A Strategy for Achieving Sustained High Levels of Safety and Economic Performance in the Operation of Commercial Nuclear Power Plants

by

James E. Lynch

B.S. Nuclear Engineering, Rensselaer Polytechnic Institute, 1980

Submitted to the Department of Nuclear Engineering in Partial fulfillment of the Requirements for the Degree of Master of Engineering in Nuclear Engineering

at the

Massachusetts Institute of Technology

June 1999

Signature of Author: ______________________
Department of Nuclear Engineering
May 10, 1999

Certified by: ______________________
Kent F. Hansen
Professor of Nuclear Engineering
Thesis Supervisor

Accepted by: ______________________
George Apostolakis
Professor of Nuclear Engineering
Thesis Reader

Accepted by: ______________________
Sow-Hsin Chen
Chairman, Department Committee on Graduate Students

A Strategy for Achieving Sustained High Levels of Safety and Economic Performance in the Operation of Commercial Nuclear Power Plants

by

James E. Lynch

Submitted to the Department of Nuclear Engineering on May 10, 1999 in partial fulfillment of the requirements for the Degree of Master of Engineering in Nuclear Engineering

ABSTRACT

For U.S. nuclear power stations to continue to generate electricity they must operate both safely and economically. Although the average safety and economic performance of U.S. power stations has improved over the past several years, some plants have not reached or have not sustained high performance levels.

Stations achieving sustained high performance levels were identified by an analysis of safety and economic performance data. The core attributes considered necessary to achieve and maintain this level of performance were identified by interviews with executives from the stations and by analysis of effective programs and practices. Core attributes for long-term sustained high performance were determined to be:

- Strong teamwork among the plant staff
- Extremely reliable equipment operation
- Clear, effective communication throughout the station
- Effective use of operating experience and benchmarking
- Knowledgeable and involved station managers
- Training focused on improving performance
- Constant focus on safe plant operation

Recommended methods to identify shortfalls and improve core attribute performance at stations that have not achieved sustained high performance are self-assessment, development of station-wide core principles, and management and supervisory training.

Thesis supervisor: Kent F. Hansen
Title: Professor of Nuclear Engineering

Acknowledgements

This thesis is the product of a team of people. Without their tireless, wholehearted support it would never have come about. Each of their names could easily be on the cover alongside mine, and I express my deep appreciation to them:

- My dear wife, Kristin, for her steadfast support and encouragement, without which my entire MIT adventure would not have been possible. Her constant love and support serve as an inspiration for me and as a shining example for our children.

- My loving children Erin and Kelly who grew up too fast while their dad was away at MIT.

- Professor Kent Hansen for his patient guidance and keen insights.

- Professor Carol Weiss of Harvard University for her expertise in formulating the interview questions.

- My employer, the Institute of Nuclear Power Operations, and especially the management team, for their commitment to professional development that provided such a phenomenal opportunity.

And finally, I express my appreciation for the goodness of an overriding Providence in my life.

Table of Contents

A Strategy for Achieving Sustained High Levels of Safety and Economic Performance in the Operation of Commercial Nuclear Power Plants

1.0 INTRODUCTION

The safety of U.S. nuclear power stations has steadily improved over the past several years as shown by the average Institute of Nuclear Power Operations (INPO) performance indicator index (Figure 1) and the Nuclear Regulatory Commission (NRC) annual industry average number of significant events per plant. (Figure 2) Additionally, the economic performance of U.S. nuclear power stations has also improved as shown by the average Federal Energy Regulatory Commission (FERC) operating, maintenance, and fuel cost data. (Figure 3) However, in spite of this overall improvement in safety and economic performance, some stations have not achieved or have not sustained high levels of safety and economic performance. For example, approximately 20 percent of all U.S. nuclear power stations are currently assessed by INPO as a 3 or lower (see Section 3.1for the definition of INPO assessment categories). One-half of these stations have been similarly rated for five or more out of the last nine years. Also, of the stations currently assessed a 2 by INPO, four have been assessed a 3 or lower four or more times in the last nine years. Further, of the twenty highest cost stations, as ranked by average FERC operating, maintenance, and fuel cost, eleven have seen their costs increase or not improve over the last five years. Therefore, while most stations have made safety and economic improvements over the past several years, some stations have not progressed or have not been able to sustain the improvement.

The purpose of this thesis is to assist commercial nuclear power plants to continue and to sustain safety and economic improvements. This purpose is accomplished in two parts. First, the core attributes of long-term high performing stations are identified. Second, a strategy for implementing the core attributes at the stations that have not yet achieved sustained high performance levels is suggested.

To fulfill this purpose, a three-part approach was taken. First, nuclear power stations that have achieved sustained high levels of safety and economic performance were identified. Although there are many ways that this identification could be accomplished, the technique used in this thesis was straightforward and used well-established information. All U.S. nuclear power stations were force ranked by a nine-year average of NRC Systematic Assessment of Licensee Performance (SALP) score, INPO assessment, INPO performance indicator index, and by a five-year average FERC operating, maintenance, and fuel cost per megawatt-hour. More detailed information on the selection technique and on the NRC SALP scores, INPO assessments, INPO performance indicator index, and FERC cost data is provided in Section 3.0, Identification High Performing Stations.

Second, core attributes that have contributed to the sustained high level of nuclear power station safety and economic performance were identified in two ways. A symptom classification analysis was performed on the effective programs and practices, called strengths, identified during INPO evaluations of its members' stations. A symptom classification analysis was also performed on the results of interviews conducted with nuclear power plant executives. These executives either currently work for or have worked at the previously identified high performing plants. The results of the two symptom classification analyses were then further analyzed to produce a set of core attributes that represent the programs, processes, and practices that are necessary to achieve sustained high performance.

Third, a strategy for implementing the core attributes is suggested. The strategy recognizes each station has unique reasons for not having achieved a sustained high level of performance. The strategy also recognizes that the core attributes are interrelated and that the positive effect of having all the attributes is greater than the sum of the attributes separately.

