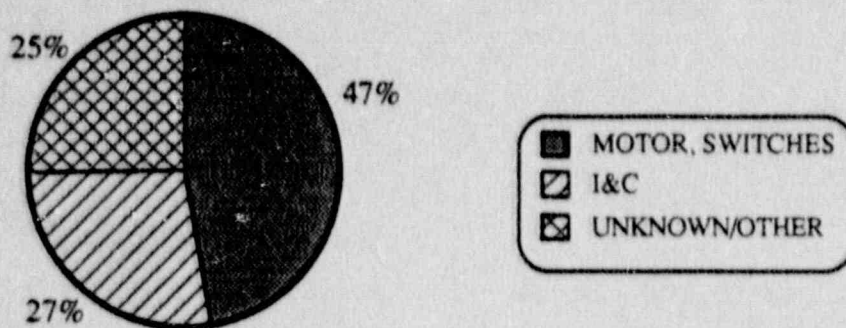


Figure 4.10 Sources of Motor Operated Valve Operator Failures

Failures associated with the operator motor and switches were responsible for almost half of the MOV Failure Counts and Relative System Degradation (limit and torque switch problems were the principal sources of failure within this subgroup). Over 15% of the MOV Failure Counts and Relative System Degradation was associated with demand situations.

4.3.5.3. Valves

Tables 4.11.1, 4.11.2, and 4.11.3 provide more detailed information concerning the types of failure sources for the Valve group. Valve related failures included all valve problems that were not included in the Valve Operator group. No distinction was made as to whether valves had power or manual only operators. Failures ranged from internal (seat) and external (packing or bonnet) leakage to separation of the disc from stem. The Valve group was broken down into the following types:

A. Control Valves

Includes all valves in either the pump suction or discharge piping, excluding check and relief valves.

B. Steam Supply Valves

Includes all valves in the steam supply lines, excluding check and relief valves.

C. Relief Valves

Includes all relief valves in either the steam supply or pump suction/discharge piping. This does not include the main steam safety or atmospheric dump valves.

D. Check Valves - Suction/Discharge

Includes all check valves located in either the pump suction or discharge lines.

E. Check Valves - Steam Supply

Includes all check valves between the steam supply connections to the main steam lines and the turbine.

There were more failures associated with the pump suction/discharge control and check valves than steam supply valves, as would be expected, due to the relative populations. The only particularly notable feature from the Valve group failure data is that less than 10% of the Failure Counts and Relative System Degradation were associated with demand failures, the smallest fraction of any of the major groups.

4.3.5.4. Pumps

Tables 4.12.1, 4.12.2, and 4.12.3 provide more detailed information concerning the type of failure sources for the Pump group. Figure 4.11 summarizes the results. Six failure/degradation sources were designated as follows:

A. Pump Internals

Includes failures of any mechanical parts of the pump, with the exception of pump packing and bearings.

B. Pump Oil/Bearing

Pump bearing failures and miscellaneous pump bearing oil related problems are included. Note that this does not include pump driver bearing problems.

C. Pump Overpressure

Includes events in which the pump casing and/or discharge piping became overpressurized.

D. Pump Packing

Includes failures of pump packing which resulted in either excessive leakage or in packing overheating.

E. Pump Suction Problems

This category covers a number of types of problems related to the pump suction, including clogged suction strainers, foreign material in the suction piping, loss of adequate suction head, and suction pressure instrumentation problems.

F. Pump Vapor Binding

This category addresses failures in which the pump became vapor bound, usually due to backleakage from main feedwater or the steam generators.

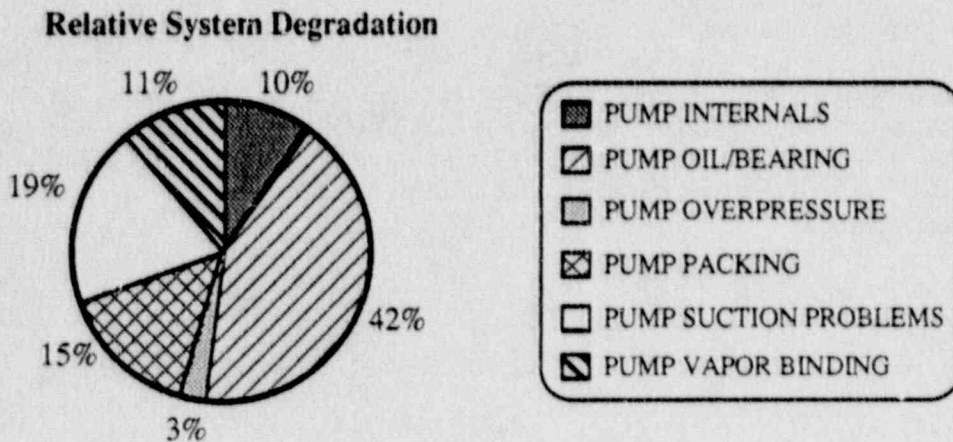


Figure 4.11 Sources of Pump Failures

The single largest source of Pump Failure Counts (54 out of 142) and Relative System Degradation (42%) was from pump bearing and oil problems. Pump suction problems were the second largest contributor to the pump related Relative System Degradation (19%). Of the 18% of Relative System Degradation associated with demand failures, 13% came from pump suction related problems.

4.3.6. REVIEW BY PLANT

A comparative review of the reported failures from individual plants was made. This review was conducted for the purposes of identifying the significance of outliers to the general failure data trends.

Figure 4.12 provides the results of a check of the total number of failures reported for the plants in the ORNL database. As noted, more than half the total reported failures came from less than 25% of the plants. At the other extreme, less than 10% of the reported failures came from over 30% of the plants.

To provide a better focus, the distribution of the historical system degradation associated with reported failures for the component types was reviewed. The results, which are provided in Figure 4.13, are even more pronounced than the results from the check of total number of failures. More than 50% of the system degradation associated with each of the designated component groups came from less than 20% of the plants, while less than 10% of the associated degradation came from almost 50% of the plants.

There are two possible observations relative to the cause of these results that can be made. The first is that the reporting practices vary considerably from plant to plant. The second is that some plants have experienced more degradation or failure of certain components than others. In reality, there is some validity to both conclusions, and the results represent the combination of both causes.

Figures 4.14 and 4.15 provide perspectives on the failure reporting practices of the ORNL database plants, based upon analysis of the available failure data. From these Figures it can be seen that a consistent pattern in terms of failure reporting to NPRDS is not evident from a comparison of total failure counts in the ORNL database to failure counts for which there was an NPRDS entry.

Figure 4.16 provides a comparison of the relative contributions of pump drivers, valve operators, valves, and pumps to overall system degradation at the five plants for which the greatest extent of AFW System degradation was reported. The range of percentages of total degradation for the component types among these five plants are listed below. It is evident that there is substantial diversity, in terms of the relative significance of component types to overall AFW System degradation, among the five plants.

<u>COMPONENT</u>	<u>RANGE OF RELATIVE SYSTEM DEGRADATION</u>
Pump Drivers	19 to 89%
Valve Operators	7 to 72%
Valves	1 to 35%
Pumps	3 to 14%

Table 4.1 COMPONENT CATEGORIZATION

<u>COMPONENT TYPE</u>	<u>SCOPE OF EQUIPMENT</u>
PUMP DRIVERS	Components included in the Pump Driver scope are: a) the pump driver itself, whether turbine, diesel, or motor, including mechanical and electrical parts of the driver, b) the control circuitry for the driver, including breakers, contacts, relays, etc., that are required to operate properly to start and/or control the pump driver, c) auxiliary components whose function is integral with the pump driver. For example, the turbine governor valve is included, since it is used to control turbine speed.
VALVE OPERATORS	Includes the valve operator itself (for example, the motor), any portion of the operator controls, including switches, contacts, controllers, etc. Does not include failures of the valve or valve stem. Valve operators for AFW pump suction, discharge, and turbine steam supply valves are included.
VALVES	This category includes failures of all types of valves, including check, gate, globe, butterfly, etc. Note that the turbine governor and trip & throttle valves are specifically not included. External leakage, seat leakage, and stem failures are examples of failures included.
PUMPS	Pumps only, regardless of drive type, are addressed by this category. Bearing failures, pump lube oil problems, air or vapor binding of the pumps, pump suction problems, and pump overpressurization problems are included.
OTHER	Includes all components not addressed by the above categories, including pipes, pipe supports, and non-control instrumentation (i.e. instruments used for indication only)

Table 4.2 COMPONENT FAILURE RECORD SUMMARY

<u>COMPONENT TYPE</u>	<u>FAILURE COUNTS</u>	<u>AVERAGE EFFECT</u>	<u>RELATIVE SYSTEM DEGRADATION</u>
PUMP DRIVERS	402	0.36	0.37
VALVE OPERATORS	534	0.20	0.28
VALVES	418	0.16	0.18
PUMPS	144	0.33	0.12
OTHER	269	0.06	0.04
TOTAL	1767	0.22	1.00

Table 4.3.1 FAILURE COUNTS, BY DISCOVERY METHOD

COMPONENT TYPE	<u>PROGRAMMATIC MONITORING</u>	<u>ROUTINE OBSERVATION</u>	<u>DEMAND</u>	<u>TOTAL</u>
PUMP DRIVERS	180	126	95	402
VALVE OPERATORS	236	223	73	534
VALVES	124	269	23	418
PUMPS	47	71	26	144
OTHER	144	108	13	269
TOTAL	731	797	230	1767

Table 4.3.2 AVERAGE EFFECT, BY DISCOVERY METHOD

COMPONENT TYPE	<u>PROGRAMMATIC MONITORING</u>	<u>ROUTINE OBSERVATION</u>	<u>DEMAND</u>	<u>TOTAL</u>
PUMP DRIVERS	0.35	0.33	0.39	0.36
VALVE OPERATORS	0.20	0.20	0.20	0.20
VALVES	0.20	0.14	0.27	0.16
PUMPS	0.37	0.30	0.33	0.33
OTHER	0.06	0.04	0.18	0.06
TOTAL	0.22	0.19	0.30	0.22

Table 4.3.3 RELATIVE SYSTEM DEGRADATION, BY DISCOVERY METHOD

COMPONENT TYPE	<u>PROGRAMMATIC MONITORING</u>	<u>ROUTINE OBSERVATION</u>	<u>DEMAND</u>	<u>TOTAL</u>
PUMP DRIVERS	0.17	0.11	0.10	0.37
VALVE OPERATORS	0.12	0.12	0.04	0.28
VALVES	0.06	0.10	0.02	0.18
PUMPS	0.05	0.06	0.02	0.12
OTHER	0.02	0.01	0.01	0.04
TOTAL	0.42	0.39	0.18	1.00

Table 4.4.1 FAILURE COUNTS BY SUBSYSTEM AFFECTED

COMPONENT TYPE	SUBSYSTEM AFFECTED					TOTAL
	TDP	MDP	COMMON	DDP	UNKNOWN	
PUMP DRIVERS	290	87	0	25	0	402
VALVE OPERATORS	258	209	51	2	14	534
VALVES	210	129	59	1	19	418
PUMPS	60	33	0	0	1	144
OTHER	62	30	112	2	63	269
TOTAL	880	533	222	30	97	1767

Table 4.4.2 AVERAGE SYSTEM EFFECT BY SUBSYSTEM AFFECTED

COMPONENT TYPE	SUBSYSTEM AFFECTED					TOTAL
	TDP	MDP	COMMON	DDP	UNKNOWN	
PUMP DRIVERS	0.36	0.31	N/A	0.49	N/A	0.35
VALVE OPERATORS	0.22	0.19	0.20	0.25	0.19	0.20
VALVES	0.16	0.17	0.17	0.25	0.10	0.16
PUMPS	0.34	0.32	N/A	N/A	0.50	0.33
OTHER	0.09	0.03	0.05	0.00	0.07	0.06
TOTAL	0.25	0.21	0.11	0.43	0.10	0.22

Table 4.4.3 RELATIVE SYSTEM DEGRADATION BY SUBSYSTEM AFFECTED

COMPONENT TYPE	SUBSYSTEM AFFECTED					TOTAL
	TDP	MDP	COMMON	DDP	UNKNOWN	
PUMP DRIVERS	0.27	0.07	0.00	0.03	0.00	0.37
VALVE OPERATORS	0.15	0.10	0.03	0.00	0.01	0.28
VALVES	0.09	0.06	0.03	0.00	0.01	0.18
PUMPS	0.05	0.07	0.00	0.00	0.00	0.12
OTHER	0.01	0.00	0.01	0.00	0.01	0.04
TOTAL	0.58	0.30	0.07	0.03	0.02	1.00

Table 4.5.1 FAILURE COUNTS PER REACTOR YEAR, BY 5 YR GROUPS

COMPONENT TYPE	<u>YEARS 1-5</u>	<u>YEARS 6-10</u>	<u>YEARS 11-15</u>	<u>YEARS 16-20</u>	<u>YEARS 1-20</u>
PUMP DRIVERS	0.75	0.78	0.84	0.95	0.79
VALVE OPERATORS	1.06	0.95	1.17	1.00	1.04
VALVES	0.66	0.87	1.07	0.77	0.82
PUMPS	0.27	0.23	0.44	0.09	0.28
OTHER	0.48	0.58	0.46	0.68	0.52
TOTAL	3.21	3.42	3.98	3.50	3.44

**Table 4.5.2 SYSTEM DEGRADATION, BY 5 YR GROUPS
(NORMALIZED FOR NUMBERS OF REACTOR YEARS OPERATION)**

COMPONENT TYPE	<u>YEARS 1-5</u>	<u>YEARS 6-10</u>	<u>YEARS 11-15</u>	<u>YEARS 16-20</u>	<u>YEARS 1-20</u>
PUMP DRIVERS	0.09	0.09	0.08	0.12	0.37
VALVE OPERATORS	0.07	0.06	0.08	0.08	0.28
VALVES	0.04	0.04	0.06	0.04	0.18
PUMPS	0.03	0.03	0.05	0.01	0.12
OTHER	0.01	0.01	0.01	0.02	0.04
TOTAL	0.23	0.23	0.28	0.27	1.00

Table 4.6 PUMP DRIVER TYPE SUMMARY DATA

PUMP DRIVER TYPE	<u>FAILURE COUNTS</u>	<u>FAILURE COUNTS PER PUMP-YEAR</u>	<u>AVERAGE EFFECT</u>	<u>RELATIVE SYSTEM DEGRADATION</u>
TURBINE	290	0.48	0.36	0.73
MOTOR	87	0.11	0.31	0.19
DIESEL	25	1.92	0.49	0.09
TOTAL	402	0.28	0.36	1.00

Table 4.7.1 TURBINE FAILURE COUNTS BY DETECTION METHOD

<u>FAILURE SOURCE</u>	<u>PROGRAMMATIC MONITORING</u>	<u>ROUTINE OBSERVATION</u>	<u>DEMAND</u>	<u>TOTAL</u>
I&C/GOV. CONTROL	82	24	43	149
T&T	23	29	11	64
GOVERNOR VALVE	15	13	2	30
OIL/BEARING	9	10	2	21
TURBINE	1	4	0	5
OTHER/UNKNOWN	11	7	3	21
TOTAL	141	87	61	290

