U. S. NUCLEAR REGULATORY COMMISSION
REGION I

DOCKET/REPORT NOS: 50-271/95-14

LICENSEE: Vermont Yankee Nuclear Power Corporation
Brattleboro, Vermont 05301

FACILITY: Vermont Yankee Nuclear Power Station

DATES: June 26-30, 1995

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Summary: Good management oversight of service water (SW) issues was evident. Sound corrective actions, consistent with Generic Letter (GL) 89-13, "Service Water System Problems Affecting Safety-Related Equipment," were being implemented regarding the licensee's SW self-assessment previously performed in February 1994. Good progress was made in resolving longstanding concerns regarding SW system surveillance testing. An extensive SW hydraulic model was developed, including validation and considerations for component degradation. A SW system design basis document was developed with an appropriate level of detail to define system design requirements. Comprehensive measures have been taken concerning heat exchanger testing, and a novel performance monitoring method was utilized which enables quick determination (by operating personnel), comparing test results against pre-established performance curves. The cooling tower thermal performance test was coordinated well, including a thorough review of the test results; in particular, the uncertainty analysis for the pre- and post-test configurations. However, it would be premature to assess the adequacy of the licensee's actions to meet the intent of requested Action I (regarding biofouling) of GL 89-13 because the implementation of a recommended chemistry action plan has been delayed since November 1994. VY had never (in over 20 years) chemically treated the SW system, and some evidence of a macrofouling slime and several recent piping leaks have been experienced, but such treatment was expected to begin in mid-July. Unresolved Item 95-14-01 was opened to track the establishment of formal preventive maintenance actions for the alternate cooling system (comprised of the west tower cell No. 1 and associated residual heat removal service water system piping).

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DETAILS

1.0 INTRODUCTION AND SCOPE

The licensee conducted a service water (SW) system self-assessment from January 10 through February 11, 1994, using the guidance provided in NRC Temporary Instruction (TI) No. 2515/118, Service Water System Operational Performance Inspection (SWSOPI). In October and November 1994, the NRC conducted a SW followup inspection (see NRC Inspection Report 50-271/94-18) to review the licensee's SW self-assessment activities and indicated several areas for continued review as follows:

1. The SW system flow analysis calculation (Flo Series Calculation 1279)

2. The results of the thermal performance test of the West Cooling Tower Cell No.1, including the cooling tower deep basin inventory calculation

3. RHR heat exchanger (HX) performance tests and calculations

4. Calculations for the emergency core cooling system (ECCS) equipment room coolers RRU-5,6,7,8

This inspection assessed the licensee's corrective actions to address the findings from the 1994 SWSOPI self-assessment, including how these corrective actions met the intent of Generic Letter (GL) 89-13. The assessment was performed by reviewing the four areas noted above and two other areas, namely actions taken to resolve SW system surveillance testing issues as identified in an unresolved item (URI 91-21-02) and SW system chemistry controls.

2.0 FINDINGS

2.1 Hydraulic Flow Model - SW Self-Assessment Items DSN/017 and 026

The SW self-assessment identified a number of the issues related to the predictions and the assumptions used in the system hydraulic model, such as the use of non-degraded pump curves, the lack of a basis for the system degradation assumptions, and the lack of documentation for flow distribution assumptions. These issues were documented in the self-assessment report as Items DSN/017 and 026.

Subsequent to the conduct of the SW self-assessment, the licensee developed a new SW system hydraulic model, using the Pipe-FLO computer program, since the previous model using the RETRAN program was not suitable. The development of the new hydraulic model, including the assumptions, results, and validation effort, was described in Calculation No. VYC-1279, "Service Water System Hydraulic Analysis." The inspectors reviewed the new hydraulic model, which satisfactorily resolved most of the points in the self-assessment, and had the following observations:

- The model development was thorough and extensive. The calculation (over 2500 pages) analyzed 20 different system alignments to assure that the calculation predictions were conservative for a comprehensive range of possible accident scenarios that are part of the SW system design basis.

- The model included appropriate considerations for system piping degradation, pump degradation, and valve throttling.

- The model was validated against actual test results. Also, some comparisons were made between the predictions using the Pipe-FLO computer program versus the old RETRAN program.