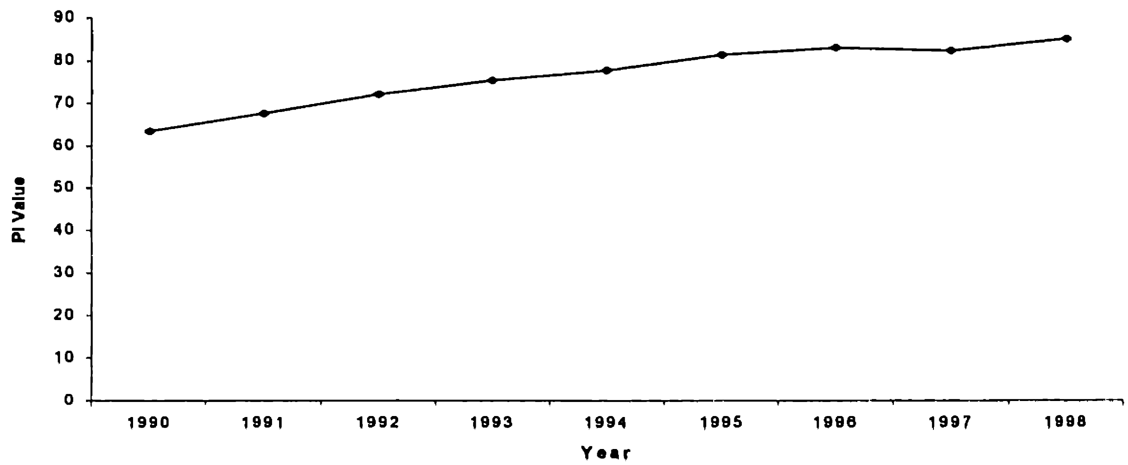

Figure 1 Performance indicator index improvement

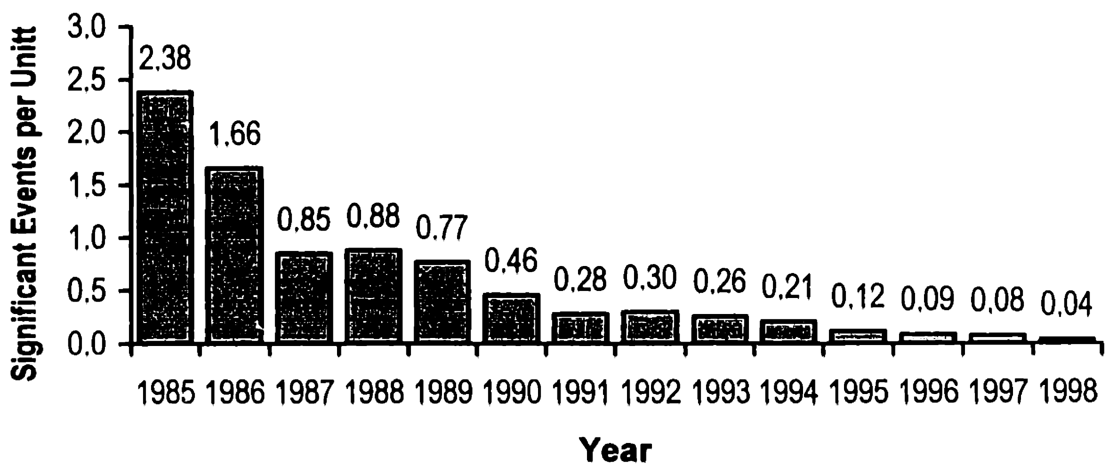

Figure 2 Significant events, annual industry averages (excluding plants in extended or permanent shutdown)

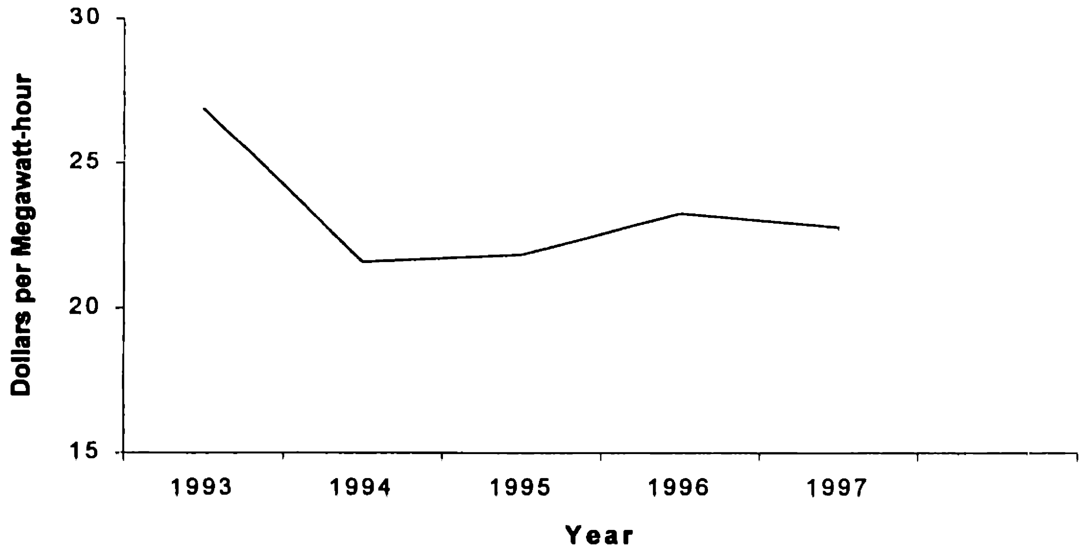

Figure 3 Operating, maintenance, and fuel cost

2.0 BACKGROUND

For nuclear power stations in the U.S. to continue to operate to the end of their licensed life (and perhaps beyond given the prospect of license extension) they must be operated safely. The mandate to operate safely has been made more challenging in recent years by increasing pressure to also operate economically. This chapter provides some background information on the link between safe and economical operation and also on the legislative changes that have caused the increased economic pressure.

The necessity to operate safely has long been recognized and pursued by nuclear professionals. The reactor safety record of U.S. stations is impressive and continues to steadily improve. Since the accident at Three Mile Island Unit 2 in March 1979, there have been no core damaging events at U.S. nuclear power stations. Additionally, the number of significant events per plant has also been steadily declining. (Figure 2) Recently, utilities that operate nuclear power stations have been challenged to improve the economic performance of their stations while maintaining or continuing to improve safety performance. The link between safety and overall performance, including economic performance, is strong and was clearly stated in the 1984 INPO Performance Indicator Report (1):

> *"... it is widely recognized that nuclear plants with high equivalent availability, small numbers of forced outages, few unplanned scrams, few significant events, and low personnel radiation exposures are generally well managed overall. Such plants are more reliable and can be expected to have higher margins of safety."*

The pressure to operate nuclear power stations economically is the result of a fundamental change in the way electric utilities are regulated. Since the 1930s, the

U.S. electric utility industry has consisted of regulated companies with two key characteristics:

- They were monopolies with exclusive franchises allowing them to sell electric power within their service territories at prices determined by state regulatory agencies; and
- They were typically vertically integrated companies, engaged in the business of generating electricity, long-haul transmission, and local distribution.

This traditional structure is changing as electric utilities separate electricity generation, transmission and distribution into distinct business units or into separate companies. Electricity generation is now a competitive business, and non-utilities play a major role. The interstate transmission system is open to all generators of electricity to ensure that all producers have access to customers. Congress and most states are considering, and a number have enacted, legislation to require competition at the retail level.

Competition in the electric power industry has been developing for almost 20 years. Four key events and trends shaped the emergence of competition in the electricity business:

> **The Public Utility Regulatory Policies Act (PURPA)** - Enacted in 1978, PURPA was intended to encourage more efficient use of oil and natural gas through cogeneration. PURPA allowed companies to build cogeneration plants and required regulated electric utilities to buy that electricity. PURPA opened the door to competition, and a new type of company emerged, independent power producers not affiliated with regulated utilities.

Competitive Bidding - Under the traditional system, electric utilities built new power plants when needed. Starting in the 1980s, most states required competitive bidding for new supply. Because PURPA had lowered the barriers to entry in electricity generation, competition to supply electricity became intense. Independent producers built almost half of all new generating capacity in the United States between 1985 and 1995. (2)

The Energy Policy Act - This legislation required competition at the wholesale level and required electric utilities to allow independent power producers open access to transmission lines.

Order 888 - In 1996, to implement the Energy Policy Act, FERC mandated competition among electricity suppliers at the wholesale level. It also mandated open access to the transmission system.

During debate on the 1992 Energy Policy Act, Congress did not mandate retail competition in the electric power business, leaving that decision to the states. At the time, however, it was recognized that wholesale competition was simply a first step, and that all electricity users—industrial, commercial and residential—would sooner or later demand the freedom to choose their electricity supplier.

Virtually all states now have regulatory proceedings under way, or are considering legislation, to restructure their electric utilities and require full competition. Fourteen states—Arizona, California, Illinois, Maine, Massachusetts, Michigan, Montana, Nevada, New Hampshire, New York, Oklahoma, Pennsylvania, Rhode Island and Vermont have passed legislation or issued final regulatory orders. (2)

Most U.S. nuclear power plants are well positioned for the new competitive environment. Measured by production cost (the cost of operating, maintaining and fueling a power plant), the average cost of electricity from U.S. nuclear power plants in 1996 was approximately 0.08 cents per kilowatt-hour higher than for coal-fired power plants, but was 1.47 cents and 2.23 cents per kilowatt-hour less expensive than plants fueled with natural gas or oil respectively. (2)

3.0 IDENTIFICATION OF HIGH PERFORMING STATIONS

This chapter identifies the nuclear power stations that have achieved and sustained high levels of both safety and economic performance over the last several years. The method used to identify these stations, the indicators of plant safety and economic performance to support the method, and detailed descriptions of the indicators are provided.