Table 4.7.2 TURBINE AVERAGE EFFECT BY DETECTION METHOD

<u>FAILURE SOURCE</u>	<u>PROGRAMMATIC MONITORING</u>	<u>ROUTINE OBSERVATION</u>	<u>DEMAND</u>	<u>TOTAL</u>
I&C/GOV. CONTROL	0.36	0.34	0.40	0.37
T&T	0.32	0.32	0.38	0.33
GOVERNOR VALVE	0.37	0.29	0.42	0.34
OIL/BEARING	0.46	0.39	0.42	0.42
TURBINE	0.17	0.23	N/A	0.22
OTHER/UNKNOWN	0.41	0.33	0.33	0.37
TOTAL	0.36	0.33	0.39	0.36

Table 4.7.3 TURBINE RELATIVE SYSTEM DEGRADATION BY DETECTION METHOD

<u>FAILURE SOURCE</u>	<u>PROGRAMMATIC MONITORING</u>	<u>ROUTINE OBSERVATION</u>	<u>DEMAND</u>	<u>TOTAL</u>
I&C/GOV. CONTROL	0.28	0.08	0.17	0.53
T&T	0.07	0.09	0.04	0.20
GOVERNOR VALVE	0.05	0.04	0.01	0.10
OIL/BEARING	0.04	0.04	0.01	0.09
TURBINE	0.00	0.01	0.00	0.01
OTHER/UNKNOWN	0.14	0.02	0.01	0.08
TOTAL	0.49	0.27	0.23	1.00

Table 4.8.1 PUMP MOTOR FAILURE COUNTS BY DETECTION METHOD

<u>FAILURE SOURCE</u>	<u>PROGRAMMATIC MONITORING</u>	<u>ROUTINE OBSERVATION</u>	<u>DEMAND</u>	<u>TOTAL</u>
I&C	21	14	17	52
BREAKER	10	8	4	22
MOTOR	4	6	0	10
MOTOR BEARINGS	0	3	0	3
TOTAL	35	31	21	87

Table 4.8.2 PUMP MOTOR AVERAGE EFFECT BY DETECTION METHOD

<u>FAILURE SOURCE</u>	<u>PROGRAMMATIC MONITORING</u>	<u>ROUTINE OBSERVATION</u>	<u>DEMAND</u>	<u>TOTAL</u>
I&C	0.29	0.26	0.30	0.29
BREAKER	0.31	0.37	0.29	0.33
MOTOR	0.33	0.33	N/A	0.33
MOTOR BEARINGS	N/A	0.33	N/A	0.33
TOTAL	0.30	0.31	0.30	0.30

Table 4.8.3 PUMP MOTOR RELATIVE SYSTEM DEGRADATION BY DETECTION METHOD

<u>FAILURE SOURCE</u>	<u>PROGRAMMATIC MONITORING</u>	<u>ROUTINE OBSERVATION</u>	<u>DEMAND</u>	<u>TOTAL</u>
I&C	0.23	0.14	0.19	0.57
BREAKER	0.12	0.11	0.04	0.27
MOTOR	0.05	0.07	0.00	0.12
MOTOR BEARINGS	0.00	0.04	0.00	0.04
TOTAL	0.40	0.36	0.24	1.00

Table 4.9.1 DIESEL SUBCOMPONENT FAILURE COUNTS BY DETECTION METHOD

<u>FAILURE SOURCE</u>	<u>PROGRAMMATIC MONITORING</u>	<u>ROUTINE OBSERVATION</u>	<u>DEMAND</u>	<u>TOTAL</u>
I&C	4	6	10	20
MECHANICAL/SUPPORT	0	2	1	3
OTHER	0	0	2	2
TOTAL	4	8	13	25

Table 4.9.2 DIESEL SUBCOMPONENT AVERAGE EFFECT BY DETECTION METHOD

<u>FAILURE SOURCE</u>	<u>PROGRAMMATIC MONITORING</u>	<u>ROUTINE OBSERVATION</u>	<u>DEMAND</u>	<u>TOTAL</u>
I&C	0.50	0.50	0.50	0.50
MECHANICAL/SUPPORT	N/A	0.38	0.50	0.42
OTHER	N/A	N/A	0.50	0.50
TOTAL	0.50	0.47	0.50	0.49

Table 4.9.3 DIESEL SUBCOMPONENT RELATIVE SYSTEM DEGRADATION BY DETECTION METHOD

<u>FAILURE SOURCE</u>	<u>PROGRAMMATIC MONITORING</u>	<u>ROUTINE OBSERVATION</u>	<u>DEMAND</u>	<u>TOTAL</u>
I&C	0.16	0.24	0.41	0.82
MECHANICAL/SUPPORT	0.00	0.06	0.04	0.10
OTHER	0.00	0.00	0.08	0.08
TOTAL	0.16	0.31	0.53	1.00

Table 4.10.1 VALVE OPERATOR TYPE FAILURE COUNTS

<u>OPERATOR TYPE</u>	<u>PROGRAMMATIC MONITORING</u>	<u>ROUTINE OBSERVATION</u>	<u>DEMAND</u>	<u>TOTAL</u>
AOV	124	130	34	289
MOV	109	84	36	230
EHOV	3	9	3	15
TOTAL	236	223	73	534

Table 4.10.2 VALVE OPERATOR TYPE AVERAGE EFFECT

<u>OPERATOR TYPE</u>	<u>PROGRAMMATIC MONITORING</u>	<u>ROUTINE OBSERVATION</u>	<u>DEMAND</u>	<u>TOTAL</u>
AOV	0.17	0.19	0.18	0.18
MOV	0.23	0.21	0.21	0.22
EHOV	0.33	0.31	0.28	0.31
TOTAL	0.20	0.20	0.20	0.20

Table 4.10.3 VALVE OPERATOR TYPE RELATIVE SYSTEM DEGRADATION

<u>OPERATOR TYPE</u>	<u>PROGRAMMATIC MONITORING</u>	<u>ROUTINE OBSERVATION</u>	<u>DEMAND</u>	<u>TOTAL</u>
AOV	0.20	0.23	0.06	0.49
MOV	0.23	0.17	0.07	0.47
EHOV	0.01	0.03	0.01	0.04
TOTAL	0.44	0.42	0.13	1.00

Table 4.10.4 AIR OPERATED VALVE FAILURE COUNTS

<u>FAILURE SOURCE</u>	<u>PROGRAMMATIC MONITORING</u>	<u>ROUTINE OBSERVATION</u>	<u>DEMAND</u>	<u>TOTAL</u>
I&C	55	60	16	131
MECHANICAL	24	27	4	56
INSTRUMENT AIR	26	16	5	47
SOLENOID	7	12	0	19
UNKNOWN/OTHER	12	15	9	36
TOTAL	124	130	34	289

Table 4.10.5 AIR OPERATED VALVE AVERAGE EFFECT

<u>FAILURE SOURCE</u>	<u>PROGRAMMATIC MONITORING</u>	<u>ROUTINE OBSERVATION</u>	<u>DEMAND</u>	<u>TOTAL</u>
I&C	0.16	0.18	0.19	0.17
MECHANICAL	0.19	0.20	0.17	0.19
INSTRUMENT AIR	0.19	0.22	0.20	0.20
SOLENOID	0.19	0.18	N/A	0.18
UNKNOWN/OTHER	0.20	0.19	0.17	0.19
TOTAL	0.17	0.19	0.18	0.18

Table 4.10.6 AIR OPERATED VALVE RELATIVE SYSTEM DEGRADATION

<u>FAILURE SOURCE</u>	<u>PROGRAMMATIC MONITORING</u>	<u>ROUTINE OBSERVATION</u>	<u>DEMAND</u>	<u>TOTAL</u>
I&C	0.16	0.21	0.06	0.43
MECHANICAL	0.09	0.10	0.01	0.20
INSTRUMENT AIR	0.09	0.07	0.02	0.18
SOLENOID	0.03	0.04	0.00	0.07
UNKNOWN/OTHER	0.04	0.05	0.03	0.13
TOTAL	0.41	0.47	0.12	1.00

Table 4.10.7 MOTOR OPERATED VALVE FAILURE COUNTS

<u>FAILURE SOURCE</u>	<u>PROGRAMMATIC MONITORING</u>	<u>ROUTINE OBSERVATION</u>	<u>DEMAND</u>	<u>TOTAL</u>
MOTOR, SWITCHES	59	37	13	109
I&C	25	24	14	64
UNKNOWN/OTHER	25	23	9	57
TOTAL	109	84	36	230

Table 4.10.8 MOTOR OPERATED VALVE AVERAGE EFFECT

<u>FAILURE SOURCE</u>	<u>PROGRAMMATIC MONITORING</u>	<u>ROUTINE OBSERVATION</u>	<u>DEMAND</u>	<u>TOTAL</u>
MOTGR, SWITCHES	0.23	0.20	0.22	0.22
I&C	0.22	0.23	0.20	0.22
UNKNOWN/OTHER	0.24	0.22	0.20	0.22
TOTAL	0.23	0.21	0.21	0.22

Table 4.10.9 MOTOR OPERATED VALVE RELATIVE SYSTEM DEGRADATION

<u>FAILURE SOURCE</u>	<u>PROGRAMMATIC MONITORING</u>	<u>ROUTINE OBSERVATION</u>	<u>DEMAND</u>	<u>TOTAL</u>
MOTGR, SWITCHES	0.27	0.15	0.06	0.47
I&C	0.11	0.11	0.06	0.27
UNKNOWN/OTHER	0.12	0.10	0.04	0.25
TOTAL	0.50	0.36	0.15	1.00

Table 4.11.1 VALVE TYPE FAILURE COUNTS

<u>VALVE TYPE</u>	<u>PROGRAMMATIC MONITORING</u>	<u>ROUTINE OBSERVATION</u>	<u>DEMAND</u>	<u>TOTAL</u>
CONTROL VALVES	39	85	14	138
STEAM SUPPLY VALVES	16	53	2	71
RELIEF VALVE	15	10	1	26
CHECK VALVES-SUCT/DISCH	33	97	5	135
CHECK VALVES-STEAM SUPPLY	21	24	1	46
TOTAL	124	269	23	416

Table 4.11.2 VALVE TYPE AVERAGE EFFECT

<u>VALVE TYPE</u>	<u>PROGRAMMATIC MONITORING</u>	<u>ROUTINE OBSERVATION</u>	<u>DEMAND</u>	<u>TOTAL</u>
CONTROL VALVES	0.17	0.14	0.27	0.16
STEAM SUPPLY VALVES	0.22	0.11	0.25	0.14
RELIEF VALVE	0.18	0.03	0.33	0.13
CHECK VALVES-SUCT/DISCH	0.23	0.16	0.27	0.18
CHECK VALVES-STEAM SUPPLY	0.18	0.14	0.33	0.16
TOTAL	0.20	0.14	0.27	0.16

Table 4.11.3 VALVE TYPE RELATIVE SYSTEM DEGRADATION

<u>VALVE TYPE</u>	<u>PROGRAMMATIC MONITORING</u>	<u>ROUTINE OBSERVATION</u>	<u>DEMAND</u>	<u>TOTAL</u>
CONTROL VALVES	0.10	0.17	0.06	0.33
STEAM SUPPLY VALVES	0.05	0.09	0.01	0.15
RELIEF VALVE	0.04	0.01	0.00	0.05
CHECK VALVES-SUCT/DISCH	0.11	0.23	0.02	0.37
CHECK VALVES-STEAM SUPPLY	0.06	0.05	0.00	0.11
TOTAL	0.36	0.55	0.09	1.00

Table 4.12.1 PUMP SUBCOMPONENT FAILURE CC

PUMP DEGRADATION SOURCE	PROGRAMMATIC MONITORING	ROUTINE OBSERVATION	DEMAND	TOTAL
PUMP INTERNALS	6	3	3	12
PUMP OIL/BEARING	23	29	2	54
PUMP OVERPRESSURE	1	5	0	6
PUMP PACKING	7	21	1	29
PUMP SUCTION PROBLEMS	7	1	19	27
PUMP VAPOR BINDING	1	12	1	14
TOTAL	45	71	26	142

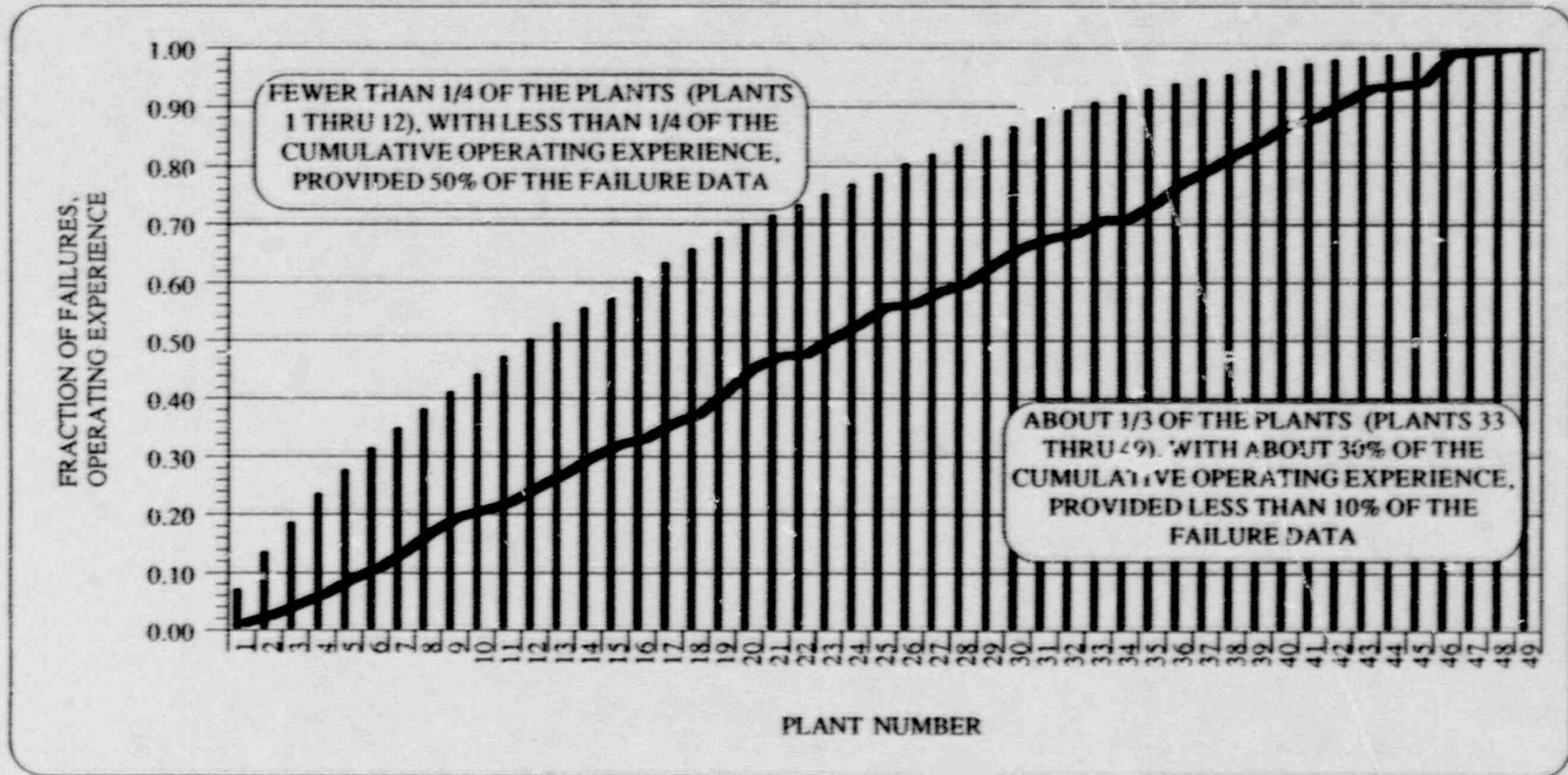
Table 4.12.2 PUMP SUBCOMPONENT AVERAGE EFFECT