- The model predicted that for all of the analyzed configurations the SW system can provide flow in excess of the design required values to all safety-related loads. These predictions were based on the use of two SW pumps. Regarding this conclusion, the technical specifications currently do not require entering an action statement if one SW pump is out of service (see URI 50-271/93-033-02). However, this would allow unrestricted, continued operation without having a flow analysis to support safe plant operation. The licensee needs to submit to NRR recommended changes to the VY technical specifications for eliminating this inconsistency.

- Results of the maintenance inspections of piping/equipment and operation surveillance were reviewed against the model. However, no formal requirements to perform such reviews existed.

While these observations were generally positive, the inspectors noted several items where additional improvements could be made to enhance future use of the model:

- The limiting pump curves used for inservice testing (IST) were not compared with the degraded SW pump curve used in the analysis. Rather, the degraded pump curve used in the analysis was based on the original vendor curves. The inspectors noted that the SW pumps had been rebuilt several times since the original vendor curves were developed, and no records existed comparing the original pump curves and the rebuilt baseline curves. The licensee should review and correct this area to ensure that future analyses with the model use degraded pump curves based on current IST information.

- Maximum allowable degradation limits for the safety-related portions of the system were not established.

- Parametric analysis to determine the effects of the instrument uncertainty and pipe roughness and fouling assumptions had not been performed.

- The Yankee Atomic engineer who prepared Calculation No. 1279 was currently collecting changes from several sources for a future revision of Calculation No. 1279. However, these changes were not being processed formally in accordance with engineering design control procedures. The inspectors considered that formal measures should be used regarding the control of information for updating the model, if the model is to be used in plant design work.

The inspectors concluded that the development of the new SW hydraulic model, including its validation and considerations for component and system degradation, was a good engineering effort. While this development work was a substantial effort, strong control measures for revising the model should be implemented to keep it current as SW system modifications are made.

2.2 Heat Exchanger Testing

The licensee has taken comprehensive measures to meet the intent of GL 89-13 requested actions regarding heat exchanger testing.

2.2.1 Cooling Tower Testing (SW Self-Assessment Items DSN/015, 035, and TST/018)

The Vermont Yankee Final Safety Analysis Report states that the alternate cooling system (ACS) is provided to bring the reactor to a safe shutdown condition in the unlikely event of the loss of the Vernon Pond. The ACS would also be required for safe shutdown in the event of a flood or a fire in the intake structure; however, the ACS design basis does not include its use for mitigating design basis events that require ECCS cooling. The major components of the ACS include the residual heat removal service water (RHRSW) pumps, Cell No. 1 of the west (No. 2) cooling tower (designated CT 2-1), and interconnecting portions of the service water (SW) system piping. The cooling tower is a mechanical draft-type design with 11 cells arranged longitudinally. Tower cell CT 2-1 is designed to supply 85°F cooling water to the RHRSW pumps and is capable of removing 120,000,000 Btu/hr (based on 75°F wet bulb and 89°F dry bulb) for accomplishing safe shutdown. The cooling tower basin is sized such that the ACS can be operated to accommodate system losses for 1 week before makeup water is required from off-site sources.

The licensee's SW self-assessment identified a number of issues associated with the thermal performance testing of tower cell CT 2-1, the cooling tower basin inventory, and associated calculations. These issues involved the verification of the modeling assumptions used in cooling tower performance calculations, such as evaporation water loss, ratio of air-to-water flow (L/G value), the potential for uneven flow distribution through CT 2-1 (i.e., channeling), and SW system valve leakage. The basin inventory issue dealt primarily with the calculation (VYC-988) which concluded that sufficient inventory existed for 1 week to provide the required net positive suction head for the RHRSW pumps.

Thermal Performance Testing

As documented in NRC Inspection Report 50-271/94-18, preliminary review of the data from a thermal performance test of tower cell CT 2-1 (Special Test Procedure 94-02, "Hydraulic/Thermal Performance of ACS - Cell No. 1") indicated that channeling should not be a concern. The licensee also conducted a hydraulic performance test of the ACS (Special Test Procedure 95-02, "Hydraulic Performance testing of the Alternate Cooling System") during the 1995 refueling outage. After the final review of all test data, which included the testing consultant's (Power Generation Technologies) final test report, the licensee concluded that tower cell CT 2-1 was capable of performing its safety function.