Safety and economic performance can be measured in many different ways. Most utilities have unique goals and a set of indicators that are monitored to measure the degree of achievement of the goals. No single indicator adequately represents both safety and economic performance. Some indicators focus primarily on safety, others solely on economic performance, and others are a blend of both safety and economics. In order to identify the long-term high performing plants, it was important to select indicators that:

- Compared plant safety and economic performance consistently as possible from station to station,
- Had been in existence long enough to assure that sustained, as opposed to recent, high performance could be identified, and
- Taken as a group, were representative of both station safety and economic performance.

The indicators used to identify the high performing stations were the INPO plant assessment, the INPO performance indicator index, the NRC SALP score, and the FERC operating and maintenance cost data. Each of these indicators is explained in detail below.

All U.S. nuclear power stations were force ranked by a nine-year average of NRC SALP scores, INPO assessments, and World Association of Nuclear Operators (WANO) Performance Indicator Indexes and by a five-year FERC average operating, maintenance, and fuel cost per megawatt-hour. A composite list was then formed by identifying stations that appeared on two or more of the lists. Finally, several INPO managers reviewed the composite list. The high performing stations are shown in Table 1. The names of the stations have been changed to preserve the privacy of the interactions between INPO and its members.

Station Name
Summit
Pinnacle
Peak
Superior
Apex
Acme
Tops

Table 1 Long-term high performing stations

The INPO review of the composite list, while qualitative, was important. INPO managers work closely with the managers at all U.S. nuclear powers stations and are familiar with both recent and long-term performance achieved by the stations. The review of the composite list allowed the judgment and experience of the managers to be applied to the quantitative rankings. Two stations were omitted from the high performing plant list as a result of this review due to recent performance declines that had not yet been reflected in the performance indicators.

3.1 INPO Assessment Process (3)

INPO was established in 1979 as part of the nuclear industry's response to the accident at the Three Mile Island power plant. All U.S utilities with operating licenses or construction permits for nuclear power plants were involved in INPO's development and all became members soon after the Institute was formed. Since that time, all organizations having direct responsibility and legal authority to operate or construct commercial nuclear electric generating plants in the United States have maintained continuous membership in the Institute.

The mission of the Institute is to promote the highest levels of safety and reliability – to promote excellence – in the operation of nuclear electric generating plants. In carrying out this mission, the Institute's technical programs are organized as four cornerstones. These cornerstone programs are:

> **Evaluation Programs** – Evaluations are conducted regularly (every 12-24 months) of nuclear power plants operated by member utilities. In these evaluations, INPO teams use standards of excellence based on experience and best practices. Written performance objectives and criteria are used to guide the evaluation process. These evaluations form the basis for the INPO assessment value, described in more detail below.

> **Training and Accreditation Programs** – INPO interacts with all members in preparing for, achieving, and maintaining accreditation of training programs for personnel involved with the operation, maintenance, and technical support of nuclear plants. These interactions include evaluation of accredited training programs, activities to verify that the standards for accreditation are maintained, and assistance at the request of member utilities. Written objectives and criteria are used to guide the accreditation process.

Event Analysis and Information Exchange Programs – The events analysis program is designed to identify precursors of potentially more serious events and the root causes of these events. Off-normal events that occur in the operation of nuclear plants are analyzed by INPO. Lessons learned are disseminated to members.

INPO operates extensive computer databases to provide members access to an electronic information exchange system. These databases include information on plant performance, operating experience, and equipment reliability.

Assistance Programs – Visits to member utilities by INPO personnel and industry peers in response to utility requests are one of the most important ways assistance is provided. This assistance deals with specific technical concerns, as well as broader management and organizational issues.

As part of the 1983 INPO Chief Executive Officer (CEO) Workshop, INPO prepared a set of indicators for each nuclear station that reflected the station's participation in and commitment to INPO programs. This information was provided to each CEO. One of these indicators was an assessment of each station's overall performance based on INPO evaluations to date and the judgment of INPO's management team. In reviewing overall station performance, it was found that the top and bottom performers were relatively easy to identify through the evaluation process, but that a station's relative position in the (broad) middle was difficult to determine.

It was decided that an assessment of overall station performance in the context described above would be made after each evaluation and shared privately with the CEO or senior utility manager. Such a process was determined to be in

1	Excellent. Overall performance is excellent. Industry standards of excellence are met in most areas. No significant weaknesses noted.
2	Overall performance is exemplary. Industry standards of excellence are met in many areas. No significant weaknesses noted.
3	Overall performance is generally in keeping with the high standards required in nuclear power. However, improvements are needed in a number of areas. A few significant weaknesses may exist.
4	Overall performance is acceptable, but improvements are needed in a wide range of areas. Significant weaknesses are noted in several areas.
5	Overall performance does not meet the industry standards of acceptable performance. The margin of nuclear safety is measurably reduced. Strong and immediate management action to correct deficiencies is required. Special attention, assistance, and follow-up are required.

Table 2 INPO Assessment category definitions

keeping with INPO's responsibility to the individual CEO and to its members for identifying the industry's low performing nuclear plants and for stimulating improvement in performance.

In September 1985, a refinement to the process was added whereby the "broad middle" assessment category was divided into three categories: "above middle," "middle," and "below middle." In addition, the "high" and "low" categories were retitled "excellent" and "marginal," although they remain the same in concept. In addition, a numerical identifier was assigned to each category. These were (1) for excellent, (2) above middle, (3) middle, (4) below middle, and (5) marginal. In October 1986, the adjective descriptions of performance categories were dropped, except for category (1) which continues to be called EXCELLENT, see Table 2.

Following each plant evaluation, an assessment of performance in several areas is determined. Area assessments categorize the station's performance as 1, 2, 3, 4, or 5. These area assessment categories are conceptually the same as those used for overall performance. Areas assessed by INPO for each plant evaluation include; organizational effectiveness, human performance, equipment performance and materiel condition, operations, maintenance, engineering, and several others.

After the individual area assessments are complete, the team manager responsible for the plant evaluation and other senior INPO managers conduct a comprehensive review of the overall strengths, findings, and plant performance information to determine the overall performance assessment for the station. A meeting among the INPO team manager, an INPO senior manager, the utility CEO, and key members of the station management team is then held to discuss the strengths, findings, and overall performance assessment.

3.2 INPO Performance Indicator Index (4)

The performance indicator index was developed as an internal tool for INPO management to consider the value and trend of a plant's performance indicators in the aggregate (see below for a discussion of the performance indicators) as an input to the plant evaluation assessment process. The performance indicator index has a value of 0 to 100 and is calculated from a weighted combination of the ten overall performance indicator values. A higher index represents stations with generally better overall performance.

The performance indicator index has served as a useful tool when considering trends in nuclear station performance as measured by the performance indicators. The index focuses attention on overall station performance and does not place undue emphasis on any single indicator.

For purposes of the index, two-year average values of individual performance indicators are used to allow the index to be more responsive to changes in plant performance. The zero to 100-point range is scaled to encompass a range of individual plant performance to allow discernment among plants, and to respond to changes in plant performance.

The detailed definitions of the individual performance indicators and the weighting factors assigned to them are constantly reexamined and refined. The definitions that follow are representative of the values in use now, recognizing that they have varied slightly over the years.