PUMP DEGRADATION SOURCE	PROGRAMMATIC MONITORING	ROUTINE OBSERVATION	DEMAND	TOTAL
PUMP INTERNALS	0.42	0.39	0.33	0.39
PUMP OIL/BEARING	0.39	0.35	0.42	0.37
PUMP OVERPRESSURE	0.33	0.17	N/A	0.20
PUMP PACKING	0.31	0.22	0.17	0.24
PUMP SUCTION PROBLEMS	0.38	0.33	0.32	0.34
PUMP VAPOR BINDING	0.33	0.36	0.33	0.35
TOTAL	0.38	0.30	0.33	0.33

Table 4.12.3 PUMP SUBCOMPONENT RELATIVE SYSTEM EFFECT

PUMP DEGRADATION SOURCE	PROGRAMMATIC MONITORING	ROUTINE OBSERVATION	DEMAND	TOTAL
PUMP INTERNALS	0.05	0.02	0.02	0.10
PUMP OIL/BEARING	0.19	0.22	0.02	0.42
PUMP OVERPRESSURE	0.01	0.02	0.00	0.03
PUMP PACKING	0.05	0.10	0.00	0.15
PUMP SUCTION PROBLEMS	0.06	0.01	0.13	0.19
PUMP VAPOR BINDING	0.01	0.09	0.01	0.11
TOTAL	0.36	0.46	0.18	1.00

Figure 4.12 FAILURE COUNTS AND OPERATING EXPERIENCE FOR PLANTS IN THE ORNL DATABASE



CUMULATIVE FAILURE COUNT FRACTION
 CUMULATIVE FRACTION OF ALL YEARS REACTOR OPERATION

NOTE: THE PLANTS ARE ORDERED BY NUMBER OF FAILURE COUNTS. PLANT 1 HAS THE HIGHEST NUMBER OF REPORTED FAILURES, AND PLANT 49 THE FEWEST

Figure 4.13 SOURCES OF COMPONENT RELATED DEGRADATION

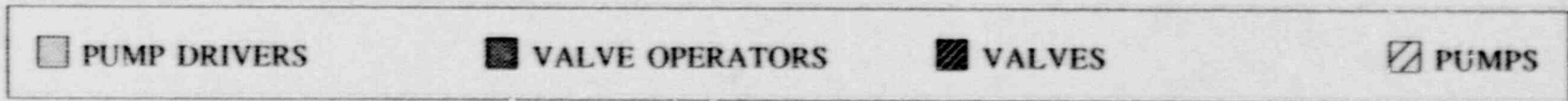
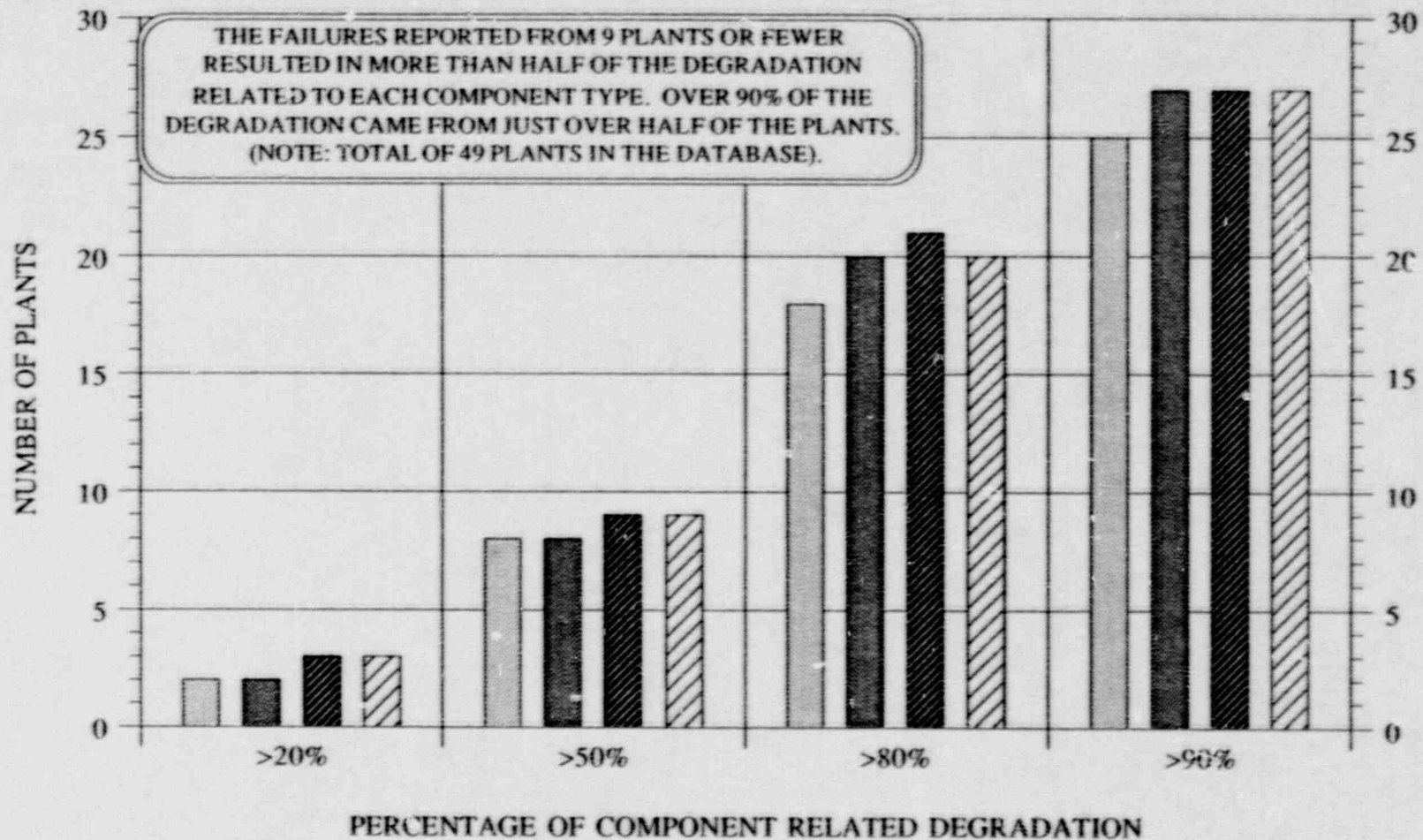
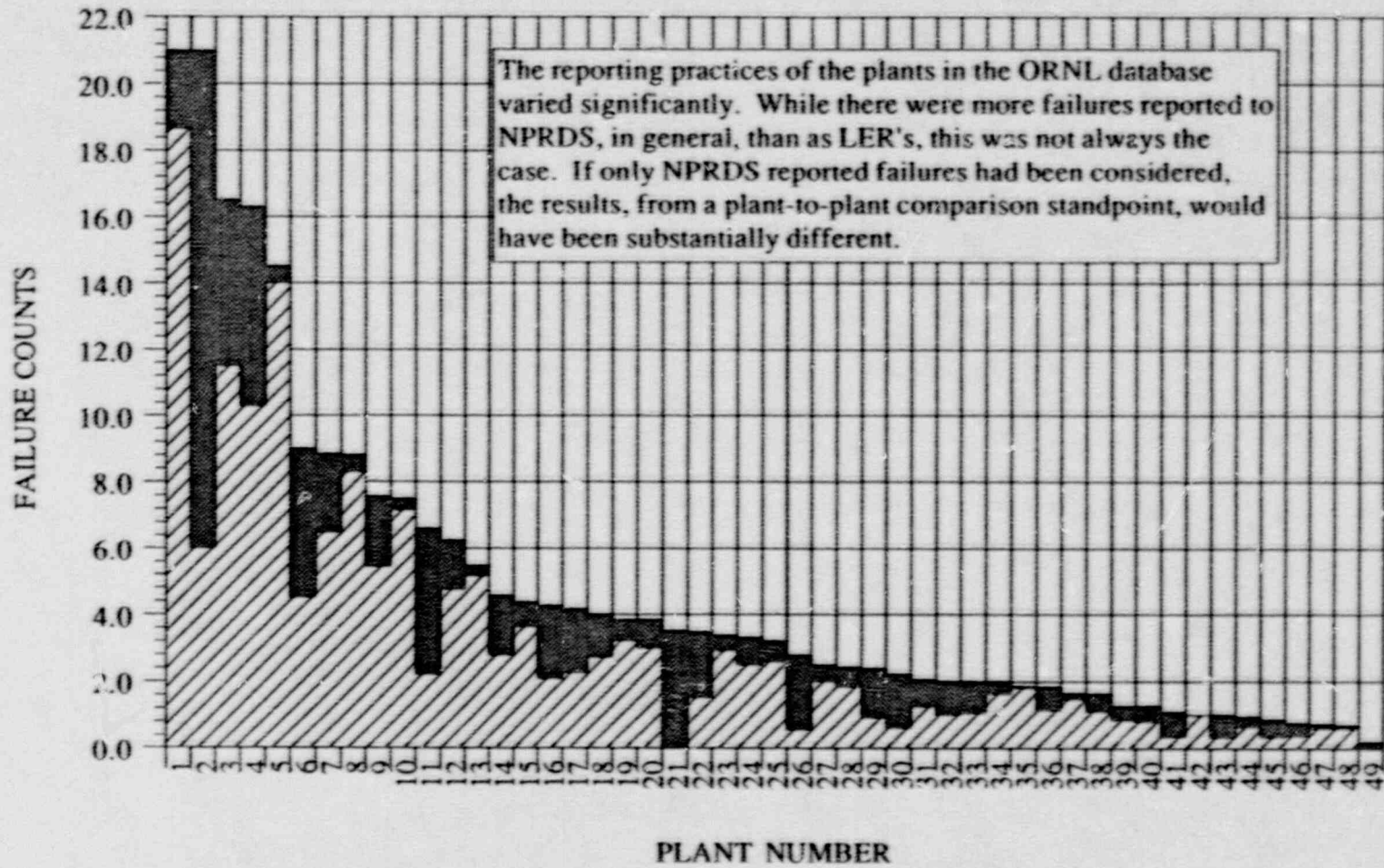


Figure 4.14 REPORTED FAILURE COUNTS PER YEAR, BY SOURCE



NPRDS FAILURE COUNTS PER YEAR
 TOTAL FAILURE COUNTS PER YEAR

Figure 4.15 SCATTER DIAGRAM OF THE FRACTION OF FAILURE COUNTS AVAILABLE FROM NPRDS DATA AS A FUNCTION OF THE AVERAGE NUMBER OF FAILURE COUNTS PER YEAR FOR ALL DATABASE PLANTS

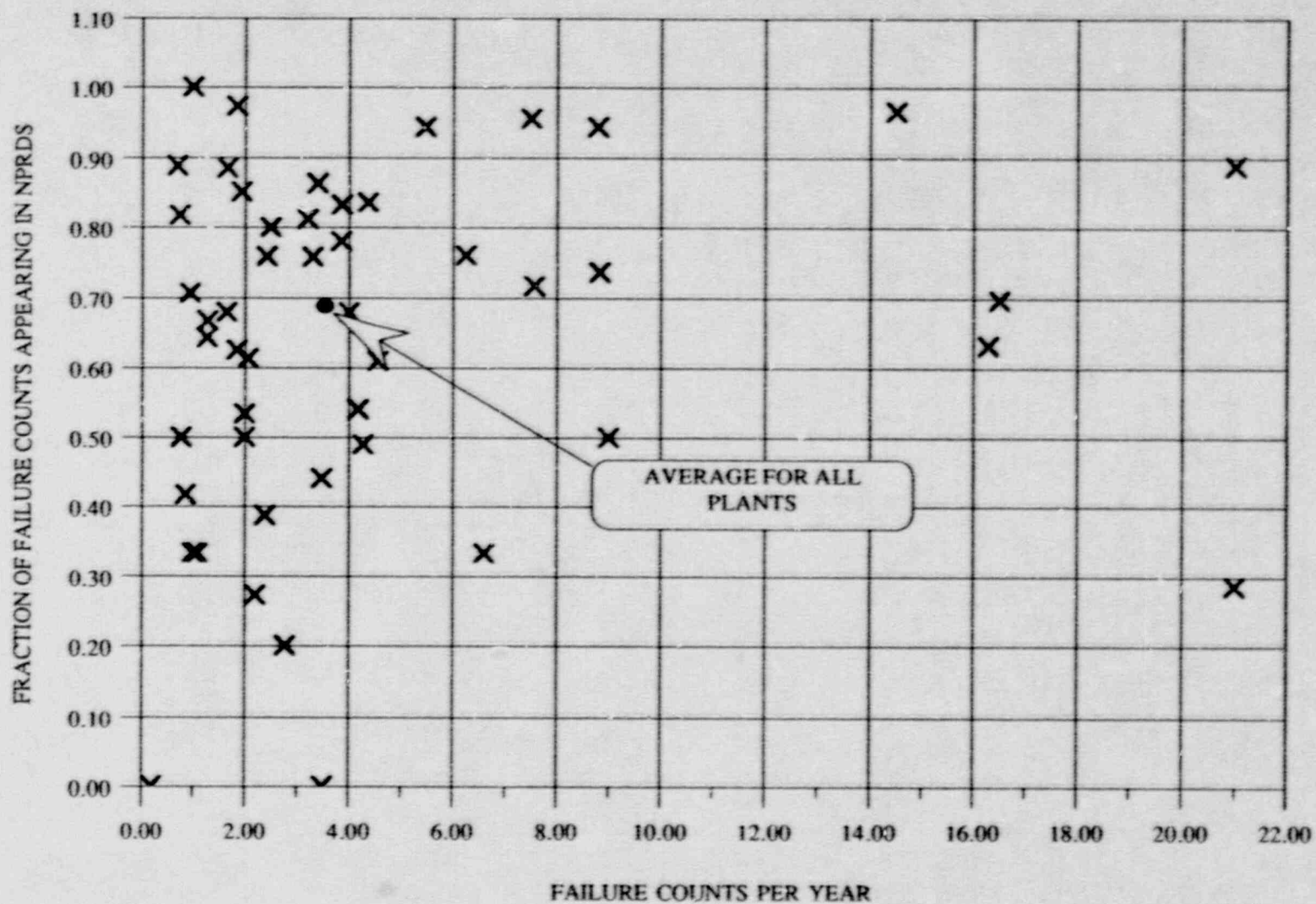
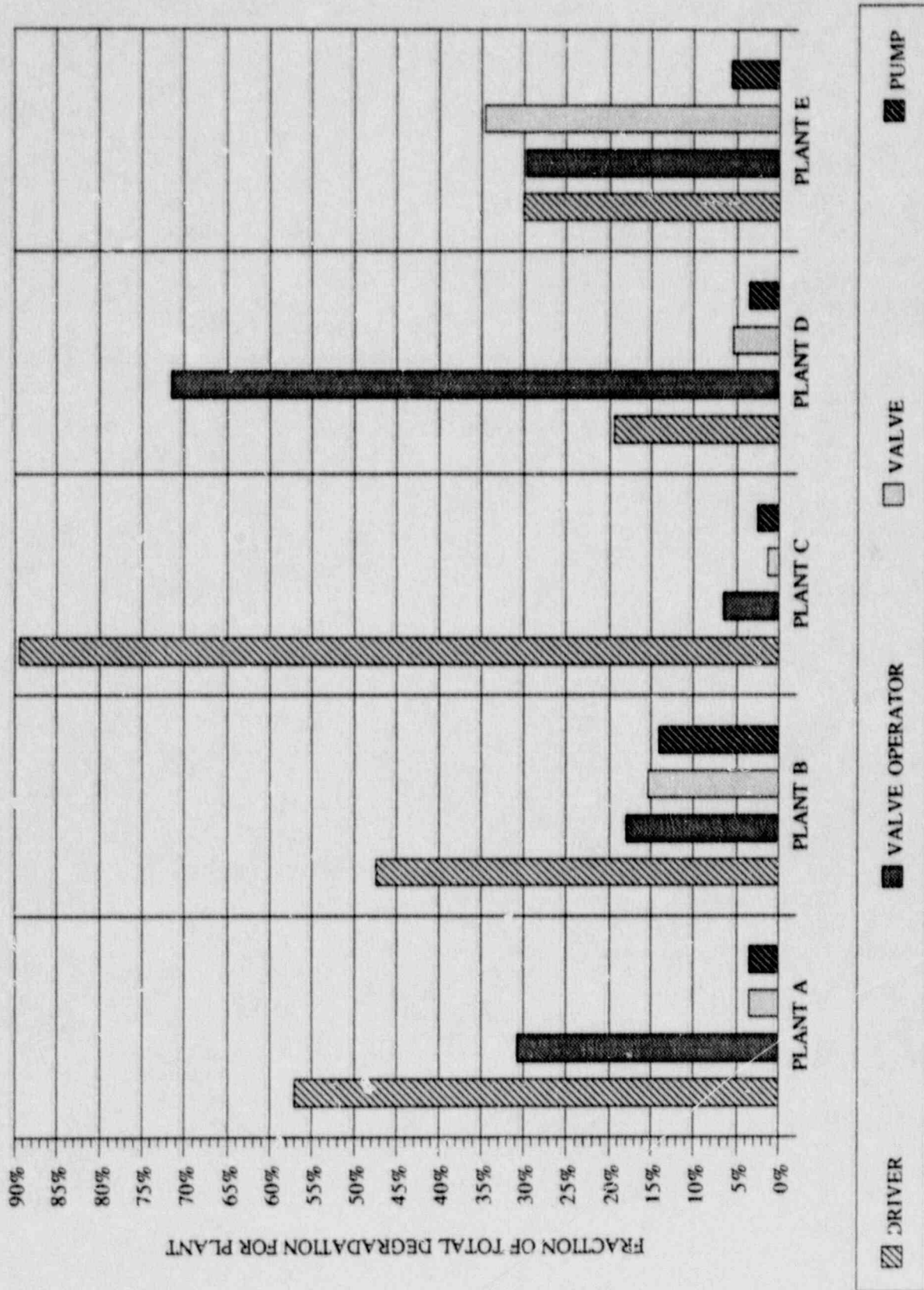