The licensee's cooling tower testing activities were of high quality and received good coordination among site, corporate, and consultant personnel. In particular, the uncertainty analyses provided a high confidence that the test conclusions were sound. The inspectors reviewed these test results and discussed them with the cognizant engineer. Based on the following observations, the inspector considered that the licensee's conclusions regarding the test results were appropriate:

1. The analysis performed by the licensee's testing consultant used an accepted industry method for evaluating the thermal performance of mechanical draft cooling towers based on data from an approved test procedure. The method used was described in the Cooling Tower Institute Acceptance Test Code - 105, Part II, "Evaluation of Results." Based on the test data, this method determines a cooling tower characteristic value, which is a dimensionless value designated as KaV/L. This value is used as a measure of the tower capability or thermal performance, is compared to that originally calculated by the tower manufacturer, and that required the licensee. Appropriate adjustments were made in the analysis to account for differences in the test versus the design condition air-to-water flow ratios and the test instruments used.

   The licensee had specified a required KaV/L value of 0.67 in the SW/ACS design basis document, the tower manufacturer had calculated a nominal KaV/L value of 1.44, and the KaV/L value determined from the test data was 1.705. These KaV/L values were all based on a SW flow of 8,000 gpm. The licensee determined that tower cell CT 2-1 capability was about 2 ½ times larger than required, and concluded that this testing demonstrated satisfactory thermal performance.

2. Visual observations and calculations from the test data provided reasonable assurance that adequate flow distribution would exist for tower cell CT 2-1 to thermally perform its safety function during ACS operation, if required.

3. To appropriately account for the uncertainties of the measured test parameters and their impact on the performance calculations, the licensee's test consultant had performed thorough uncertainty analyses before and after the cooling tower testing.

4. The licensee received good technical support from Yankee Atomic personnel and coordinated well with its testing consultant in evaluating the test results.

Cooling Tower Basin Inventory

When reviewing cooling tower basin 7-day inventory calculation VYC-988, the inspectors observed that this calculation did not account for SW isolation valve(s) leakage. However, other assumptions related to the plant heat loads required for the cooling tower to remove, such as the use of four RHRSW pumps and continuous operation of both emergency diesel generators, were considered to be sufficiently conservative to bound the valve leakage consideration. Based on this calculation, the licensee concluded that an adequate water supply would exist in the cooling tower basin for a 7-day period to support ACS operation. The inspectors considered that this conclusion was supported with reasonable technical justification.

2.2.2 Future Testing of the ACS

The inspector noted that an engineering internal memorandum titled, "Closeout of Open Item 91-21-02 - Surveillance Testing of the Service Water System," dated May 25, 1995, provided the recommendation and technical basis regarding future integrated performance testing of the ACS. The licensee considered its position to be consistent with the intent of Generic Letter 89-13. The salient points in this memorandum were as follows:

1. The licensee noted that Special Test Procedure 95-02 necessitated the removal of one SW loop from normal service. Also, the ACS was not immediately available since it was being tested. The unavailability of this SW equipment required that special administrative controls be established to account for the possible loss of the intake structure. Although the testing was performed while in shutdown, the licensee considered the undesirable SW system alignment during Special Test Procedure 95-02 to be a reasonable basis for minimizing the frequency of future integrated performance testing of the ACS.

2. No additional thermal performance testing of the cooling tower was considered necessary based on: (1) significant thermal margins were demonstrated from the fall 1994 testing; (2) no extraordinary preparations to precondition the cooling tower were made for the fall 1994 testing; and (3) tower cell CT 2-1 has received annual preventative maintenance (on the air side) since initial plant operation.