Performance Indicator Definitions (5)

Unit Capability Factor – Unit capability factor is the percentage of maximum energy generation that a plant is capable of supplying to the electrical grid, limited only by factors within the control of plant management. A high unit capability factor indicates effective plant programs and practices to minimize unplanned energy losses and to optimize planned outages

Unplanned Capability Loss Factor – Unplanned capability loss factor is the percentage of maximum energy generation that a plant is not capable of supplying to the electrical grid because of unplanned energy losses, such as unplanned shutdowns or outage extensions. A low value indicates important plant equipment is well maintained and reliably operated and there are few outage extensions.

Unplanned Automatic Scrams – The unplanned automatic scrams per 7000 hours critical indicator tracks the median scram (automatic shutdown) rate for approximately one year (7000 hours) of operation. Unplanned automatic scrams result in thermal and hydraulic transients that affect plant systems.

Safety System Performance – The safety system performance indicator monitors the availability of three important standby safety systems to mitigate off-normal events. The industry's goal is to encourage a high state of readiness for these systems.

The safety systems monitored for pressurized water reactors are high-pressure injection, auxiliary feedwater, and emergency AC power (diesel generators). The systems monitored for boiling water reactors are high pressure injection and heat removal (a combination of high pressure core spray, reactor core isolation cooling, and isolation condenser (depending on the design of the plant), residual heat removal, and emergency AC power (diesel generators).

Thermal Performance – Thermal performance monitors how efficiently a plant converts thermal energy into electrical output. Plants measure thermal performance by comparing the best achievable heat rate to the heat rate actually attained.

Fuel Reliability – The fuel reliability indicator monitors progress in preventing defects in the metal cladding that surrounds fuel. The long-term industry goal is that units should strive to operate with zero fuel cladding defects, even though minor defects pose no significant safety concern and are difficult to eliminate entirely.

Chemistry Performance – The chemistry performance indicator monitors operational chemistry control effectiveness as measured by the concentration of important impurities and corrosion products. In boiling water reactors, the indicator focuses on reactor coolant chemistry control. In pressurized water reactors, the focus is on secondary system chemistry.

Collective Radiation Exposure – The collective radiation exposure indicator monitors the effectiveness of personnel radiation exposure controls. Low exposure indicates strong management attention to radiological protection.

Volume of Solid Radioactive Waste – This indicator monitors the volume of solid radioactive waste that is produced per unit for pressurized water and boiling water reactors. Minimizing radioactive waste reduces storage, transportation, and disposal needs and lessens the environmental impact of nuclear power.

Industrial Safety Accident Rate – The industrial safety accident rate tracks the number of accidents that result in lost work time, restricted work or fatalities per 200,000 worker-hours.

3.3 NRC Systematic Assessment of Licensee Performance (6)

Although the SALP process is no longer in use by the NRC, it was actively used during the time period from 1990-1998, when the other indicators used to select the high performing station were also in use. Therefore, the NRC SALP scores provided a means to compare consistently station safety performance over a long time period.

The SALP process is used to:

- Conduct an integrated assessment of station safety performance that focuses on the safety significance of the NRC findings and conclusions during an assessment period.

- Provide a vehicle for meaningful dialogue with the licensee regarding its safety performance based on the insights gained from synthesis of NRC observations.

- Assist NRC management in making sound decisions regarding allocation of NRC resources used to oversee, inspect, and assess licensee performance.

- Provide a method for informing the public of the NRC's assessment of licensee performance.

The NRC reviews and evaluates each power reactor licensee that possesses an operating license or a construction permit every 12 to 24 months. The regional administrator determines the exact frequency within this interval on the basis of the station's performance.

Members of the resident inspector staff and other NRC staff members with inspection responsibilities or oversight functions develop background information for the SALP board. Sources of background information include the following: inspection report findings, licensee events, enforcement results, information from safety evaluation reports, the outcome of licensee and NRC management meetings, results of periodic plant performance reviews, and other performance information.

The SALP board produces an assessment for each functional area on the basis of the information and staff briefings. The assessment addresses the observed performance and places it in context with plant safety. The SALP board members ensure that each functional area concisely conveys the board's views, with selected examples to illustrate key findings. SALP board members discuss characteristics of a licensee's performance in a functional area and the common themes or symptoms that extend through multiple functional areas. The SALP board recommends a category rating for each functional area. The board forwards its assessment of performance and recommendations for category ratings to the regional administrator.

The four standard functional areas for operating reactors are:

- **Plant Operations** - This functional area consists of the control and execution of activities directly related to operating the plant. It includes activities such as plant startup, power operation, plant shutdown, and system lineups. It also includes activities such as monitoring and logging plant conditions, normal operations, response to transient and off-normal conditions, adequacy and implementation of emergency operating procedures and abnormal operating procedures, manipulating the reactor and auxiliary controls, and control room professionalism. Initial and requalification training of licensed operators are also included.

- **Maintenance** - This functional area includes all activities associated with diagnostic, predictive, preventive, or corrective maintenance of plant structures, systems, and components, or maintenance of the physical condition of the plant, and training of the maintenance staff. It also includes conduct of all surveillance testing activities, all inservice inspection and testing, instrument calibrations, equipment operability tests, post-maintenance testing, post-outage testing, containment leak rate tests, and special tests.

- **Engineering** - This functional area addresses the adequacy of technical and engineering support for all plant activities. It includes all licensee activities associated with design control; the design, installation, and testing of plant modifications; engineering and technical support for operations, outages, maintenance, testing, surveillance, and procurement activities; configuration management;

design-basis information and its retrieval; training of the engineering staff; and support for licensing activities.

- **Plant Support** - This functional area includes all activities related to plant support functions, including radiological controls, emergency preparedness, security, chemistry, and fire protection. It includes all activities associated with occupational radiation safety, radioactive waste management, radiological effluent control and monitoring, transportation of radioactive materials, licensee performance during emergency preparedness exercises and actual events that test emergency plans, emergency plan notifications, interactions with onsite and offsite emergency response organizations during exercises and actual events, and safeguards measures that protect plant equipment, including physical security, fitness for duty, access authorization, and control of special nuclear material. Housekeeping controls and training of the staff are included in this area.

A category rating is given for each of the functional areas described above. The definitions for each of the ratings are as follows:

Category 1- Station attention and involvement have been properly focused on safety and resulted in a superior level of safety performance. Station programs and procedures have provided effective controls. The licensee's self-assessment efforts have been effective in the identification of emergent issues. Corrective actions are technically sound, comprehensive, and thorough. Recurring problems are eliminated and resolution of issues is timely. Root cause analyses are thorough.

Category 2 - Station attention and involvement are normally well focused and resulted in a good level of safety performance. Station programs and procedures normally provide the necessary control of activities, but deficiencies may exist. The licensee's self-assessments are normally good, although issues may escape identification. Corrective actions are usually effective, although some may not be complete. Root cause analyses are normally thorough.

Categories 3 - Station attention and involvement have resulted in an acceptable level of safety performance. Station programs and procedures have not provided sufficient control of activities in important areas. The station's self-assessment efforts may not occur until after a potential problem becomes apparent. A clear understanding of the safety implications of significant issues may not have been demonstrated. Numerous minor issues combine to indicate that the licensee's corrective action is not thorough. Root cause analyses do not probe deep enough, resulting in the incomplete resolution of issues. Because the margin to unacceptable performance in important aspects is small, increased NRC and licensee attention is required.

3.4 Federal Energy Regulatory Commission Cost Data

The Federal Energy Regulatory Commission is responsible for overseeing the operations of key parts of America's energy industries: electric utilities, hydropower facilities, and natural gas and oil pipelines. The Commission ensures that consumers receive adequate, reliable supplies of energy at the lowest possible price, and provides energy suppliers and transporters a just and reasonable return on capital investment and the opportunity to adjust to rapidly changing market conditions.