Figure 4.16 RELATIVE SYSTEM DEGRADATION: COMPONENT PERCENTAGE CONTRIBUTION FOR TOP FIVE PLANTS



CHAPTER 5 AFW SYSTEM CONFIGURATIONS

A review of AFW System configurations was conducted for sixty-one B&W and Westinghouse plants which are either currently operating or are scheduled for near term operation. Only B&W and Westinghouse plants were included because the failure data used in constructing the ORNL failure database (Chapter 4) was only available for these type plants (note that not all sixty-one plants are included in the failure database). Thirty-three of the plants are four loop, fourteen are three loop, and fourteen are two loop units. There are one hundred-three motor driven, sixty-three turbine driven, and five diesel driven safety related AFW pumps at these plants.

Table 5A provides general steam generator/AFW pump configuration information for these plants. In general, for two and three loop plants, each available pump can feed each steam generator (SG). For four loop plants, motor driven pumps discharge lines are normally aligned to allow each pump to feed two SGs, while turbine and diesel driven pump discharge lines are normally aligned to feed all four SGs.

Reactor thermal power and AFW pump design values are listed in Table 5B. It can be seen that, in general, motor driven pump capacities are typically one-half that of turbine driven pumps at the same plant.

Actuation signals for both motor driven and turbine driven pumps are provided in Tables 5C and 5D. Explanations of the designated actuation signals follow.

Loss of Feedwater (FW)	The methods of detecting loss of normal feedwater vary. Signals based on low main feedwater pump discharge pressure, main feed pump breaker open, or main feed pump turbine tripped are typical.
Loss of Emergency or Reactor Coolant Pump (RCP) Bus	These signals are typically based on low bus voltage, although some plants use Reactor Coolant Pump tripping as a signal source.
Low Level in one Steam Generator (SG)	This signal source is fairly straightforward. It is typically based on low level detected by 2/3 or 2/4 level channels for a single SG.
Low Level in two SGs	Same as low level for one SG, except that the 2/3 or 2/4 logic exists for two SGs.
Safety Injection	AFW start signal from any Safety Injection signal
Other	Includes various other sources of automatic pump starting.

AFW start signals are based upon detection of conditions that, at least in most cases, indicate extant or imminent degradation of the ability of the SGs to remove heat from the Reactor Coolant System.

Both B&W and Westinghouse plants use the loss of normal feedwater as a common start source, particularly for motor driven pumps. It should be noted that this is a non-safety related start signal, owing to the fact that the normal feedwater pumps and associated instrumentation are not safety related. AFW pump starting from loss of normal feedwater

is an anticipatory start in recognition of the fact that loss of feedwater would rapidly lead to other automatic starting, such as from low SG level.

Starting of AFW pumps due to emergency bus or RCP bus loss or RCP tripping is the single most common source of pump starting, considering both motor and turbine driven pumps. Since emergency bus undervoltage start signals necessitate that the bus providing power to the motor driven pumps be reenergized prior to breaker closure, the motor driven pumps are normally sequenced on, along with other safety related loads, in conjunction with and following emergency diesel generator starting. Since turbine driven pumps are typically started by opening valves that are not dependent upon AC power (other than vital AC busses powered off of the station batteries through inverters), they are started independently of emergency bus reenergization.

Steam generator low level starting of AFW pumps is a safety related start signal that is relied upon for both motor and turbine driven pump starting. Turbine driven pump starting normally requires low level in two SGs, while motor driven pumps typically only require low level in one SG.

Depending upon individual plant design, safety injection signals originate from several different sources, such as low Reactor Coolant System (RCS) pressure, low Pressurizer level, and high Containment pressure. Signals such as these could originate, in turn, from multiple causes, such as excessive cooldown/depressurization of the RCS due to excessive steam flow, SG tube rupture in which the loss of RCS inventory exceeds makeup capacity, or a loss of coolant accident.

Table 5E lists the numbers of, and types of valve operators in the AFW System at B&W and Westinghouse plants. Some valves with power operators, as well as the AFW pumps, have automatic actions to perform in conjunction with AFW System starting. All turbine driven pumps depend upon at one or more steam supply valves, or the turbine's trip and throttle valve, to open to start the turbine. Depending upon individual plant design, discharge valves (including those in the recirculation or other alternative flow paths) may be required to automatically open, control pressure or flow, or close on automatic AFW System actuation. Discharge valves may also be required, for certain conditions at some plants, such as on detection of a faulted SG, to isolate flow. Pump suction valves at some plants are required to automatically reposition on detection of low suction pressure in order to ensure the availability of a source of water for the pumps.

As can be seen from Table 5E, the total numbers of air operated valves (AOVs) and motor operated valves (MOVs) in both steam supply and pump discharge piping applications are almost equal at Westinghouse plants, while the B&W plants incorporate more motor operated valves than air operated valves. It should be noted that neither trip and throttle valves (normally DC motor operated) nor governor valves (normally with hydraulic actuators) are included in this list. There are a few solenoid operated valves (SOVs) and electrohydraulic operated valves (EH(OV)s) in both types of applications. Pump suction valves with power operators are predominantly motor operated.

It should be noted that not all valves with power operators have automatic functions, but rather may depend upon remote operator action. On the other hand, some valves, such as pump discharge pressure control valves, may have an automatic control function, with no provision for remote operator control.

Table 5F provides a breakdown of the operator types and normal standby positions for discharge flow control valves and discharge isolation valves. Note that some plants do not have power operated isolation valves other than the flow control valves.

Table 5G includes a designation of the type of minimum flow restriction device used and identification of the availability of a full ("full flow" meaning design flow) test loop. Determination of both characteristics was made based upon FSAR flow diagrams. It should be noted that some plants for which a full flow test loop is available may not use the full flow test loop for routine pump testing. Furthermore, some plants without full flow test loops may run their AFW pumps at full flow periodically (typically at each cold shutdown) in conjunction with their Pump and Valve Inservice Test program.

The minimum flow restriction devices are normally orifices and/or control valves. At some plants, the control valves in the minimum flow lines automatically isolate or open based on control signals, while at others, the valves are set at fixed positions.

Table 5H identifies the required inventory of condensate supply and the type of switchover to the alternate suction source that is provided. Where automatic switchover is provided, the means of initiation is normally by low pump suction pressure switches.

Table 5.A. GENERAL AFW CONFIGURATIONS

UNIT	NUMBER SGS	NUMBER MDP	NUMBER SG'S / MDP	NUMBER TDP	NUMBER SG'S / TDP	NUMBER DDP	NUMBER SG'S / DDP
ANO 1	2	1	2	1	2	0	N/A
CRYSTAL RIVER	2	1	2	1	2	0	N/A
DAVIS-BESSE	2	0	N/A	2	2	0	N/A
OCONEE 1	2	2	1**	1	2	0	N/A
OCONEE 2	2	2	1**	1	2	0	N/A
OCONEE 3	2	2	1**	1	2	0	N/A
RANCHO SECO	2	1	2	1	2	0	N/A
THREE MILE ISLAND 1	2	2	2	1	2	0	N/A
BEAVER VALLEY 1	3	2	3	1	3	0	N/A
BEAVER VALLEY 2	3	2	3	1	3	0	N/A
BRAIDWOOD 1	4	1	4	0	N/A	1	4
BRAIDWOOD 2	4	1	4	0	N/A	1	4
BYRON 1	4	1	4	0	N/A	1	4
BYRON 2	4	1	4	0	N/A	1	4
CALLAWAY	4	2	2**	1	4	0	N/A
CATAWBA 1	4	2	2**	1	4	0	N/A
CATAWBA 2	4	2	2**	1	4	0	N/A
COMANCHE PEAK 1	4	2	2**	1	4	0	N/A
COMANCHE PEAK 2	4	2	2**	1	4	0	N/A
DC COOK 1	4	2	2	1	4	0	N/A
DC COOK 2	4	2	2	1	4	0	N/A
DIABLO CANYON 1	4	2	2**	1	4	0	N/A
DIABLO CANYON 2	4	2	2**	1	4	0	N/A
FARLEY 1	3	2	3	1	3	0	N/A
FARLEY 2	3	2	3	1	3	0	N/A
GINNA	2	2	2	1	2	0	N/A
HADDAM NECK	4	0	N/A	2	4	0	N/A
HARRIS 1	3	2	3	1	3	0	N/A
INDIAN POINT 2	4	2	2	1	4	0	N/A
INDIAN POINT 3	4	2	2	1	4	0	N/A
KEWAUNEE	2	2	2	1	2	0	N/A
MCGUIRE 1	4	2	2**	1	4	0	N/A
MCGUIRE 2	4	2	2**	1	4	0	N/A

Table 5.A. GENERAL AFW CONFIGURATIONS

UNIT	NUMBER SGS	NUMBER MDP	NUMBER SG'S / MDP	NUMBER TDP	NUMBER SG'S / TDP	NUMBER DDP	NUMBER SG'S / DDP
MILLSTONE 3	4	2	2**	1	4	0	N/A
NORTH ANNA 1	3	2	3	1	3	0	N/A
NORTH ANNA 2	3	2	3	1	3	0	N/A
POINT BEACH 1 *	2	2	1	1	2	0	N/A
POINT BEACH 2 *	2	2	1	1	2	0	N/A
PRARIE ISLAND 1 *	2	1	2	1	2	0	N/A
PRARIE ISLAND 2 *	2	1	2	1	2	0	N/A
ROBINSON 2	3	2	3	1	3	0	N/A
SALEM 1	4	2	4	1	4	0	N/A
SALEM 2	4	2	4	1	4	0	N/A
SAN ONOFRE 1	3	1	3	1	3	0	N/A
SEABROOK 1	4	1	4	1	4	0	N/A
SEQUOYAH 1	4	2	2	1	4	0	N/A
SEQUOYAH 2	4	2	2	1	4	0	N/A
SOUTH TEXAS 1	4	3	1**	1	1**	0	N/A
SOUTH TEXAS 2	4	3	1**	1	1**	0	N/A
SUMMER	3	2	3	1	3	0	N/A
SURRY 1	3	2	3	1	3	0	N/A
SURRY 2	3	2	3	1	3	0	N/A
TROJAN	4	0	N/A	1	4	1	4
TURKEY POINT 3 *	3	0	N/A	3	3	0	N/A
TURKEY POINT 4 *	3	0	N/A	3	3	0	N/A
VOGTLE 1	4	2	2**	1	4	0	N/A
VOGTLE 2	4	2	2**	1	4	0	N/A
WOLF CREEK	4	2	2**	1	4	0	N/A
YANKEE ROWE	4	2	4	1	4	0	N/A
ZION 1	4	2	4	1	4	0	N/A
ZION 2	4	2	4	1	4	0	N/A

* UNITS SHARE ONE OR MORE AFW PUMPS.