3. Integrated testing of the ACS, comparable to the hydraulic performance test STP 95-02, was recommended to be conducted on a 10-year frequency. In conjunction with this testing, the following component testing was considered to be sufficient for demonstrating ongoing operability of the ACS:

    a. Testing of RHRSW and SW pumps and valves, including the manual valves which establish the ACS boundaries, would be performed in accordance with the requirements of the inservice testing program.

b. On a refueling outage basis, inspection, engineering evaluation of the inspection results, and cleaning as necessary would be performed for the 24-inch suction line to the RHRSW pumps from the cooling tower basin. After this inspection activity, this piping is placed in wet layup with the addition of a chemical biocide and corrosion inhibitor.

c. Since both cooling towers normally operate during the months of May to October, the licensee has been implementing routine preventive maintenance for the cooling tower equipment since initial plant operation. The thermal performance test of tower cell CT 2-1 demonstrated that this maintenance has preserved the material condition of the cooling tower equipment such that adequate thermal margin existed to remove the required heat loads.

The inspector noted that the 10-year frequency for the integrated performance test of CT 2-1 differed from the 5-year maximum frequency requested in GL 89-13. However, the inspector concluded that the licensee's proposed 10-year test frequency was reasonable based on the following considerations:

- Since the VY mechanical draft cooling tower involves direct air-to-water contact, degradation of the heat transfer surface is not a concern. The parameters subject to degradation, which are the air and water flow-rates and the mixing of the streams, can be predicted with confidence provided that routine inspection and preventive maintenance (PM) is performed on the cooling tower for the absence of fouling of air flow paths and uniform water flow through the tower. Also, examination of the cooling tower deep basin for any silt accumulation and RHRSW intake pipe condition would be routinely required.

- The unique SW system valve alignment that is required to accomplish the integrated performance test presented associated challenges to the plant operations staff to ensure safe operation (even while shutdown).

The engineering memorandum of May 25, 1995, did not clearly define the formal implementation of the routine PM requirements for the cooling tower and the RHRSW piping for assuring adequate air and water flows for ACS operation. While a 10-year test interval to demonstrate satisfactory hydraulic performance would satisfy the requested actions (Action II) of GL 89-13, review of the cooling tower and RHRSW piping PM requirements is required prior to NRC acceptance of such measures as part of requested Action III. Pending the satisfactory definition and incorporation of these PM requirements into the licensee's procedures, this item is unresolved **(URI 50-271/95-14-01)**.

2.2.3 RHR and Standby Fuel Pool Cooling System (SFPCS) Heat Exchanger Testing - SW Self-Assessment Items TST/015, 016, and MNT/021

The SW self-assessment identified a number of the issues related to the RHR heat exchanger (HX) performance modeling and evaluation of the test results. These issues were related to tube plugging control, inaccurate representation of the HX in the model, the model predictions not accurately representing the HX specification sheet information, and the lack of specific acceptance criteria for HX inspections. These issues were documented in the self-assessment report as Items TST/015, 016, and MNT/021.

Subsequent to the conduct of the self-assessment, the licensee developed a novel method for monitoring the performance of water-to-water HXs. The method was thoroughly described in a technical paper, "Using Actual-to-Maximum Delta T Curves for Monitoring Service Water Heat Exchanger Performance," which was presented by a licensee corporate engineer at an EPRI Service Water System Reliability Improvement seminar in June 1995. The method requires the development of the following five curves for a given set of tube and shell side flow rates and a range of temperatures:

1. 100% effective or infinite HX performance line

2. Clean condition (i.e., no fouling) based on the HX manufacturer's calculated performance with design heat removal capability

3. Design condition for accident/rated heat load condition with allocation for fouling and uncertainties (Upper bound)

4. Design condition for accident/rated heat load condition without uncertainties

5. Design condition for accident/rated heat load condition with allocation for fouling and uncertainties (Lower bound)

These curves establish five performance regions and were developed for the RHR HX in Calculation No. VYC-1328, performed by Yankee Atomic, using a combination of the "Heat Transfer" and "Temperature Effectiveness" methods as described in EPRI NP-7552, "Heat Exchanger Performance Monitoring Guidelines." The calculation was clearly presented with the assumptions and references used. Figures 1 and 2, which were extracted from the aforementioned technical paper, are attached to this report to illustrate the Delta Temperature (dT) method.