FERC also collects data on the cost of producing electricity at these facilities. This data is reported on FERC Form 1 and includes the costs to operate, maintain, fuel, and improve (capital expenditures) the facilities. The average annual operating, maintenance, and fuel costs reported in dollars per megawatt-hour was used for this thesis.

4.0 HIGH PERFORMING STATION STRENGTHS AND EXECUTIVE INSIGHTS

This chapter describes the information and methods used to identify the core attributes of the high performing stations. The information consists of programs and practices that have been found to be effective during INPO evaluations of the high performing stations and interviews with executives from these stations. A symptom classification analysis of the information was performed to identify the core attributes. The core attributes are discussed and their role in achieving sustained high performance is explained in Section 5.0.

4.1 High Performing Station Strengths

Performance-based evaluations are a key element of INPO's mission. During these evaluations, teams of INPO and utility personnel conduct detailed inspections, extensive interviews with site personnel, and compare plant performance to standards of excellence based on broad industry experience and best practices. Programs or practices that are found to be particularly effective are called "strengths" and are documented in the evaluation report and are shared with other plants.

At the high performing plants, and indeed at any currently operating nuclear power plant, a large number of programs, practices, and activities are performed to a very high standard. The evaluation teams do not attempt to document all of these programs and practices. Rather, the teams attempt to identify those programs and practices that are particularly effective and that play a key role in the success of the plant.

An analysis of these strengths using a standard symptom classification technique was performed. A symptom classification technique is an analysis technique that organizes and identifies themes or common attributes of large amounts of qualitative data. Each data element, in this case the strengths, is reviewed and the central theme(s) identified. The themes are then grouped and reported. The symptom classification analysis for the high performing plant strengths is shown as Table 3, Symptom Classification for High Performing Plant Strengths.

4.1.1 SUMMIT

A multidisciplined team has developed effective actions to minimize the effects of heavy influxes of ocean debris at the intake structure. A thorough technical review was conducted by representatives from the environmental operations, operations, maintenance, engineering, and material services departments. Operations procedures were revised to establish an overall strategy and simulator scenarios were developed to better prepare operators to respond to intake debris problems. Also, equipment performance was enhanced by design modifications and improved maintenance practices. Many of the recommended changes have been effectively implemented as indicated by no lost generation from intake debris problems during the 1996 storm season. Long-term improvements such as the installation of a debris grinder in the refuse sumps, the purchase of a second kelp cutter to provide maximum availability, and additional screen enhancements to improve structural integrity and debris removal are scheduled for implementation in 1997.

Control room operators effectively use peer-checking practices for routine component operation, verification of expected alarms, and reduction of human errors. Prior to performing a control room activity such as paralleling and loading an emergency diesel generator, operators request a peer check from another operator. The peer verifies the correct component prior to a manipulation. When specific detail is important, the peer will state the direction a switch should be turned for making an adjustment. Additionally, control operators request a peer check on the first receipt of an alarm to verify that the annunciator was caused by an authorized activity.

Timely repairs and reduced work backlogs have resulted from effective implementation of the Fix-It-Now team. The team provides a strong operational focus on equipment repair. The team is a multidiscipline maintenance group composed of mechanics, electricians, instrumentation technicians, and a licensed operator. The team works primarily on emerging corrective maintenance activities. The team reviews all new work in detail to more effectively distribute the work to the appropriate work groups during the daily planning meetings. This has reduced work reassignments and delays in performing maintenance activities.

The following benefits have been attained by the team approach:

a. Sixty percent of new corrective maintenance work is performed by the team, with the remaining work performed by maintenance crews.

b. The team has significantly reduced oxygen concentrations in secondary plant systems through timely repair of leaks.

c. Operations personnel indicated that equipment problems affecting operations are resolved in a timely manner, with many resolved the day they are discovered.

Strong management emphasis and support are developing a high degree of health physics technical expertise. Health physics technical staff personnel provide practical timely resolutions to technical problem areas and have enhanced their credibility and the confidence of plant personnel and industry peers. Noteworthy accomplishments resulting from management emphasis and support include the following:

a. attaining a high degree of accuracy and precision in the processing of thermal luminescent dosimeters

b. aggressively pursuing resolution of problems and improving the performance of personal electronic dosimeters and supporting software

c. developing a comprehensive desktop guide and instructions for dosimetry clerks -- These instructions allow less experienced personnel to accurately and completely perform the specialized dosimetry clerk tasks with minimal supervision.

d. technically supporting an effective ALARA program that has been integrated into other work groups such as work planning, high intensity teams, and engineering

e. developing a simplified method using common field measurement techniques for field personnel to determine the equivalent derived air concentrations and correlation to alpha emitters that reflect the actual physical and chemical characteristics of the airborne radioactive material

f. providing on-site training and certification testing for the National Registry of Radiation Protection Technologists -- A significant portion of the radiological protection staff has achieved this certification.

Additionally, there are six health physicists certified by the American Academy of Health Physics.

The influence of this technical expertise is felt outside of the utility because radiological protection personnel are actively supporting over 20 industry standards committees and users groups. Through this participation, they are able to help ensure that appropriately high standards of performance are reflected in the development of industrywide guidance in the radiological protection area.

The generation of low-level radioactive waste has continued to be reduced as a result of plantwide support and innovative volume reduction approaches. There has been a continuing trend of improved performance in radioactive waste reduction, and the station has become an industry leader in effectively applying waste reduction techniques. The following have been effectively used to reduce radioactive waste:

a. Cross-functional support of radioactive waste minimization has been fostered by strong management support and high intensity team leadership. All personnel have been sensitized to the need for waste minimization through training and in-field coaching.

b. Unnecessary material is effectively excluded from entry into the radiologically controlled area.

c. Recyclable and incinerable consumable materials are almost exclusively used in radiologically controlled area.

d. Innovative approaches to analyzing and characterizing waste streams and then developing techniques to further improve specific waste stream performance have been effectively employed to reduce waste volume. These techniques have also been effective in reducing the volume of mixed waste (radioactive and chemical hazard) that is difficult and costly to dispose of.

Chemistry personnel routinely conduct extensive benchmarking of industry chemistry programs, resulting in program enhancements such as improved use of primary coolant demineralizers for lithium and impurity control and detection of chlorides in closed cooling water systems by ion chromatography. In addition, benchmarking has enhanced site and laboratory chemical control programs.

A document to capture specific information was developed and used on benchmarking visits. Each trip was made with a chemistry team that included a technician, a supervisor, and technical support individuals. Trip reports are written by each team member.

Significant improvements in nonlicensed operator continuing training have resulted from effective line ownership of the training program. Nonlicensed operators serving on a subcommittee to the operations continuing training steering committee established a list of priorities for improving the training program and have made several improvements based on those priorities. For example, nonlicensed operators analyzed and updated the task list and qualification cards based on feedback from each crew. In addition, the nonlicensed operators established feedback processes to continuously identify and provide solutions to training problems and to determine the effectiveness of training. The following items were noted:

a. The nonlicensed operator subcommittee includes a representative from each crew. A nonlicensed operator instructor facilitates subcommittee meetings, and recommendations are approved by the operations continuing training steering committee that includes management representatives. This process provides direct nonlicensed operator input to the steering committee and operations management oversight of subcommittee activities. In addition, training provides consultation on processes such as the systematic approach to training that are important to the effectiveness of training.

b. Nonlicensed operator feedback is effectively incorporated into the training program. The following are examples of changes based on operator feedback:

    1. Continuing training focuses on a specific watchstation each cycle and is conducted on important systems and procedures. In addition, watchstation logs are reviewed during training with an emphasis on the reasons for recording specific parameters with applicable setpoints, precautions, and limitations.

    2. Applicable theory is incorporated into system training. For example, recent training on the electrohydraulic control system for the main turbine included a review of the principles of fluid viscosity.