TOTAL OF 2 MOTOR, 2 TURBINE DRIVEN PUMPS AT BOTH POINT BEACH AND PRARIE ISLAND PLANTS

TOTAL OF 3 TURBINE DRIVEN PUMPS AT TURKEY POINT PLANT

**NORMAL ALIGNMENT. PUMP DISCHARGE LINES CAN BE REALIGNED TO FEED ALL SG'S

Table 5.B. B&W AND WESTINGHOUSE PLANT THERMAL AND PUMP DESIGN RATINGS

UNIT	MWTH RATING	MDP GPM (DESIGN)	MDP DESIGN TDH, PSID	TDP GPM (DESIGN)	TDP DESIGN TDH, PSID	DDP GPM (DESIGN)	DDP DESIGN TDH, PSID
ANO 1	2568	640	1224	770	1223	N/A	N/A
CRYSTAL RIVER	2542	740	1300	740	1300	N/A	N/A
DAVIS-BESSE	2772	N/A	N/A	1050	1050	N/A	N/A
OCONEE 1	2568					N/A	N/A
OCONEE 2	2568					N/A	N/A
OCONEE 3	2568					N/A	N/A
RANCHO SECO	2772	840	1150 *	840	1150 *	N/A	N/A
THREE MILE ISLAND1	2568	460	1170	920	1170	N/A	N/A
BEAVER VALLEY 1	2660	350	1168	700	1168	N/A	N/A
BEAVER VALLEY 2	2652	375	1196	750	1196	N/A	N/A
BRAIDWOOD 1	3411	990	1452	N/A	NA	990	1452
BRAIDWOOD 2	3411	990	1452	N/A	NA	990	1452
BYRON 1	3411	990	1452	N/A	NA	990	1452
BYRON 2	3411	990	1452	N/A	NA	990	1452
CALLAWAY	3425	575	1387	1145	1495	N/A	N/A
CATAWBA 1	3411	500	1391	1000	1394	N/A	N/A
CATAWBA 2	3411	500	1391	1000	1394	N/A	N/A
COMANCHE PEAK 1	3425	490	1430	985	1452	N/A	N/A
COMANCHE PEAK 2	3425	490	1430	985	1452	N/A	N/A
DC COOK 1	3250	450	1176	900	1176	N/A	N/A
DC COOK 2	3250	450	1176	900	1176	N/A	N/A
DIABLO CANYON 1	3338	490	1300	930	1300	N/A	N/A
DIABLO CANYON 2	3411	490	1300	930	1300	N/A	N/A
FARLEY 1	2652	350	1233	700	1229	N/A	N/A
FARLEY 2	2652	350	1233	700	1229	N/A	N/A
GINNA	1520	200	1235	400	1300	N/A	N/A
HADDAM NECK	1825	N/A	N/A	450	1075	N/A	N/A
HARRIS 1	2775	450	1265	900	1265	N/A	N/A
INDIAN POINT 2	2758	400	1352	940	1352	N/A	N/A
INDIAN POINT 3	3025	400	1352	940	1352	N/A	N/A
KEWAUNEE	1650	240	1235	240	1235	N/A	N/A
MCGUIRE 1	3411	450	1387	900	1387	N/A	N/A

Table 5.B. B&W AND WESTINGHOUSE PLANT THERMAL AND PUMP DESIGN RATINGS

UNIT	MWTH RATING	MDP GPM (DESIGN)	MDP DESIGN TDH, PSID	TDP GPM (DESIGN)	TDP DESIGN TDH, PSID	DDP GPM (DESIGN)	DDP DESIGN TDH, PSID
MCGUIRE 2	3411	450	1387	900	1387	N/A	N/A
MILLSTONE 3	3411	575	1289	1150	1289	N/A	N/A
NORTH ANNA 1	2775	340	1250	340	1430	N/A	N/A
NORTH ANNA 2	2775	340	1250	340	1430	N/A	N/A
POINT BEACH 1	1518	200		400		N/A	N/A
POINT BEACH 2	1518	200		400		N/A	N/A
PRARIE ISLAND 1	1721	220	1285	220	1285	N/A	N/A
PRARIE ISLAND 2	1721	220	1285	220	1285	N/A	N/A
ROBINSON 2	2300	300	1300	600	1300	N/A	N/A
SALEM 1	3338	440	1300	980	1550	N/A	N/A
SALEM 2	3411	440	1300	980	1550	N/A	N/A
SAN ONOFRE 1	1347	235	1035	300	1088	N/A	N/A
SEABROOK 1	3411	710	1320	710	1320	N/A	N/A
SEQUOYAH 1	3411	440	1257	880	1127	N/A	N/A
SEQUOYAH 2	3411	440	1257	880	1127	N/A	N/A
SOUTH TEXAS 1	3800					N/A	N/A
SOUTH TEXAS 2	3800					N/A	N/A
SUMMER	2775	400	1430	900	1473	N/A	N/A
SURRY 1	2546	350	1183	700	1183	N/A	N/A
SURRY 2	2546	350	1183	700	1183	N/A	N/A
TROJAN	3423	N/A	N/A	960	1473	960	1473
TURKEY POINT 3	2200	N/A	N/A	600	1203	N/A	N/A
TURKEY POINT 4	2200	N/A	N/A	600	1203	N/A	N/A
VOGTLE 1	3425	630	1517	1175	1517	N/A	N/A
VOGTLE 2	3425	630	1517	1175	1517	N/A	N/A
WOLF CREEK	3411	575	1387	1145	1495	N/A	N/A
YANKEE RGWE	600					N/A	N/A
ZION 1	3391	495	1343	990	1343	N/A	N/A
ZION 2	3391	495	1343	990	1343	N/A	N/A

*VALUE CITED IS DESIGN DISCHARGE PRESSURE, NOT TOTAL DEVELOPED HEAD

**Table 5.C. MOTOR DRIVEN PUMP
AFW ACTUATION SIGNALS FOR WESTINGHOUSE AND B&W PLANTS**

UNIT	LOSS OF FW	LOSS OF EMERGENCY OR RCP BUS	LOW LEVEL ONE SG	LOW LEVEL TWO SG'S	SAFETY INJECTION	OTHER
B&W PLANTS						
ANO-1	YES	YES	YES	NO	YES	YES
CRYSTAL RIVER	YES	YES	YES	NO	YES	YES
DAVIS-BESSE	N/A	N/A	N/A	N/A	N/A	N/A
OCONEE 1	YES	NO	NO	NO	NO	YES
OCONEE 2	YES	NO	NO	NO	NO	YES
OCONEE 3	YES	NO	NO	NO	NO	YES
RANCHO SECO	YES	YES	NO	NO	YES	NO
TMI-1	YES	YES	NO	NO	NO	NO
B&W TOTAL	7	4	2	0	3	5
WESTINGHOUSE PLANTS						
BEAVER VALLEY 1	YES	YES	NO	YES	YES	YES
BEAVER VALLEY 2	YES	YES	NO	YES	YES	YES
BRAIDWOOD 1	NO	YES	YES	NO	YES	NO
BRAIDWOOD 2	NO	YES	YES	NO	YES	NO
BYRON 1	NO	YES	YES	NO	YES	NO
BYRON 2	NO	YES	YES	NO	YES	NO
CALLAWAY	YES	YES	YES	NO	YES	NO
CATAWBA 1	YES	YES	YES	NO	YES	NO
CATAWBA 2	YES	YES	YES	NO	YES	NO
COMANCHE PEAK 1	YES	YES	YES	NO	YES	NO
COMANCHE PEAK 2	YES	YES	YES	NO	YES	NO
DC COOK 1	YES	YES	YES	NO	YES	NO
DC COOK 2	YES	YES	YES	NO	YES	NO
DIABLO CANYON 1	YES	YES	YES	NO	YES	NO
DIABLO CANYON 2	YES	YES	YES	NO	YES	NO
FARLEY 1	YES	YES	YES	NO	YES	NO
FARLEY 2	YES	YES	YES	NO	YES	NO
GINNA	YES	YES	YES	NO	YES	NO
HADDAM NECK	N/A	N/A	N/A	N/A	N/A	N/A
HARRIS 1	YES	YES	YES	NO	YES	NO
INDIAN POINT 2	YES	YES	YES	NO	YES	NO
INDIAN POINT 3	YES	YES	YES	NO	YES	NO

**Table 5.C. MOTOR DRIVEN PUMP
AFW ACTUATION SIGNALS FOR WESTINGHOUSE AND B&W PLANTS**

UNIT	LOSS OF FW	LOSS OF EMERGENCY OR RCP BUS	LOW LEVEL ONE SG	LOW LEVEL TWO SG'S	SAFETY INJECTION	OTHER
WESTINGHOUSE PLANTS (CONTINUED)						
KEWAUNEE	YES	YES	YES	NO	YES	NO
MCGUIRE 1	YES	YES	YES	NO	YES	NO
MCGUIRE 2	YES	YES	YES	NO	YES	NO
MILLSTONE 3	NO	YES	YES	NO	YES	YES
NORTH ANNA 1	YES	YES	YES	NO	YES	NO
NORTH ANNA 2	YES	YES	YES	NO	YES	NO
POINT BEACH 1	YES	NO	YES	NO	YES	NO
POINT BEACH 2	YES	NO	YES	NO	YES	NO
PRARIE ISLAND 1	YES	YES	YES	NO	YES	NO
PRARIE ISLAND 2	YES	YES	YES	NO	YES	NO
ROBINSON 2	YES	YES	YES	NO	YES	NO
SALEM 1	YES	YES	YES	NO	YES	NO
SALEM 2	YES	YES	YES	NO	YES	NO
SAN ONOFRE 1	NO	NO	NO	YES	NO	NO
SEABROOK 1	NO	YES	YES	NO	YES	NO
SEQUOYAH 1	YES	YES	YES	NO	YES	NO
SEQUOYAH 2	YES	YES	YES	NO	YES	NO
SOUTH TEXAS 1	NO	YES	YES	NO	YES	NO
SOUTH TEXAS 2	NO	YES	YES	NO	YES	NO
SUMMER	YES	YES	YES	NO	YES	NO
SURRY 1	YES	YES	YES	NO	YES	NO
SURRY 2	YES	YES	YES	NO	YES	NO
TROJAN	N/A	N/A	N/A	N/A	N/A	N/A
TURKEY POINT 3	N/A	N/A	N/A	N/A	N/A	N/A
TURKEY POINT 4	N/A	N/A	N/A	N/A	N/A	N/A
VOGTLE 1	YES	YES	YES	NO	YES	NO
VOGTLE 2	YES	YES	YES	NO	YES	NO
WOLF CREEK	YES	YES	YES	NO	YES	NO
YANKEE ROWE	NO	NO	NO	NO	NO	NO
ZION 1	NO	YES	YES	NO	YES	NO
ZION 2	NO	YES	YES	NO	YES	NO
WESTINGHOUSE TOTAL	37	45	45	3	47	3

**Table 5.D. TURBINE DRIVEN PUMP
AFW ACTUATION SIGNALS FOR WESTINGHOUSE AND B&W PLANTS**

UNIT	LOSS OF FW	LOSS OF EMERGENCY OR RCP BUS	LOW LEVEL ONE SG	LOW LEVEL TWO SG'S	SAFETY INJECTION	OTHER
B&W PLANTS						
ANO 1	YES	YES	YES	NO	YES	YES
CRYSTAL RIVER	YES	YES	YES	NO	YES	YES
DAVIS-BESSE	YES	YES	YES	NO	NO	YES
OCONEE 1	YES	NO	NO	NO	NO	YES
OCONEE 2	YES	NO	NO	NO	NO	YES
OCONEE 3	YES	NO	NO	NO	NO	YES
RANCHO SECO	YES	YES	NO	NO	YES	NO
THREE MILE ISLAND	YES	YES	NO	NO	NO	NO
B&W TOTAL	9	7	6	4	8	12
WESTINGHOUSE PLANTS						
BEAVER VALLEY 1	NO	YES	YES	NO	NO	NO
BEAVER VALLEY 2	NO	YES	YES	NO	NO	NO
BRAIDWOOD 1	NO	NO	NO	NO	NO	NO
BRAIDWOOD 2	NO	NO	NO	NO	NO	NO
BYRON 1	NO	NO	NO	NO	NO	NO
BYRON 2	NO	NO	NO	NO	NO	NO
CALLAWAY	NO	YES	NO	YES	NO	NO
CATAWBA 1	NO	YES	NO	YES	NO	NO
CATAWBA 2	NO	YES	NO	YES	NO	NO
COMANCHE PEAK 1	NO	YES	NO	YES	NO	NO
COMANCHE PEAK 2	NO	YES	NO	YES	NO	NO
DC COOK 1	NO	YES	YES	NO	NO	NO
DC COOK 2	NO	YES	YES	NO	NO	NO
DIABLO CANYON 1	NO	YES	NO	YES	NO	NO
DIABLO CANYON 2	NO	YES	NO	YES	NO	NO
FARLEY 1	NO	YES	NO	YES	NO	NO
FARLEY 2	NO	YES	NO	YES	NO	NO
GINNA	NO	YES	NO	YES	NO	NO
HADDAM NECK	YES	NO	YES	NO	NO	NO
HARRIS 1	NO	YES	NO	YES	NO	NO
INDIAN POINT 2	NO	YES	NO	YES	NO	NO
INDIAN POINT 3	NO	YES	NO	YES	NO	NO

**Table 5.D. TURBINE DRIVEN PUMP
AFW ACTUATION SIGNALS FOR WESTINGHOUSE AND B&W PLANTS**

UNIT	LOSS OF FW	LOSS OF EMERGENCY OR RCP BUS	LOW LEVEL ONE SG	LOW LEVEL TWO SG'S	SAFETY INJECTION	OTHER
WESTINGHOUSE PLANTS (CONTINUED)						
KEWAUNEE	NO	YES	NO	YES	NO	NO
MCGUIRE 1	NO	YES	NO	YES	NO	NO
MCGUIRE 2	NO	YES	NO	YES	NO	NO
MILLSTONE 3	NO	YES	NO	YES	NO	NO
NORTH ANNA 1	YES	YES	YES	NO	YES	NO
NORTH ANNA 2	YES	YES	YES	NO	YES	NO
POINT BEACH 1	NO	YES	NO	YES	NO	NO
POINT BEACH 2	NO	YES	NO	YES	NO	NO
PRARIE ISLAND 1	YES	YES	YES	NO	YES	NO
PRARIE ISLAND 2	YES	YES	YES	NO	YES	NO
ROBINSON 2	NO	YES	NO	YES	NO	NO
SALEM 1	NO	YES	NO	YES	NO	NO
SALEM 2	NO	YES	NO	YES	NO	NO
SAN ONOFRE 1	NO	YES	NO	YES	NO	NO
SEABROOK 1	NO	YES	YES	NO	YES	NO
SEQUOYAH 1	YES	YES	NO	YES	YES	NO
SEQUOYAH 2	YES	YES	NO	YES	YES	NO
SOUTH TEXAS 1	NO	NO	YES	NO	YES	NO
SOUTH TEXAS 2	NO	NO	YES	NO	YES	NO
SUMMER	NO	YES	NO	YES	NO	NO
SURRY 1	NO	YES	NO	YES	NO	NO
SURRY 2	NO	YES	NO	YES	NO	NO
TROJAN	YES	YES	YES	NO	YES	NO
TURKEY POINT 3	YES	YES	YES	NO	YES	NO
TURKEY POINT 4	YES	YES	YES	NO	YES	NO
VOGTLE 1	NO	YES	NO	YES	NO	NO
VOGTLE 2	NO	YES	NO	YES	NO	NO
WOLF CREEK	NO	YES	NO	YES	NO	NO
YANKEE ROWE						
ZION 1	NO	YES	NO	YES	YES	NO
ZION 2	NO	YES	NO	YES	YES	NO
WESTINGHOUSE TOTAL	18	50	18	33	17	6