Use of the dT method is a departure from conventional engineering techniques, which calculate other parameters (e.g., heat transfer coefficients and fouling factors) to evaluate HX performance. The dT method compares the Maximum Delta Temperature (Tprocess hot - Tsw cold) to the Actual Delta Temperature (Tsw hot - Tsw cold). The results of the heat exchanger tests permit an immediate graphical plot by plant operating personnel of the actual HX performance in relation to the design required performance, which makes this method "user friendly." Significant differences in temperatures and flow rates will require development of a corresponding set of curves. Although the licensee considered that the test results can also be easily trended, the trending capability was not apparent to the inspectors, since the dT method provided a qualitative and quantitative analysis of heat exchanger performance, which could be subjective. The use of the dT method to assess the HX test results addressed most of the points in the SW self-assessment.

The licensee used the dT method for the evaluating the performance of the RHR and the SFPCS HXs. The inspector reviewed the test results given in the respective operating procedures (OP 4124 and OP 4179) and observed that satisfactory results were obtained. The temperature data placed the HXs in the acceptable performance region (Region C) in the graphical plot. The inspectors considered the dT method to be a good, novel approach which facilitated a quick and easy assessment of heat exchanger performance. Furthermore, the acceptance criteria include clearly defined instrument uncertainty regions. However, the capability to use this method for trending heat exchanger performance was not yet apparent.

2.2.4 ECCS Room Coolers - SW Self- Assessment Items DSN/033, TST/011, and TST/012

The SW self-assessment identified a number of the issues related to the ECCS room cooler (RRU) modeling, including the modeling assumptions. These issues were related to validity of the acceptance criteria based on the dP monitoring and the implementation of the acceptance criteria and were documented in the self-assessment report as Items DSN/033, TST/011, TST/012.

The ECCS RRUs had been replaced twice due to the differential pressure (dP) increase in excess of the acceptance value. The licensee had been attributing the root cause of this increase to silting or other macro fouling mechanisms of tube blockage. However, the results of an investigation, which included a physical examination of the cooling coils following the last replacement, indicated that the RRUs did not exhibit any silt or other macro fouling mechanisms of tube blockage. The licensee stated that the interior RRU surfaces were covered with a slime-like substance and a foul odor was present after RRU-8 was removed, which was indicative of microbiological effects. This information evidenced a misleading conclusion from the prior root cause determinations. The licensee was reevaluating the problem to determine the reason for the dP increase.

The design of the original RRUs did not allow for quick access for cleaning the tubes. However, the last replacement of the RRUs included units with design features which will permit cleaning in place. Currently, the performance of the RRUs is still being monitored based on the differential pressure across the HX (at a fixed flowrate). The licensee is considering a change in the method of monitoring the RRU performance from the dP method to the dT method (described in Section 2.2.3), which would provide the capability to quickly and more directly evaluate the RRU performance.

The inspectors concluded that the licensee had taken appropriate corrective actions to address the SW self-assessment comments regarding the potential for unsatisfactory performance of the RRUs. The implementation of the new RRU, suitable for cleaning in place, was a strong corrective action. However, a new issue was identified regarding biofouling in the RRUs, but the licensee's long-term actions for addressing this issue were not fully established.

2.3 SW System Surveillance Testing - URI 91-21-02 (Closed)

This unresolved item had been last updated in NRC Inspection Report 50-271/94-18. During the current inspection, the inspector concluded that the licensee has made good progress in resolving longstanding concerns regarding service water system surveillance testing. Unresolved Item 50-271/91-21-02 is therefore considered to be closed.

The licensee had conducted a special performance test of the West Cooling Tower Cell No. 1 in November 1994. Also, the analytical work for a new SW system hydraulic model had been completed, but benchmarking the model with actual plant flow and pressure drop data had not yet been completed. Several other aspects remained unresolved including the development of improved heat exchanger performance monitoring tests, and acceptance criteria for various SW system component preventive maintenance procedures. The licensee also expected to issue a SW system design basis document by December 31, 1994. Pending completion of these items and subsequent inspection by the NRC, this item remained unresolved.

Prior sections of this report described the licensee's satisfactory resolution of unresolved issues regarding validation of the SW system hydraulic model, testing of the alternate cooling system (ACS), including the cooling tower, cooling tower inventory for 7 days, and heat exchanger performance testing. The inspectors also reviewed the licensee's corrective actions to develop SW system design basis document and component preventive maintenance procedures with appropriate acceptance criteria. Although the design basis had not been formally issued, the draft version reviewed by the inspectors included an appropriate level of detail to define the SW system design requirements.