    3. Troubleshooting techniques are included in some lectures to enhance the nonlicensed operators' abilities to provide control room operators with more useful information when reporting

problems. For example, training was recently given on troubleshooting during operator rounds. The purpose of the training was to review problems that might be identified during rounds and to determine the potential causes of those problems.

c. The nonlicensed operators on the subcommittee revised the nonlicensed operator qualification card after receiving operator feedback. Several tasks were added to the qualification card, including some that had been previously deselected for training.

d. All nonlicensed operators interviewed stated that training has been significantly improved since the inception of the subcommittee. In addition, they said training was improved because a nonlicensed operator on loan from the plant was now the primary instructor and brought recent plant knowledge and experience into the classroom.

Improvements were made to the nonlicensed operator continuing training program because operators self-identified potential weaknesses in their abilities to effectively perform duties. Although specific performance problems were not identified, the nonlicensed operators felt their knowledge and skill needed upgrading to ensure a continued high level of performance. Evaluators noted that nonlicensed operators effectively carried out duties and exhibited a high level of system and component knowledge.

An effective tracking system automatically and easily identifies reactor mode change constraints during outages. As a result, mode changes performed over the past several outages have been effectively executed. A specialized computer program was developed for the plant information management system that tracks and identifies all maintenance and modification-related activities to outage modes. Each outage-related work document is coded with an operational or testing mode in which it must be completed. Searches can be easily performed for any outage document that requires action before the reactor mode is changed. Additionally, efforts to identify testing and work document closeout are executed in a timely manner.

Detailed planning has contributed to well run unscheduled outages. The planning process subdivides the work scope for an unscheduled outage into committed work and approved potential work. The committed and approved potential work lists provide status of the associated work orders, support activities, clearance numbers, applicable operating mode for the work, job duration, and number of people to do the work. Following an event, managers select unscheduled outage work to be done from the approved potential work list.

Committed work is typically the required surveillance tests performed during the reactor shutdown and startup for each mode of operation. This work is sequenced on a detailed schedule and reviewed by operations and maintenance representatives for correctness.

Approved potential work is a list of corrective maintenance that should be worked in the event of an unscheduled outage. Additions to the approved potential work list are considered weekly based on action requests generated in the previous week. The entire list is reviewed monthly by outage services supervisors, operations scheduling supervisors, maintenance supervisor representatives, a materials representative, and an engineering representative. A work order package for a new action request is completed within three weeks of the item being added to the list.

Operations and maintenance personnel stated that using the unscheduled outage plan allowed the post-trip activities to be executed in a timely, effective, and controlled manner during the November 1996 Unit 1 outage. In another example, the outage services scheduler stated that a contingency outage schedule for a degrading main generator hydrogen seal was prepared by having the basic template for an unscheduled shutdown already completed.

The chromium content of carbon steel piping is monitored to aid in determining appropriate inspection intervals for flow accelerated corrosion. Inspection data has shown a correlation between chromium content of carbon steel pipe and flow accelerated corrosion rate. These results were confirmed with independent laboratory examinations. Chromium composition varies greatly because of the carbon steel used. Manufacturer specifications allow up to 0.4 percent chromium by weight.

Experience and testing have shown that a 0.1 percent or higher chromium level in piping with single-phase flow significantly reduces flow accelerated corrosion. The station has identified the system piping that satisfies this specification and verified, through inspection results, that flow accelerated corrosion rates are low enough to not exceed minimum wall thickness throughout plant life. This correlation is further validated by monitoring the iron transport values associated with each unit. The number of outage piping inspections and iron transport values are lower for the unit with a chromium content greater than 0.1 percent.

The chromium content of each section of piping is measured by using a simple spark gap test device that performs a spectrum analysis on the sample gas obtained. In addition to a reduction in pipe wall thinning for sections with chromium content, the knowledge of each section location provides the following additional benefits:

a. The amount of testing is reduced by eliminating monitoring for wall thinning on all pipe with chromium content greater than 0.1 percent.

b. Only pipe locations with less than 0.1 percent chromium content are tested to prevent possible false conclusions as to the condition of the complete system.

4.1.2 PINNACLE

Management use of the Independent Safety Engineering Group (ISEG) in day-to-day activities has promoted a station culture focused on nuclear safety. The following practices were noted:

a. ISEG involvement during the planning and execution phases of refueling outages contributes to the safe and efficient conduct of these outages. Prior to an outage, ISEG performs a comprehensive review of the outage schedule to identify periods of reduced safety margin and to verify contingency plans are provided for periods when defense-in-depth is reduced. During outages, an ISEG representative provides 24-hour shift coverage and participates in the shift turnovers of operating crews. During the turnovers, the ISEG representative makes presentations on key safety functions and, at appropriate times, presents the operating crews with the time to boiling upon loss of decay heat removal capability. An ISEG representative also reviews changes to the outage schedule to determine any impact the changes would have on key safety functions.

b. During plant operations, ISEG personnel perform independent reviews of station programs, equipment performance, and plant operational events and make recommendations for improvement to enhance plant safety and performance. Topics for review are based on industry initiatives, equipment history, and industry operating experience. Recent examples of these independent, in-depth reviews include a historical review of turbine-driven emergency feedwater pump maintenance, a functional inspection of the fire service safety system, a review of the calorimetric program, and a review of an inadvertent dilution event caused by a failed boric acid valve.

c. Throughout the operating cycle, ISEG personnel make monthly presentations at the plan-of-the-day meeting to increase awareness of the importance of nuclear safety. The topics of these presentations include items currently under ISEG review, industry operating experience, and the station operating and outage safety philosophy.

Strong management support of benchmarking activities has resulted in several process enhancements. Management actively encourages personnel to benchmark the industry through participation in various industry forums such as user group meetings, EPRI and INPO workshops, and joint utility audits and assessments. Approximately 50 of these interactions occurred during the first six months of 1997. Improvements have been implemented as a direct result of these benchmarking activities and industry interactions. The following enhancements were noted:

a. As a result of chemistry benchmarking visits to two other plants to review auxiliary system corrosion monitoring, three new procedures were implemented to improve oversight of auxiliary system corrosion control.

b. Outage benchmarking visits have identified several potential improvements to the outage process. For example, during the fall 1997 outage, the station plans to use a special underwater reactor vessel flange cleaning device to reduce dose. The station also plans to use the work window manager concept for all major work areas and systems to reduce outage rework and delays and to increase efficiency.

c. Operations benchmarking visits provided input for the development of a new danger tag program. The new program includes on-line control room supervisor and shift supervisor logging and text search capability. The station plans to interface the tagging program with the maintenance database, providing greater reliability for tagging of equipment.

d. Radiation protection benchmarking visits identified several opportunities for improvement. For example, during one visit, a new radon discriminating survey instrument was observed in use. As a result, personnel are evaluating use of this instrument. During another visit, a machine for manufacturing standardized radiological postings was noted. The station plans to purchase the machine to enhance its program.

e. Security benchmarking visits resulted in the implementation of a biometrics hand monitoring system.

Shift operating crew members exhibit effective communication and conduct activities in a way that minimizes control room distractions. Clear written standards and consistent reinforcement of expectations by managers, supervisors, and trainers contribute to the effectiveness of these practices. The following effective practices were observed:

a. Crew communication practices during simulator and control room operations and simulated events support individual and crew understanding of plant conditions. The following are examples:

   1. Crew members consistently repeat back directions to gain confirmation of the message. During simulated events, this practice contributed to the appropriate correction of minor miscommunications prior to operator action.

   2. Operators report incoming annunciator alarms and control rod movements to other crew members. In addition, during simulated events, the operators provided the values and trends for board indications to the control room supervisor. These communications allowed the supervisor to better understand changing plant conditions.