Table 5.E. NUMBERS OF B&W AND WESTINGHOUSE PLANT VALVE OPERATOR TYPES

UNIT	DISCHARGE VALVES				SUCTION VALVES		STEAM SUPPLY VALVES			
	AOV	MOV	SOV	EHOV	AOV	MOV	AOV	MOV	SOV	EHOV
ANO 1	1	6	4	0	0	6	0	5	2	0
CRYSTAL RIVER	0	4	4	0	0	4	0	4	0	0
DAVIS-BESSE	0	8	0	0	0	2	0	4	0	0
OCONEE 1	4	7	0	0	0	2	2	2	0	0
OCONEE 2	4	7	0	0	0	2	2	2	0	0
OCONEE 3	4	7	0	0	0	2	2	2	0	0
RANCHO SECO	3	6	2	0	0	0	0	3	0	0
TMI 1	5	2	0	0	0	2	3	4	0	0
B&W TOTAL	21	47	10	0	0	20	9	26	2	0
BEAVER VALLEY 1	3	9	0	0	0	0	2	1	0	0
BEAVER VALLEY 2	0	0	0	6	0	0	0	0	6	0
BRAIDWOOD 1	10	8	0	0	0	4	0	0	0	0
BRAIDWOOD 2	10	8	0	0	0	4	0	0	0	0
BYRON 1	10	8	0	0	0	4	0	0	0	0
BYRON 2	10	8	0	0	0	4	0	0	0	0
CALLAWAY	4	4	0	0	0	7	2	0	0	0
CATAWBA 1	6	8	0	0	0	7	2	0	0	0
CATAWBA 2	6	8	0	0	0	7	2	0	0	0
COMANCHE PEAK 1	10	8	0	0	0	2	2	0	4	0
COMANCHE PEAK 2	10	8	0	0	0	2	2	0	4	0
D.C. COOK 1	7	8	0	0	0	3	0	2	0	0
D.C. COOK 2	7	8	0	0	0	3	0	2	0	0
DIABLO CANYON 1	0	4	0	4	0	2	0	2	0	0
DIABLO CANYON 2	0	4	0	4	0	2	0	2	0	0
FARLEY 1	6	9	0	0	0	5	5	0	0	0
FARLEY 2	6	9	0	0	0	5	5	0	0	0
GINNA	7	5	0	0	1	3	0	2	0	0
HADDAM NECK	4	1	0	0	0	0	2	0	0	0
HARKIS 1	0	8	0	8	0	8	0	2	0	0
INDIAN POINT 2	10	0	0	0	4	0	3	0	0	0
INDIAN POINT 3	10	0	0	0	4	0	3	0	0	0
KEWAUNEE	2	2	0	0	0	0	0	2	0	0
McGUIRE 1	11	8	0	0	0	8	2	0	0	0

Table 5.E. NUMBERS OF B&W AND WESTINGHOUSE PLANT VALVE OPERATOR TYPES

UNIT	DISCHARGE VALVES				SUCTION VALVES		STEAM SUPPLY VALVES			
	AOV	MOV	SOV	EHOV	AOV	MOV	AOV	MOV	SOV	EHOV
McGUIRE 2	11	8	0	0	0	8	2	0	0	0
MILLSTONE 3	2	4	12	0	2	0	3	3	0	0
NORTH ANNA 1	5	4	0	0	0	0	2	0	0	0
NORTH ANNA 2	5	4	0	0	0	0	2	0	0	0
POINT BEACH 1	3	4	0	0	0	0	0	2	0	0
POINT BEACH 2	3	4	0	0	0	0	0	2	0	0
PRAIRE ISLAND 1	0	6	0	0	0	4	1	2	0	0
PRAIRE ISLAND 2	0	6	0	0	0	4	1	2	0	0
ROBINSON 2	0	8	0	3	0	0	0	3	0	0
SALEM 1	10	0	0	0	3	0	1	0	0	0
SALEM 2	10	0	0	0	3	0	1	0	0	0
SAN ONOFRE 1	4	2	0	0	0	0	2	0	0	0
SEABROOK 1	4	0	0	0	0	0	0	0	0	2
SEQUOYAH 1	8	0	0	0	0	8	0	4	0	0
SEQUOYAH 2	8	0	0	0	0	8	0	4	0	0
SOUTH TEXAS 1	4	8	0	0	0	0	0	1	1	0
SOUTH TEXAS 2	4	8	0	0	0	0	0	1	1	0
SUMMER	9	0	0	0	0	6	1	2	0	0
SURRY 1	0	6	0	0	0	0	2	0	0	0
SURRY 2	0	6	0	0	0	0	2	0	0	0
TROJAN	0	8	0	0	0	2	4	1	0	0
TURKEY POINT 3	6	0	0	0	0	0	0	3	0	0
TURKEY POINT 4	6	0	0	0	0	0	0	3	0	0
VOGTLE 1	0	10	0	0	0	3	0	3	0	0
VOGTLE 2	0	10	0	0	0	3	0	3	0	0
WOLF CREEK	4	4	0	0	0	3	2	0	0	0
YANKEE ROWE	4	3	0	0	0	0	1	0	0	0
ZION 1	8	8	0	0	0	5	0	2	0	0
ZION 2	8	8	0	0	0	5	0	2	0	0
WESTINGHOUSE	275	272	12	25	17	139	59	58	16	2
TOTAL										

Table 5.F. FLOW CONTROL AND ISOLATION VALVE TYPES, NORMAL POSITIONS

UNIT	FCV OPERATOR TYPE	FCV NORMAL POSITION	OTHER ISOLATION VALVE OPERATOR TYPE	ISOLATION VALVE NORMAL POSITION
ANO 1	SOV	NO	MOV	NO
CRYSTAL RIVER	MOV	NO	SOV	NO
DAVIS-BESSE	MOV	NO	MOV	NO/NC
OCONEE 1	AOV	NC	MOV	NO
OCONEE 2	AOV	NC	MOV	NO
OCONEE 3	AOV	NC	MOV	NO
RANCHO SECO	AOV/SOV	NO	MOV	NC
THREE MILE ISLAND 1	AOV	NO	MOV	NO
BEAVER VALLEY 1	MOV	NO	MOV	NO
BEAVER VALLEY 2	EHOV	NO	N/A	N/A
BRAIDWOOD 1	AOV	NO	MOV	NO
BRAIDWOOD 2	AOV	NO	MOV	NO
BYRON 1	AOV	NO	MOV	NO
BYRON 2	AOV	NO	MOV	NO
CALLAWAY	MOV/AOV	NO	N/A	N/A
CATAWBA 1	AOV	NO	MOV	NO/NC
CATAWBA 2	AOV	NO	MOV	NO/NC
COMANCHE PEAK 1	AOV	NO	MOV	NO
COMANCHE PEAK 2	AOV	NO	MOV	NO
DC COOK 1	MOV	NO	N/A	N/A
DC COOK 2	MOV	NO	N/A	N/A
DIABLO CANYON 1	EHOV/MOV	NO/NC	N/A	N/A
DIABLO CANYON 2	EHOV/MOV	NO/NC	N/A	N/A
FARLEY 1	AOV	NC	MOV	NO
FARLEY 2	AOV	NC	MOV	NO
GINNA	MOV/AOV	NO/NC	N/A	N/A
HADDAM NECK	AOV	NC	N/A	N/A
HARRIS 1	EHOV	NO	MOV	NG
INDIAN POINT 2	AOV	NO	N/A	N/A
INDIAN POINT 3	AOV	NO	N/A	N/A
KEWAUNEE	AOV/MOV	NO	N/A	N/A
MCGUIRE 1	AOV	NO	MOV	NO
MCGUIRE 2	AOV	NO	MOV	NO
MILLSTONE 3	SOV	NO	SOV/MOV	NO
NORTH ANNA 1	AOV/MOV	NO	N/A	N/A
NORTH ANNA 2	AOV/MOV	NO	N/A	N/A

Table 5.F. FLOW CONTROL AND ISOLATION VALVE TYPES, NORMAL POSITIONS

UNIT	FCV OPERATOR TYPE	FCV NORMAL POSITION	OTHER ISOLATION VALVE OPERATOR TYPE	ISOLATION VALVE NORMAL POSITION
(CONTINUED)				
POINT BEACH 1	MOV	NO	N/A	N/A
POINT BEACH 2	MOV	NO	N/A	N/A
PRARIE ISLAND 1	MOV	NO	MOV	NO
PRARIE ISLAND 2	MOV	NO	MOV	NO
ROBINSON 2	EHOV	NC	MOV	NC
SALEM 1	AOV	NO	N/A	N/A
SALEM 2	AOV	NO	N/A	N/A
SAN ONOFRE 1	AOV	NO	N/A	N/A
SEABROOK 1	AOV	NO	N/A	N/A
SEQUOYAH 1	AOV	NC	N/A	N/A
SEQUOYAH 2	AOV	NC	N/A	N/A
SOUTH TEXAS 1	MOV	NO	MOV	NC
SOUTH TEXAS 2	MOV	NO	MOV	NC
SUMMER	AOV	NO	AOV	NO
SURRY 1	MOV	NO	N/A	N/A
SURRY 2	MOV	NO	N/A	N/A
TROJAN	MOV	NO	N/A	N/A
TURKEY POINT 3	AOV	NC	N/A	N/A
TURKEY POINT 4	AOV	NC	N/A	N/A
VOGTLE 1	MOV	NO	N/A	N/A
VOGTLE 2	MOV	NO	N/A	N/A
WOLF CREEK	AOV/MOV	NO	N/A	N/A
YANKEE ROWE	MOV	NO	N/A	N/A
ZION 1	AOV	NO	MOV	NO
ZION 2	AOV	NO	MOV	NO

FCV-FLOW CONTROL VALVE
 AOV-AIR OPERATED VALVE
 EHOV-ELECTROHYDRAULIC OPERATED VALVE
 MOV-MOTOR OPERATED VALVE
 SOV-SOLENOID OPERATED VALVE
 NO-NORMALLY OPEN
 NC-NORMALLY CLOSED

Table 5.G. TEST LOOP AND RECIRCULATION CONTROL TYPES

<u>UNIT</u>	<u>FULL FLOW TEST LOOP AVAILABLE?</u>	<u>MINIFLOW FLOW RESTRICTION TYPE</u>
ANO 1	YES	ORIFICE
CRYSTAL RIVER	NO	LINE SIZE
DAVIS-BESSE	YES	ORIFICE
OCONEE 1	TDP ONLY	ORIFICE/CV
OCONEE 2	TDP ONLY	ORIFICE/CV
OCONEE 3	TDP ONLY	ORIFICE/CV
RANCHO SECO	YES	ORIFICE
THREE MILE ISLAND 1	NO	ORIFICE/LINE SIZE
BEAVER VALLEY 1	PARTIAL	ORIFICE/CV
BEAVER VALLEY 2	NO	ORIFICE
BRAIDWOOD 1	NO	ORIFICE
BRAIDWOOD 2	NO	ORIFICE
BYRON 1	NO	ORIFICE
BYRON 2	NO	ORIFICE
CALLAWAY	NG	ORIFICE
CATAWBA 1	YES	CV
CATAWBA 2	YES	CV
COMANCHE PEAK 1	YES	ORIFICE
COMANCHE PEAK 2	YES	ORIFICE
DC COOK 1	YES	CV
DC COOK 2	YES	CV
DIABLO CANYON 1	NO	ORIFICE
DIABLO CANYON 2	NO	ORIFICE
FARLEY 1	YES	ORIFICE/CV
FARLEY 2	YES	ORIFICE/CV
GINNA	NO	ORIFICE/CV
HADDAM NECK	NO	ORIFICES
HARRIS 1	NO	ORIFICE/CV
INDIAN POINT 2	YES	ORIFICE/CV
INDIAN POINT 3	YES	ORIFICE/CV
KEWAUNEE	NO	
MCGUIRE 1	YES	CV
MCGUIRE 2	YES	CV

Table 5.G. TEST LOOP AND RECIRCULATION CONTROL TYPES

<u>UNIT</u>	<u>FULL FLOW TEST LOOP AVAILABLE?</u>	<u>MINIFLOW FLOW RESTRICTION TYPE</u>
MILLSTONE 3	NO	ORIFICE
NORTH ANNA 1	NO	ORIFICE
NORTH ANNA 2	NO	ORIFICE
POINT BEACH 1	NO	ORIFICE/CV
POINT BEACH 2	NO	ORIFICE/CV
PRARIE ISLAND 1	NO	ORIFICE
PRARIE ISLAND 2	NO	ORIFICE
ROBINSON 2	NO	ORIFICE
SALEM 1	NO	ORIFICE/CV
SALEM 2	NO	ORIFICE/CV
SAN ONOFRE 1	NO	ORIFICE
SEABROOK 1	NO	ORIFICE
SEQUOYAH 1	NO	ORIFICE
SEQUOYAH 2	NO	ORIFICE
SOUTH TEXAS 1	YES	CV
SOUTH TEXAS 2	YES	CV
SUMMER	NO	ORIFICE
SURRY 1	NO	ORIFICE
SURRY 2	NO	ORIFICE
TROJAN	NO	ORIFICE
TURKEY POINT 3	NO	ORIFICE
TURKEY POINT 4	NO	ORIFICE
VOGTLE 1	NO	ORIFICE/CV
VOGTLE 2	NO	ORIFICE/CV
WOLF CREEK	NO	ORIFICE
YANKEE ROWE		CV
ZION 1	NO	ORIFICE
ZION 2	NO	ORIFICE

Table 5.H. NORMAL SUCTION SUPPLY QUANTITY AND SUCTION SWITCHOVER METHOD

<u>UNIT</u>	<u>TECH SPEC REQUIRED SUPPLY, KGAL.</u>	<u>AUTO OR MANUAL SUCTION SWITCHOVER</u>
ANO 1	107	MANUAL
CRYSTAL RIVER	150	MANUAL
DAVIS-BESSE	250	AUTO
OCONEE 1	72	MANUAL
OCONEE 2	72	MANUAL
OCONEE 3	72	MANUAL
RANCHO SECO	250	MANUAL
THREE MILE ISLAND 1	150	MANUAL
BEAVER VALLEY 1	140*	MANUAL
BEAVER VALLEY 2	127	MANUAL
BRAIDWOOD 1	200	AUTO
BRAIDWOOD 2	200	AUTO
BYRON 1	200	AUTO
BYRON 2	200	AUTO
CALLAWAY	281	AUTO
CATAWBA 1	225	AUTO
CATAWBA 2	225	AUTO
COMANCHE PEAK 1	276*	MANUAL
COMANCHE PEAK 2	276*	MANUAL
DC COOK 1		MANUAL
DC COOK 2		MANUAL
DIABLO CANYON 1	178	MANUAL
DIABLO CANYON 2	178	MANUAL
FARLEY 1	150	MANUAL
FARLEY 2	150	MANUAL
GINNA	22.5	MANUAL
HADDAM NECK	130	MANUAL
HARRIS 1	240	MANUAL
INDIAN POINT 2	360	MANUAL
INDIAN POINT 3	350	MANUAL
KEWAUNEE	30	MANUAL
MCGUIRE 1	297.5 MAX *	AUTO
MCGUIRE 2	297.5 MAX *	AUTO

Table 5.H. NORMAL SUCTION SUPPLY QUANTITY AND SUCTION SWITCHOVER METHOD

<u>UNIT</u>	<u>TECH SPEC REQUIRED SUPPLY, KGAL.</u>	<u>AUTO OR MANUAL SUCTION SWITCHOVER</u>
MILLSTONE 3	334	MANUAL
NORTH ANNA 1	110	MANUAL
NORTH ANNA 2	110	MANUAL
POINT BEACH 1	90	MANUAL
POINT BEACH 2	90	MANUAL
PRARIE ISLAND 1	100	MANUAL
PRARIE ISLAND 2	100	MANUAL
ROBINSON 2	35	MANUAL
SALEM 1	200	MANUAL
SALEM 2	200	MANUAL
SAN ONOFRE 1	190	MANUAL
SEABROOK 1	212	MANUAL
SEQUOYAH 1	190	AUTO
SEQUOYAH 2	190	AUTO
SOUTH TEXAS 1	518	MANUAL
SOUTH TEXAS 2	518	MANUAL
SUMMER	173	AUTO
SURRY 1	96	MANUAL
SURRY 2	96	MANUAL
TROJAN	450*	MANUAL
TURKEY POINT 3	185	MANUAL
TURKEY POINT 4	185	MANUAL
VOGTLE 1	340	MANUAL
VOGTLE 2	340	MANUAL
WOLF CREEK	281	AUTO
YANKEE ROWE		
ZION 1	170	MANUAL
ZION 2	170	MANUAL

* VALUE CITED IS FROM UNIT FSAR

CHAPTER 6 RESULTS, CONCLUSIONS, AND RECOMMENDATIONS

The Phase I study of the AFW System consisted of three primary parts:

- a) A detailed review of the AFW System design and operating/monitoring practices of a Reference Plant owned by a cooperating utility was conducted.
- b) Operational failure events for AFW System components from three failure database sources were reviewed and analyzed.
- c) A summary review and tabulation of AFW System configurations and design information available from individual plant Final Safety Analysis Reports and Technical Specifications was completed.