Most of the periodic testing requirements to demonstrate system performance within the design basis were included in three surveillance operating procedures: (1) OP 4124, Residual Heat removal and Service Water System Surveillance; (2) OP 4179, Standby Fuel Pool Cooling Surveillance; and (3) OP 4181, Service Water/Alternate Cooling System Surveillance. This testing includes the stroking of the manual valves that are required to change position to place the ACS into operation. The inspectors noted that the licensee had defined SW component inspection criteria in OP 5265, "Service Water Component Inspection and Acceptance Criteria." The licensee had initiated implementation of this procedure during the recent refueling outage. The inspector verified this implementation by reviewing a sample of SW component inspection records.

The inspector also confirmed that appropriate acceptance criteria were included for the 24-inch SW piping between the cooling tower and the RHRSW pump suction. However, the licensee had not established formal requirements for periodically inspecting this piping and cleaning it, as necessary, to ensure adequate flow during ACS operation. The corrective actions for this item will be tracked under previously opened Item 95-14-01.

2.4 Chemistry Control for SW System/Requested Action 1 of GL 89-13

The inspector noted that several SW piping leaks had occurred in 1993 and 1994 of which some were attributed, in part, to microbiologically influenced corrosion (MIC). The SW self-assessment had also identified a silting issue (Item No. MNT/012), which questioned whether maintenance was adequately tracking the performance of piping inspections where silting was suspected. More recently, as noted in Section 2.2.4, the lack of chemistry control may be a contributing cause to a macrofouling slime, resulting in a high differential pressure across RRU 8, previously thought to have been silt accumulation. Consequently, the inspector reviewed the licensee's actions regarding chemistry control in the SW system.

A chemistry action plan had been submitted and reviewed by the plant operations review committee (PORC) in November 1994 to address the biofouling issue. A chlorine/bromine treatment, in conjunction with a biocide (Betz Clamtrol product), was recommended for injection into the SW system. A chemical injection system was already installed (and fully tested) to inject the chemicals, but had not been used as of this inspection. The chemistry engineer indicated that chemical treatment would begin in mid July. The inspector discussed this issue with the Plant Manager, who indicated that he had recently authorized this chemical treatment, which would be the first time that such chemicals have been used in the SW system at VY. The inspector also noted that the licensee was just initiating a plan for future inspection of SW piping welds, to evaluate the extent of any piping degradation due to MIC comparable to that recently experienced downriver at another facility.

The inspectors concluded that it would be premature to assess the adequacy or effectiveness of the licensee's response to GL 89-13, Recommended Action I (Surveillance & Control Techniques to Preclude Biofouling Problems). The licensee has never chemically treated the SW system and was considering the pros and cons regarding chemical treatment of a 20-year untreated SW system. However, chemical treatment of the SW system was expected to begin in mid July, 1995.

3.0 MANAGEMENT OVERSIGHT

Good corporate engineering and plant management oversight was demonstrated concerning the resolution of the licensee's service water self-assessment findings. Licensee plant and corporate management jointly agreed with the quality assurance (QA) organization concerning the need for an independent audit of the status of the corrective actions to the SW self-assessment findings. A thorough QA audit was performed from March to May 1995, just prior to this inspection. The audit provided a good assessment of the licensee's current procedures in meeting the intent of GL 89-13 with recommendations for further improvement of the SW system performance.

4.0 MANAGEMENT MEETINGS

The scope and purpose of the inspection were discussed at an entrance meeting conducted on June 26, 1995. During the course of the inspection, the inspectors' findings were discussed with various licensee representatives. The inspector met with the principals listed below on June 30, 1995, to summarize the preliminary findings. During the inspection, the licensee indicated that there was no proprietary information involved in the inspection, or expected to be included as part of this inspection report.