   3. The shift supervisor used summary briefings during simulated component failures to keep the crew informed of ongoing support actions related to the failures.

b. Control room activities are conducted in a manner that reduces crew distractions. The following specific controls and physical enhancements are implemented:

1. Control room access is only by permission of the control room supervisor. Access to the control board area is only by permission of the operator at the controls.

2. A phone is provided at the entrance to the control room to obtain access permission. Carpeting in the control room deadens sound and marks the restricted control board area.

3. The control room tagging desk is located such that personnel traffic through the control room is avoided.

The shift turnover process results in an accurate exchange of important information. The process incorporates the means to resolve information discrepancies prior to crew members accepting the watch. The following describes key elements of the turnover process:

a. Each oncoming crew member receives turnover information from his or her respective counterpart. The oncoming crew then meets to discuss the information provided from the on-duty crew. Discrepancies are resolved in the meeting and are confirmed by discussion with the counterparts prior to accepting the watch.

b. During the turnover meeting for the first workday of the week, the shift engineer provides a summary of changes to plant status that have occurred since the last time the crew was on duty.

c. The shift supervisor discusses new administrative information and identifies potential risks concerning the day's tasks.

d. Representatives from various support groups such as chemistry, health physics, and engineering services attend the crew briefing. This allows for discussion on the day's priorities and improves cognizance of planned activities.

e. The process is supported by clear written standards. Forms are used for each crew position to list turnover information. These forms are reviewed by the shift supervisor during the first part of the shift.

Response to degraded instrument and controls equipment conditions is improved through the development and use of preapproved troubleshooting procedures. Currently, 25 troubleshooting procedures provide guidance in diagnosis and correction of problems ranging from individual components to a complete control panel. For example, the procedures describe the consequences of deenergizing instrument power supplies and list steps for replacing key components.

The use of preapproved procedures helps reduce errors in planning a repair activity and has increased timeliness in responding to abnormal conditions. The procedures also improve the consistency with which a problem is diagnosed and corrected. Examples of available troubleshooting procedures include source and intermediate range nuclear instrument alignment, on-line work on feedwater isolation valve controls, and rod control troubleshooting.

Three-phase breaker testing has increased 480-volt AC breaker reliability. Station staff developed a testing device and associated procedures to simultaneously check test currents on three phases of a 480-volt breaker. This has increased breaker reliability by allowing identification of problems overlooked by the single-phase testing previously used. The single-phase breaker testing process would permit faults on some breakers to pass the testing process; for those breakers, overcurrent trips would occur following installation. Examples of problems previously overlooked and now identified by the three-phase testing process include the following:

a. wire crossover on the current transformers in the power shield

b. upside-down or otherwise incorrectly installed current transformers

c. wire crossover to the current transformer in the breaker

d. faulty wiring on the power shield, including current transformer secondary wiring problems

The breaker testing procedures include all mechanical and electrical measurements and adjustments needed to set up the breaker for proper operation. The breaker testing device can be easily modified to test breakers manufactured by multiple suppliers.

The development and use of effective methods for monitoring motor-operated valves have resulted in improved valve reliability. The following actions were taken to improve motor-operated valve reliability:

a. Stem-mounted strain gauges are used to accurately measure torque performance of numerous motor-operated butterfly valves. This allows time-related degradation of valve performance to be monitored and provides information to maintain butterfly valve performance within required criteria.

b. In addition to thrust values, torque performance of motor-operated valves during dynamic testing is used to determine the amount of load sensitivity. This method reduces the effect of torque switch setting repeatability from the measurements and provides more accurate data. The improved accuracy contributes to an increased size of the thrust window and allows more margin in motor-operated valve analysis.

c. A computer database is used to trend motor-operated valve performance and failure history. This database includes key industry regulatory-defined parameters that need to be reverified as test data accumulates. The data is easily retrieved by the motor-operated valve engineer, who reviews it for any adverse performance trends.

Contributing to the above, valve engineers actively participate in industry working groups and with other plants to exchange information and experience. This has increased awareness of performance problems that could affect valves at the station and has resulted in performance improvements through modifications to reduce the risk of pressure locking or thermal binding.

Implementation of an improved fuel loading strategy has reduced in-core neutron flux tilt and increased operating margin. The station had experienced a large neutron flux tilt in the previous fuel cycle that caused the initial power ascension to full power to be extended about one day, required frequent excore detector calibrations, and reduced the enthalpy-rise hot channel factor operating margin. Core design engineers changed the fuel loading patterns and resolved the in-core tilt problem. Subsequent startup and operations during the current cycle demonstrated that the in-core tilt was significantly reduced.

The previous three operating cycles had shown increasing in-core tilts. This required close monitoring of the changes in the tilt over core life and frequent recalibration of the excore nuclear instrumentation and other reactor protection instrument channels to comply with station technical specifications. The frequent calibrations, at times every three weeks instead of every three months under normal conditions, required increased operational attentiveness and increased the potential for personnel error or equipment failure that could lead to a reactor trip. Intensive troubleshooting efforts were initially unsuccessful in resolving the problem.

After identifying the large in-core tilt in cycle 9, the core design engineers investigated other causes of the tilt and developed actions to prevent future problems. The engineers worked with the fuel vendor, using data from other utilities, to analyze potential causes of in-core tilts. A university professor from outside the industry also reviewed the data to provide fresh insight into potential causes. This helped identify that the major contributor to the in-core tilt was increased numbers of once-burned fuel assemblies that were reloaded in a 180-degree pattern. The current cycle 10 fuel loading pattern was adjusted to eliminate the 180-degree fuel movements, and the tilt was significantly reduced. The station shared the information learned with other utilities, which have implemented the fuel loading strategy to reduce their in-core tilts.

Low dose rates in the plant, effective contamination control, and intensive planning and work coordination have been effective in maintaining low collective radiation exposure. Nonoutage accumulated dose has been among the lowest in the industry for the last two and a half years. Outage dose has been substantially reduced. For example, the nonoutage exposure for the first half of 1997 is 3 person-rem, and the 1996 refueling outage exposure was 89 person-rem. The following has helped the station achieve these results:

a. Source-term reduction efforts have maintained exposure rates low in the plant. Effective control of reactor coolant system pH (see strength CY.3-1) also contributes to the low source term and reduced exposures. For example, pH control contributes to 1 rem/hr dose rates on the primary side of steam generators, several times lower than typical at other plants.

b. Contamination levels in most areas, including the containment, are maintained low, permitting personnel access without wearing protective clothing. Elimination of contamination control restrictions in most areas of containment during outages has improved worker productivity and significantly improved timeliness of responding to changes in work conditions. These contribute to reduced outage radiation exposure.

c. Coordination and planning among several groups contributed to low exposures during repairs of leaks in residual heat removal heat exchangers. This type of repair has typically been performed during outages when dose rates at the heat exchangers are much higher. Engineering, licensing, and ALARA staffs developed plans to conduct on-line repairs and obtained a change in technical specifications to permit sufficient time for the repairs. Conducting the repairs on-line improved the overall defense-in-depth of the plant and reduced the expected dose from 50 to 10 person-rem.

d. During the outage to replace steam generators in 1994, intensive planning contributed to achieving low total dose. Lessons learned from other utilities were incorporated into work plans to avoid repeat mistakes.

Continuing efforts at reducing the generation of low-level radioactive waste have resulted in significant reductions in both solid and liquid waste. The quantities of solid radioactive waste generated and liquid waste discharged from the plant have decreased over the last three years about 95 and 45 percent, respectively. The following practices contribute to reductions in radioactive waste:

a. General access areas of the radiologically controlled area, including the containment building, are maintained as radiologically clean areas.

b. The major constituents of dry active waste are identified to determine departments and activities for which waste reduction improvements can be made.

c. A polymer was added to the liquid waste ion exchanger system that has improved the removal of Co-60.

d. Health physics has ownership of liquid waste processing to ensure thorough analysis and effective treatment methods.

e. The auxiliary building sump and liquid waste collection tanks are kept clean to reduce the organic component in the waste stream. This practice improves the efficiency and life of the resin beds.

f. The station uses a small incinerator to burn contaminated oil.