The detailed results of these three parts are provided in Chapters 3, 4, and 5. The combined results of parts a and b above (part c was performed primarily for general information and to support the studies of parts a and b) provide the basis for the following observations and recommendations.

6.1 RELATIVE SIGNIFICANCE OF AFW COMPONENTS

In order to gain some perspective as to the more significant contributors to AFW System degradation, the historical failure data was heavily relied upon. While the failure data available has substantial limitations, even with the uniformity of characterization afforded by the ORNL compilation, it is useful as a rough indicator of relative trends.

6.1.1 RESULTS

The review of the failure data indicated that a few types of AFW System components were responsible for a large fraction of system degradation. Turbine drivers (which includes the turbine, its trip & throttle valve, governor valve, and associated control circuitry), valve air operators, and valve motor operators accounted for over one-half of the system degradation. Problems with the turbine drivers alone accounted for 27% of the system degradation. Valve air operators, motor operators, pumps, and check valves were responsible for 14%, 13%, 12%, and 9% of system degradation, respectively.

The AFW System degradation associated with turbine drivers is particularly noteworthy in that there is a total of population of only 51 turbine drivers at the plants in the failure database, compared to 77 motor drivers, 315 air operated valves, and 438 motor operated valves. Of the turbine failures, only a very small portion (less than 10%) involved failures or degradation of the turbine itself. The majority of the failures involved problems with turbine auxiliaries (primarily I&C/governor control and trip and throttle valve problems). On demand failures of turbines were responsible for almost one-fourth of all turbine related degradation, and for over one-third of all on demand failure degradation.

6.1.2 CONCLUSIONS

The turbine drive is the single component type that stands out in the failure data as the most significant source of AFW System degradation. It is also, by far, the single largest source of system degradation associated with on-demand failures. More specifically, problems associated with the governor and controls for turbine driven pumps have been significant sources of degradation.

The other significant AFW System component types, including pumps, check valves, and air and motor operators have been, or are being reviewed in detail as a part of the NPAR program. In light of the significance of the turbine to historical AFW System degradation, as well as the fact that the turbines used on AFW pumps are similar to those used on some safety related pumps in Boiling Water Reactor plants, further review of turbine drives in general, and more specifically the turbine controls, appears warranted.

6.2 ADEQUACY OF CURRENT MONITORING PRACTICES

In keeping with the goals of the NPAR program, one of the driving forces behind the reviews was an attempt to ascertain the adequacy of current monitoring practices. The extent to which failure sources could be detected by the surveillance and operating practices at an individual plant was determined as a part of the Reference Plant review. The extent to which actual failure events have been detected by programmatic monitoring practices, routine observation, and during demand events was ascertained during the review of historical failure data. The results from the combined reviews provide important insights into what types of failures have occurred, how those failures have been detected historically, and how well failures could be detected by existing monitoring methods.

In conjunction with the review of the Reference Plant procedures, the frequency of test related actuation of AFW System components was estimated. The reason that the numbers of test actuations was tabulated was to give an indication of a) the likelihood of degradation or failure of a component being identified, whether that particular component was being verified operable or not, and b) the extent of service wear that may be associated with testing.

The results available from the reviews of: a) reference Plant failure source detectability, b) historical failure records, and c) the frequency of test related actuation provide a combination of information that is useful for making a general assessment of monitoring requirements and implementing program efficiency. By comparing the relative significance of a particular component, from both an historical failure and identified failure non-detectability perspective, to the relative attention given the component by the Reference Plant monitoring program, a summary indication of the extent of monitoring optimization can be gathered.

6.2.1 RESULTS

6.2.1.1 DETECTABILITY OF FAILURE / DEGRADATION

The types of failure sources or conditions that were found to not be detectable by current monitoring or routine operating practices at the Reference Plant largely fall into two categories. The categories, and examples of each are:

A) A component or group of components is unable to perform as required under design basis accident or off-normal conditions, even though the general performance is demonstrated under more normal conditions.

Example:

Failure Condition: A motor driven pump is degraded and unable to deliver required flow with the associated steam generators at maximum post accident/transient pressure.

Non-Detectability: The motor driven pumps are verified to be operable by testing under recirculation flow only (at approximately 10% of design flow).. Although discharge check valves are verified operable by delivery of the required flow to the

steam generators, there is no requirement for, nor monitoring of steam generator, pump suction, and pump discharge pressure.

B). A component or group of components is unable to perform as required due to failures of related Instrumentation and Controls (I&C) which are not observed during routine testing or operation.

Example:

Failure Condition: The steam generator blowdown isolation valves fail to close following turbine driven pump start due to failure of contacts associated with a stem operated limit switch for the turbine trip and throttle valve.

Non-Detectability: SG blowdown isolation valves are not verified to close in response to starting of the turbine driven pump by any testing.

It should be noted that some of the noted non-detectable failure conditions actually apply to both categories; that is, failures in I&C circuitry that would only be challenged under design basis accident or off-normal conditions. As an example, there is no verification that the Steam Supply Valves can complete the automatic steam supply transfer in the event that the normal steam supply source (Steam Generator A) is not available to drive the turbine driven pump (as would be the case following an event in which SG A was depressurized, such as a feedwater line break). There are a number of I&C components (relays, contacts) which must operate properly to accomplish the transfer that are not tested.

6.2.1.2 FAILURE HISTORY

The review of historical failure data provided a broader, but less detailed perspective of the ability of current monitoring programs and routine observations to detect degradation/failure of AFW System components. By virtue of the fact that design basis challenges of most components are extremely rare, the historical failure data, even for demand related failures, is not a good indicator of the ability of components to perform under design basis conditions. It is therefore not particularly useful as a means of confirming the observations made in the Reference Plant review relative to the ability of components to perform as required under design basis/off-normal conditions (see discussion under section 6.2.1.1, category "A", above). The different perspective offered by the failure data review does, however, complement the observations made as a part of the Reference Plant review in that about one-half of the degradation detected during demand events was due to I&C related failures, while, as noted in category "B" of section 6.2.1.1, many of the non-detectable failure conditions that could exist at the Reference Plant were I&C related.

The failure data review found that about one-fifth of overall AFW System degradation was detected during demand events. This finding is also complementary to the results of the Reference Plant review, in which a significant number of failure conditions were found which would not be detectable by programmatic monitoring or by routine observations.

6.2.1.3 TEST FREQUENCY

Table 6.1 provides a summary of estimated test related actuation frequency for various AFW System components at the Reference Plant. Some components were found to be actuated, for testing purposes, about an order of magnitude more frequently than others.

It should be noted that the numbers of actuations cited in the table include actuations which result from two sources: 1) those that are required in support of testing that demonstrates operability of the individual component and 2) actuations which occur in conjunction with testing other components or systems. For the components tested least frequently, the majority or all of the actuations come from the former, while for many of those components most frequently actuated, the majority of the actuations come about as a result of the latter.

6.2.2 CONCLUSIONS

The fraction of AFW System degradation that has historically been found during demand events, as well as the number and types of failure and degradation sources that were found to not be detectable by the monitoring methods in place at the Reference Plant, indicate the need for improvements in certain aspects of the current monitoring practices. While there are no guidelines to establish what is an acceptable level of fraction of failures detected during demand, the rate indicated by the failure data review (about 18% of all system degradation was detected during demand conditions) appears excessive. This is particularly the case for certain component types and parts (for example, the Pump Driver Group and Turbine Driven Pump I&C/Governor Controls).

It was also found, in the Reference Plant review, that the ability of some components to function as required under design basis or off-normal conditions is not verified periodically. This was found to be the case particularly where multiple component interaction is involved. There are decidedly adverse effects that could result from routine testing of some of these currently non-tested areas (such as checking the ability of the AFW pumps to successfully negotiate the suction transfer from the Condensate Storage Tank to Emergency Service Water), while other areas could be fairly easily checked with little additional effort and no adverse consequences (such as verification of pump capability by monitoring additional parameters during the full stroking of discharge check valves).

When the test frequency, and the information that can be gathered from the various test related actuations of AFW System components are considered in light of historical failure experience and areas of non-detectability identified by the review of the Reference Plant's monitoring program, it is apparent that both the test requirements and the actual implementation of those requirements are not optimized. While an attempt to tabulate areas of non-optimization has not been made, the following example is indicative of the lack of test optimization.

Example

The historical failure data showed that over half of the system degradation associated with turbine failures was due to I&C and governor control related problems (It should be remembered that turbine related failures were the single most significant source of system degradation.). Yet there is no Tech Spec specific requirement for the calibration of the governor control system. At the Reference Plant, the governor is calibrated, per ST-27, on a refueling frequency. However, the procedure notes, in the "Scope" section that "This instruction does not satisfy any Technical Specification surveillance requirements.", and "This instruction is intended to be performed during each refueling outage but may be performed in whole or in part as needed." In the ORNL compilation of non-detectable failure sources, it was assumed that this procedure was conducted in full each refueling outage. Since there is no requirement to conduct this testing, it is possible that the testing would not be conducted for an indefinite period. It should be noted that some plants do not even designate the governor calibration procedure as a "Surveillance Procedure". In fact, since Tech Specs do not require the calibration, it is to be expected that governor calibration procedures would normally not be designated as such. As noted in the discussion for the turbine driven pump for the Reference Plant, there are also a number of turbine related I&C failure sources (ignoring governor related areas) that are not detectable by the existing monitoring program.

Thus, the single largest source of turbine related problems is monitored directly on a refueling frequency (roughly every 12 to 18 months) at best.

On the other hand, the Trip & Throttle (T&T) valve, which was found to be a less significant source of turbine related problems, is estimated to be stroked over 40 times a year in support of testing at the Reference Plant. Ironically, worn linkage was identified as the source of many of the T&T valve problems in the failure data. Inasmuch as a substantial portion of T&T valve operation occurs from testing, testing itself may be a significant source of T&T valve problems.

In light of these observations, it appears that enhancements in current monitoring requirements and practices are warranted. Enhancements should focus on:

- 1) optimizing the testing requirements / programs to reduce testing of components which have historically not been major contributors to system degradation and for which the current testing provides little useful information, while at the same time focusing more attention on those components and functional areas that have been more significant historically,
- 2) specifically improving the monitoring of I&C portions of the AFW System, and
- 3) better verifying the ability of components to function under design basis / off-normal conditions.

6.3 RECOMMENDATIONS

1. Conduct a Phase II study of the AFW System. The Phase II study should include the following:

a) the detailed identification of areas of current monitoring / operating practices and requirements which are not optimal for maintaining the availability and demonstrating the operability of the AFW System. The areas which appear to be inadequately monitored (for example, governor controls/I&C for the turbine) as well as areas in which the level of testing appears excessive (for example, stroking of the T&T valve), based upon the results of the Phase I study should be specifically addressed.

b) the development of recommended changes, based upon the results of item a, to monitoring / operating practices and requirements in order to ensure that appropriate attention is provided to historically significant sources of AFW System degradation, while minimizing unnecessary testing (and the accompanying test-related wear).

2. Conduct a Phase I study of the AFW turbine drive. In light of the similarity of the AFW turbines to safety related turbines used in Boiling Water Reactor (BWR) systems, a review of safety related turbine drives in general should be considered.

3. Because of the significance of turbine governor and I&C related problems found in both the failure data and the Reference Plant reviews, consideration should be given to the conduct of a Phase I study of governors and their controls. Governors used on AFW turbines, as well as BWR safety related pump turbines, emergency diesels and diesel driven pumps should be considered for inclusion in this study.

**Table 6.1 ESTIMATED TEST FREQUENCY FOR
REFERENCE PLANT AFW SYSTEM COMPONENTS**

<u>COMPONENT</u>	<u>NUMBER OF TEST ACTUATIONS PER YEAR</u>
Motor Driven Pump (MDP) Suction Check Valves C-3, 4,	13 Partial, 2 Full
Turbine Driven Pump (TDP) Suction Check Valve C-5	11 Partial, 4 Full
Emergency Service Water Supply Valves MOV-1, 2, 3, 4	5 Full
Emergency Service Water Supply Valves MOV-5, 6, 7, 8	5 Full
Motor Driven Pumps	12 Recirc / 2 Full Flow
Turbine Driven Pump	11 Recirc / 4 Full Flow
Trip & Throttle Valve	43 Full
MDP Miniflow Check Valves C-6, C-8	14 Full
TDP Miniflow Check Valve C-10	15 Full
Common Miniflow Check Valves C-1, C-2	39 Partial, 1 Full
MDP Discharge Check Valves C-7, C-9	2 Full
TDP Discharge Check Valve C-11	4 Full
MDP Level Control Valves LCV-1,3, 5, 7	23 Full
MDP Bypass Level Control Valves LCV-1A, 3A, 5A, 7A	21 Full
TDP Level Control Valves LCV-2, 4, 6, 8	26 Full
MDP Level Control Valve Check Valves C-13, 15, 17, 19	2 Full
TDP Level Control Valve Check Valves C-12, 14, 16, 18	4 Full
Check Valves C-21, 22, 24, 25	6 Full
Main Feedwater Check Valves C-20, 23, 26, 27	0 Full
Feedwater Isolation Valves FWIV-1, 2, 3, 4	5 Full
SG Blowdown Isolation Valves BDV-1, 2, 3, 4	29 Full
Turbine Steam Supply Valves MOV-11, MOV-12	25 Full
Turbine Steam Supply Isolation Valves MOV-9 / MOV-10	29 / 25 Full

All test actuation frequencies are estimated based upon assumed 18 month fuel cycle length.