B. Buteau, Engineering Director
G. Capuccio, Mechanical Engineering Manager
M. Metell, Corporate Engineer
R. Pagodin, SW Project Manager
D. Reid, Vice-President Operations
R. Wanczyk, Plant Manager

H. Eichenholz, Project Engineer, NRC, Region I

Figure 1 - Actual to Maximum Delta T Performance Curves

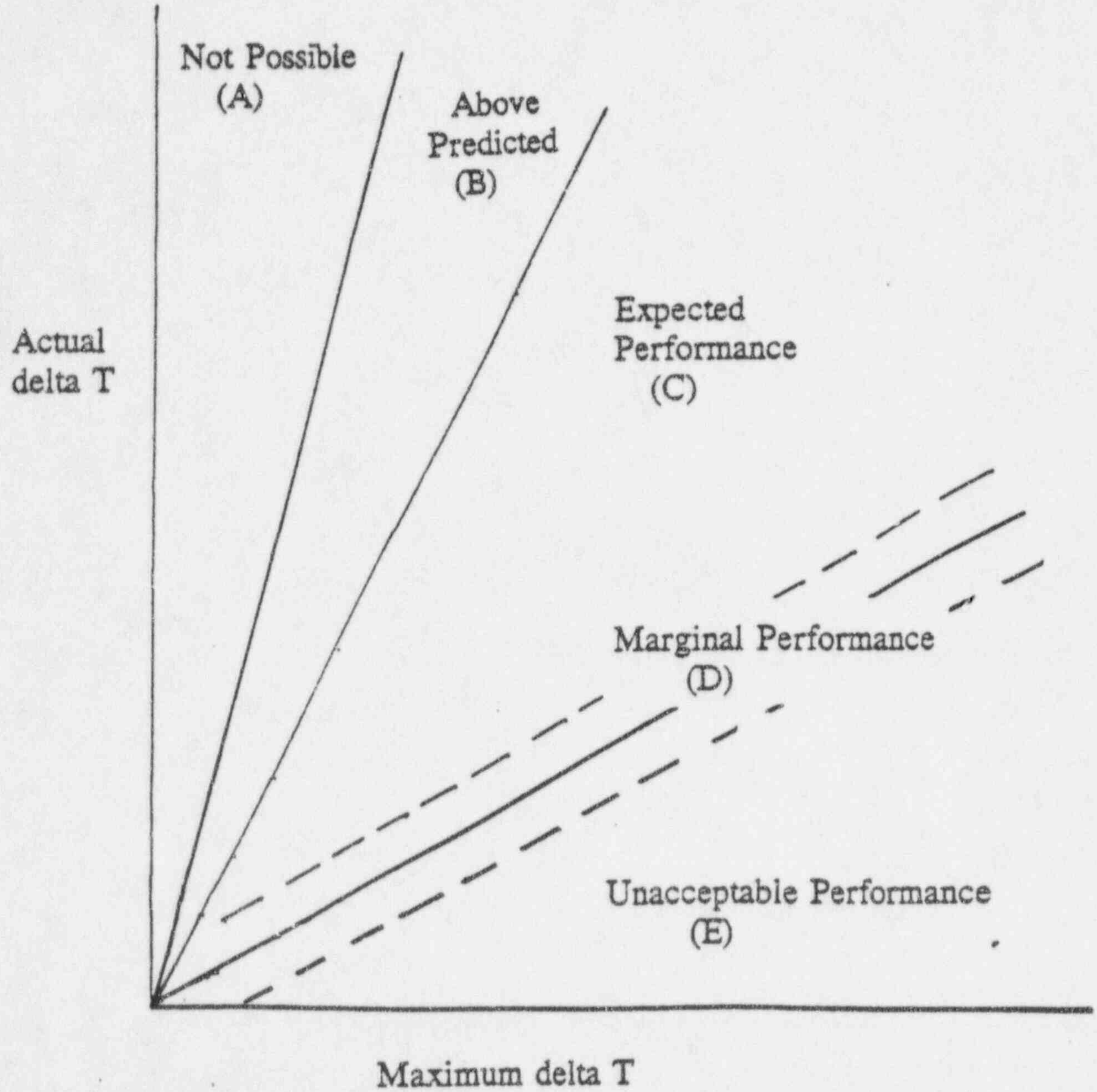

Figure 2 - Bases for Performance Regions