APPENDIX A
RELEVANT TECHNICAL SPECIFICATIONS

AUXILIARY FEEDWATER SYSTEM

LIMITING CONDITION FOR OPERATION

3.7.1.2 At least three independent steam generator auxiliary feedwater pumps and associated flow paths shall be OPERABLE with:

- a. Two motor-driven auxiliary feedwater pumps, each capable of being powered from separate shutdown boards, and
- b. One turbine-driven auxiliary feedwater pump capable of being powered from an OPERABLE steam supply system.

APPLICABILITY: MODES 1, 2, and 3.

ACTION:

- a. With one auxiliary feedwater pump inoperable, restore the required auxiliary feedwater pumps to OPERABLE status within 72 hours or be in at least HOT STANDBY within the next 6 hours and in HOT SHUTDOWN within the following 6 hours.
- b. With two auxiliary feedwater pumps inoperable, be in at least HOT STANDBY within 6 hours and in HOT SHUTDOWN within the following 6 hours.
- c. With three auxiliary feedwater pumps inoperable, immediately initiate corrective action to restore at least one auxiliary feedwater pump to OPERABLE status as soon as possible.

SURVEILLANCE REQUIREMENTS

4.7.1.2 In addition to the requirements of Specification 4.0.5 each auxiliary feedwater pump shall be demonstrated OPERABLE by:

- a. Verifying that :
 1. each motor-driven pump develops a differential pressure of greater than or equal to 1397 psid on recirculation flow.
 2. the steam-turbine driven pump develops a differential pressure of greater than or equal to 1183 psid on recirculation flow when the secondary steam supply pressure is greater than 842 psig. The provisions of Specification 4.0.4 are not applicable for entry into MODE 3.
 3. each automatic control valve in the flow path is OPERABLE whenever the auxiliary feedwater system is placed in automatic control or when above 10% of RATED THERMAL POWER.

b. At least once per 18 months during shutdown* by:

1. Verifying that each automatic valve in the flow path actuates to its correct position upon receipt of an auxiliary feedwater actuation test signal and a low auxiliary feedwater pump suction pressure test signal.
2. Verifying that each auxiliary feedwater pump starts as designed automatically upon receipt of each auxiliary feedwater actuation test signal.

c. At least once per 7 days by verifying that each non-automatic valve in the auxiliary feedwater system flowpath is in its correct position.

*The provisions of Specification 4.0.4 are not applicable for entry into MODE 3 for the turbine-driven Auxiliary Feedwater Pump

BASIS

The OPERABILITY of the auxiliary feedwater system ensures that the Reactor Coolant System can be cooled down to less than 350°F from normal operating conditions in the event of a total loss of off-site power.

The steam driven auxiliary feedwater pump is capable of delivering 880 gpm (total feedwater flow) and each of the electric driven auxiliary feedwater pumps are capable of delivering 440 gpm (total feedwater flow) to the entrance of the steam generators at steam generator pressures less than 1133 psia. At 1133 psia the open steam generator safety valve(s) are capable of relieving at least 11% nominal steam flow. A total feedwater flow of 440 gpm at pressures less than 1133 psia is sufficient to ensure that adequate feedwater flow is available to remove decay heat and reduce the Reactor Coolant System temperature to less than 350°F where the Residual Heat Removal System may be placed into operation.

4.0.4 Entry into an OPERATION MODE or other specified condition shall not be made unless the Surveillance Requirement(s) associated with the Limiting Condition for Operation have been performed within the specified surveillance interval or as otherwise specified.

4.0.5 Surveillance Requirements for inservice inspection and testing of ASME Code Class 1, 2, and 3 components shall be applicable as follows:

a. Inservice inspection of ASME Code Class 1, 2, and 3 components and inservice testing of ASME Code Class 1, 2, and 3 pumps and valves shall be performed in accordance with Section XI of the ASME Boiler and Pressure Vessel Code and applicable Addenda as required by 10 CFR 50, Section 50.55a (g), except where specific written relief has been granted by the Commission pursuant to 10 CFR 50, Section 50.55(g)(6)(i).

b. Surveillance intervals specified in Section XI of the ASME Boiler and Pressure Vessel Code and applicable Addenda for the inservice inspection and testing activities required by the ASME Boiler and Pressure Vessel Code and applicable Addenda shall be applicable as follows in these Technical Specifications:

ASME Boiler and Pressure Vessel Code and applicable Addenda terminology for inservice inspection and testing activities

Required frequencies for performing inservice inspection and testing activities

Weekly
Monthly
Quarterly or every 3 months
Semiannually or every 6 months
Every 9 months
Yearly or annually

At least once per 7 days
At least once per 31 days
At least once per 92 days
At least once per 184 days
At least once per 276 days
At least once per 366 days

c. The provisions of Specification 4.0.2 are applicable to the above required frequencies for performing inservice inspection and testing activities.

d. Performance of the above inservice inspection and testing activities shall be in addition to other specified Surveillance Requirements.

e. Nothing in the ASME Boiler and Pressure Vessel Code shall be construed to supersede the requirements of any Technical Specification.

3/4.3.2 ENGINEERED SAFETY FEATURE ACTUATION SYSTEM INSTRUMENTATION

LIMITING CONDITION FOR OPERATION

3.3.2 The Engineered Safety Feature Actuation System (ESFAS) instrumentation channels and interlocks shown in Table 3.3-3 shall be OPERABLE with their trip setpoints set consistent with the values shown in the Trip Setpoint column of Table 3.3-4 and with RESPONSE TIMES as shown in Table 3.3-5

APPLICABILITY: As shown in Table 3.3-3

ACTION:

- a. With an ESFAS instrumentation channel or interlock trip setpoint less conservative than the value shown in the Allowable Values column of Table 3.3-4, declare the channel inoperable and apply the applicable ACTION requirement of Table 3.3-3 until the channel is restored to OPERABLE status with the trip setpoint adjusted consistent with the Trip Setpoint value.
- b. With an ESFAS instrumentation channel or interlock inoperable, take the ACTION shown in Table 3.3-3.

SURVEILLANCE REQUIREMENTS

4.3.2.1.1 Each ESFAS instrumentation channel and interlock shall be demonstrated OPERABLE by the performance of the CHANNEL CHECK, CHANNEL CALIBRATION, and CHANNEL FUNCTIONAL TEST operations for the MODES and at the frequencies shown in Table 4.3-2.

4.3.2.1.2 The logic for the interlocks shall be demonstrated OPERABLE during the automatic actuation logic test. The total interlock function shall be demonstrated OPERABLE at least once per 18 months during CHANNEL CALIBRATION testing of each channel affected by interlock operation.

4.3.2.1.3 The ENGINEERED SAFETY FEATURES RESPONSE TIME of each ESFAS function shall be demonstrated to be within the limit at least once per 18 months. Each test shall include at least one logic train such that both logic trains are tested at least once per 36 months and one channel per function such that all channels are tested at least once per N times 18 months where N is the total number of redundant channels in a specific ESFAS function as shown in the "Total No. of Channels" Column of Table 3.3-3.

**TECH SPEC TABLE 3.3-3 ENGINEERED SAFETY FEATURE ACTUATION SYSTEM
INSTRUMENTATION (AFW RELATED PORTION ONLY)**

<u>FUNCTIONAL UNIT</u>	<u>TOTAL NO. OF CHANNELS</u>	<u>CHANNELS TO TRIP</u>	<u>MINIMUM CHANNELS OPERABLE</u>	<u>APPLICABLE MODES</u>	<u>ACTION</u>
AUXILIARY FEEDWATER					
a. Manual Initiation	2	1	2	1, 2, 3	1
b. Automatic Actuation Logic	2	1	2	1, 2, 3	2
c. Main Stm Gen Water Level Low-Low					
i. Start Motor Driven Pumps	3/stm. gen.	2/stm. gen. any stm. gen.	2/stm. gen.	1, 2, 3	3
ii. Start Turbine Driven Pump	3/stm. gen.	2/stm. gen. any 2 stm. gen.	2/stm. gen.	1, 2, 3	3
d. S.I. Start Motor Driven Pumps and Turbine Driven Pump					
		(References the Safety Injection channel operability requirements)			
e. Station Blackout Start Motor Driven Pump associated with the shutdown board and Turbine Driven Pump	2/shutdown board	1/shutdown board	2/shutdown board	1, 2, 3	4
f. Trip of Main Feedwater Pumps Start Motor Driven Pumps and Turbine Driven Pump	1/pump	1/pump	1/pump	1, 2	4
g. Auxiliary Feedwater Suction Pressure-Low	3/pump	2/pump	2/pump	1, 2, 3	4

**TECH SPEC TABLE 3.3-4 ENGINEERED SAFETY FEATURE ACTUATION SYSTEM
INSTRUMENTATION TRIP SETPOINTS (AFW RELATED PORTION ONLY)**

<u>FUNCTIONAL UNIT</u>	<u>TRIP SETPOINT</u>	<u>ALLOWABLE VALUES</u>
AUXILIARY FEEDWATER		
a. Manual	Not Applicable	Not Applicable
b. Automatic Actuation Logic	Not Applicable	Not Applicable
c. Main Stm Gen Water Level Low-Low	$\geq 18\%$ of narrow range instrument span each SG	
d. S.I.	(References the Safety Injection Setpoints requirements)	
e. Station Blackout	0 volts with a 5.0 second time delay	0 volts with a 5.0 ± 1.0 second time delay
f. Trip of Main Feedwater Pumps	Not Applicable	Not Applicable
g. Auxiliary Feedwater Suction Pressure-Low	≥ 2 psig (motor driven pump) ≥ 13.9 psig (turbine driven pump)	≥ 1 psig (motor driven pump) ≥ 12 psig (turbine driven pump)

**TECH SPEC TABLE 3.3-5 ENGINEERED SAFETY FEATURES
RESPONSE TIMES (AFW RELATED PORTIONS ONLY)**

<u>INITIATING SIGNAL AND FUNCTION</u>	<u>RESPONSE TIME IN SECONDS</u>
1. Manual Auxiliary Feedwater Pumps	Not Applicable
2. Containment Pressure-High Auxiliary Feedwater Pumps	≤ 60
3. Pressurizer Pressure-Low Auxiliary Feedwater Pumps	≤ 60
4. Differential Pressure Between Steam Lines-High Auxiliary Feedwater Pumps	≤ 60
5. Steam Flow in Two Steam Lines - High Coincident with T_{avg} - Low-Low Auxiliary Feedwater Pumps	≤ 60
6. Steam Flow in Two Steam Lines - High Coincident with Steam Line Pressure-Low Auxiliary Feedwater Pumps	≤ 60
7. Main Steam Generator Water Level - Low-Low	
a. Motor driven Auxiliary Feedwater Pumps ⁽¹⁾	≤ 60
b. Turbine driven Auxiliary Feedwater Pump ⁽²⁾	≤ 60
8. Station Blackout Auxiliary Feedwater Pumps	≤ 60
9. Trip of Main Feedwater Pumps Auxiliary Feedwater Pumps	≤ 60
(1) On 2/3 any Steam Generator	
(2) On 2/3 in 2/4 Steam Generator	

**TECH SPEC TABLE 4.3-2 ENGINEERED SAFETY FEATURE ACTUATION SYSTEM
INSTRUMENTATION SURVEILLANCE REQUIREMENTS (AFW RELATED PORTION ONLY)**

<u>FUNCTIONAL UNIT</u>	<u>CHANNEL CHECK</u>	<u>CHANNEL CALIBRATION</u>	<u>CHANNEL FUNCTIONAL TEST</u>	<u>MODE FOR WHICH SURVEILLANCE IS REQUIRED</u>
AUXILIARY FEEDWATER				
a. Manual	N.A.	N.A.	R	1, 2, 3
b. Automatic Actuation Logic	N.A.	N.A.	M(1)	1, 2, 3
c. Main Steam Generator Water Level Low-Low	S	R	Q	1, 2, 3
d. S. I.	(References the Safety Injection instrumentation surveillance requirements)			
e. Station Blackout	N. A.	R	N. A.	1, 2, 3
f. Trip of Main Feedwater Pumps	N. A.	N. A.	R	1, 2
g. Auxiliary Feedwater Suction	N. A.	R	M	1, 2, 3

PERTINENT TECH SPEC DEFINITIONS

CHANNEL CALIBRATION

A CHANNEL CALIBRATION shall be the adjustment, as necessary, of the channel output such that it responds with the necessary range and accuracy to known values of the parameter which the channel monitors. The CHANNEL CALIBRATION shall encompass the entire channel including the sensor and alarm and/or trip functions, and shall include the CHANNEL FUNCTIONAL TEST. The CHANNEL CALIBRATION may be performed by any series of sequential, overlapping or total channel steps such that the entire channel is calibrated.

CHANNEL CHECK

A CHANNEL CHECK shall be the qualitative assessment of channel behavior during operation by observation. This determination shall include, where possible, comparison of the channel indication and/or status with other indications and/or status derived from independent instrument channels measuring the same parameter.

CHANNEL FUNCTIONAL TEST

A CHANNEL FUNCTIONAL TEST shall be:

- a. Analog channels - the injection of a simulated signal into the channel as close to the sensor as practicable to verify OPERABILITY including alarm and/or trip functions.
- b. Bistable channels - the injection of a simulated signal into the sensor to verify OPERABILITY including alarm and/or trip functions.

ENGINEERED SAFETY FEATURE RESPONSE TIME

The ENGINEERED SAFETY FEATURE RESPONSE TIME shall be that time interval from when the monitored parameter exceeds its ESF actuation setpoint at the channel sensor until the ESF equipment is capable of performing its safety function (i.e., the valves travel to their required positions, pump discharge pressures reach their required values, etc.). Times shall include diesel generator starting and sequence loading delays where applicable.

OPERABLE - OPERABILITY

A system, subsystem, train, component, or device shall be OPERABLE or have OPERABILITY when it is capable of performing its specified function(s), and when all necessary attendant instrumentation, controls, electrical power, cooling or seal water, lubrication or other auxiliary equipment that are required for the system, subsystem, train, component, or device to perform its function(s) are also capable of performing their related support function(s).

OPERATIONAL MODES

MODE	REACTIVITY CONDITION, K_{eff}	%RATED THERMAL POWER*	AVERAGE COOLANT TEMPERATURE
1. POWER OPERATION	≥ 0.99	$> 5\%$	$\geq 350^{\circ}\text{F}$
2. STARTUP	≥ 0.99	$\leq 5\%$	$\geq 350^{\circ}\text{F}$
3. HOT STANDBY	< 0.99	0	$\geq 350^{\circ}\text{F}$
4. HOT SHUTDOWN	< 0.99	0	$350^{\circ}\text{F} > T_{avg} > 200^{\circ}\text{F}$
5. COLD SHUTDOWN	< 0.99	0	$\leq 140^{\circ}\text{F}$
6. REFUELING	< 0.95	0	$\leq 140^{\circ}\text{F}$

FREQUENCY NOTATION

NOTATION	FREQUENCY
S	At least once per 12 hours
M	At least once per 31 days
Q	At least once per 92 days
R	At least once per 18 months
N.A.	Not applicable