Chemistry and operations personnel maintain a high degree of control over reactor coolant pH, contributing to low radiation levels in the steam generators and reduced radiation exposure. A constant pH of 6.9 at temperature has been maintained by using a tight control band, conducting frequent analyses for boron and lithium, and promptly correcting adverse trends. The following practices were noted:

a. Recommendations for pH control were evaluated carefully, and the decision to maintain constant pH for the replacement steam generators was based on operating experience with the steam generators prior to replacement. The experience demonstrated a constant pH of 6.9 contributed to low radiation levels in the steam generators. The low radiation levels contribute to reductions in radiation exposure. (See strength RP.3-1.) Constant pH control also avoids higher lithium concentrations that can increase primary side stress-corrosion cracking of the steam generator tubes.

b. The nuclear steam supply system vendor recommended a control band for lithium of plus or minus 0.15 parts per million (ppm) of the target lithium concentration. Chemistry Department personnel established and have routinely maintained a tighter control band of plus or minus 0.075 ppm.

c. Boron and lithium are measured three times a day, and adverse trends are promptly corrected. Most pressurized water reactors measure boron and lithium once a day.

d. The uncertainty of measurement of lithium is plus or minus 0.007 ppm on a 1.0 ppm check standard. Typical industry performance is less precise, with most plants having at least twice the uncertainty.

Licensed operator continuing simulator training effectively corrects identified crew and individual performance weaknesses. Effective use of a simulator training corrective action database, thorough instructor and shift supervisor preparation for training, and facilitative posttraining critiques contribute to the effectiveness of simulator training.

Prior to simulator training, shift supervisors and instructors review the corrective action database for previously identified crew and individual performance weaknesses. The shift supervisors characterize the weaknesses as performance initiatives and review them with the crew prior to each scenario. Examples of initiatives that have resulted in improved performance include improving crew communications (see strength OP.1-1), conducting more effective shift supervisor briefings, and using alarm response procedures.

Instructors provide feedback on crew performance to the shift supervisors immediately following performance-based and training scenarios. The instructor and the shift supervisor agree on the issues to be critiqued prior to reviewing crew performance with the operators. Shift supervisors effectively facilitate the critiques, and operators routinely provide critical feedback on individual and crew performance. At the conclusion of each critique, the shift supervisor summarizes the crew performance and reviews the previously identified initiatives.

Following the critique, an instructor records crew and individual strengths and weaknesses in the corrective action database. The database is used by operations managers to identify areas for improvement and determine the associated corrective actions. Instructors also use the database when developing training so that simulator scenarios provide operators and crews the opportunity to improve their performance.

Continuous improvement efforts, varied and effective training methods, experienced instructors, and effective line and training supervisor involvement in training have resulted in improved maintenance, health physics, and chemistry performance. The use of mockups and multiple self-checking laboratories, use of student feedback, and maintained instructor technical skills contribute to effective training.

Training Department personnel exhibit strong ownership for worker performance, as indicated by routine observations to determine training effectiveness. Line personnel have noted this ownership and stated that training personnel are interested in improving plant performance and are very responsive to requests for training. The following practices were noted:

a. Mockups that duplicate plant equipment are used to provide just-in-time training prior to infrequently performed evolutions. This reduces the potential for errors in the field. Training in the self-checking laboratories also contributes to improved human performance in the field and in recommended changes to plant procedures aimed at improved human performance. For example, following a recent self-checking laboratory training session on static inverter preventive maintenance, instrument and controls technicians and the instructor marked up the procedure with recommended changes intended to clarify several procedure steps and reduce the potential for errors.

b. Subject-matter experts are used extensively to conduct training. This practice results in increased line ownership of training and provides the subject-matter expert with the opportunity to share expert knowledge with other workers.

c. Workers routinely provide feedback to training personnel that includes suggestions for improvement, requests for additional training, and recommendations for improving training logistics. Training and line managers review the feedback and incorporate many of the suggestions into training. For example, chemistry technicians requested training on gas chromatography based on self-identified recalibration problems. Root-cause analysis indicated that the problems were related to the injection techniques used by some technicians. Training was subsequently provided that corrected the problem.

d. Each instructor was recognized by station personnel as an expert prior to his or her assignment to training. In addition, instructors maintain their technical expertise by working in their disciplines during refueling outages. During the most recent refueling outage, 16 of 17 instructors worked in the plant. For example, a mechanical maintenance instructor was the second technician on a variety of jobs, including the reactor coolant pump seal replacement and several pump overhauls. A training supervisor served as night-shift manager of technical services during the outage and was one of three outage managers during previous outages. By working refueling outages and participating in all aspects of shop activities, instructors keep their knowledge current and identify areas that can be improved through training.

4.1.3 PEAK

Engineering use of a simple, but effective work management process facilitates the timely completion of important engineering work. The process prioritizes and balances workload and has resulted in a sitewide understanding of engineering priorities and activities. Use of the process has given engineering the ability to shift resources, resulting in more timely completion of work. This includes steam generator sleeving repairs, testing of safety-related circuits in response to industry issues, and resolution of unqualified coatings used in containment. Key process attributes include the following:

a. A clearly understood prioritization scheme is used by work flow coordinators to screen and prioritize work. All noncorrective action item tasks requiring more than eight hours of work are prioritized and tracked, and agreement on the assigned priority is reached among all personnel involved.

b. Biweekly meetings of all engineering personnel are used to review outstanding work, clearly communicate current priorities, and provide a forum for realigning resources. Personnel outside engineering often attend the meetings to ensure that engineering priorities are aligned with operational priorities.

c. Work flow leaders demonstrate a strong ownership for the process and use an informal assessment group to gather feedback, leading to continued improvement.

Radiological protection and training worked together to develop training scenarios that have been used to improve technician understanding and performance of infrequently performed, complex radiation protection tasks. The scenarios were developed using data from various monitors and other instrumentation to simulate actual conditions and practices. Use of the scenarios has improved technician proficiency and understanding of how slight changes in the data can have significant impact on the calculated results. Training scenarios have been developed for the following:

a. skin dose calculations using a computer software package

b. emergency offsite dose calculations

c. internal dose calculations

d. offsite dose calculations for routine effluent releases

Use of a valve location guide that references valves to radiological survey map grid coordinates has contributed to a reduction in collective radiation dose. Sensing the need for a better valve location process, a small group of technicians obtained lists of valves located in the auxiliary building and containment from engineering. As time was available, technicians walked down areas, identified the valves, and assigned reference locations using the radiological survey map grid coordinates. A notebook was developed to maintain the list of approximately 2,500 valves and associated reference locations. The valves are arranged in numerical order, by system, to assist in locating them in the list.

Aggressive station actions have resulted in reduced activity of liquid radioactive waste and low usage of waste processing ion exchange resin. Mixed fission and activation products in liquid waste have been reduced to less than 0.051 curies per year. In addition, the amount of resin used for waste processing has been maintained at 30 cubic feet per year for each of the last three years. This performance can be attributed to cooperation among work groups and continued efforts to reduce radioactive waste. Examples of actions taken include the following:

a. Processed water is evaluated prior to discharge to determine if additional processing is warranted. In some instances, an additional factor-of-10 improvement in radionuclide removal has been achieved by adjusting the pH of the water and reprocessing through the demineralizers.

b. Floor cleaning detergents are controlled to reduce the potential for chelating agents to enter the radwaste processing system. Chelating agents reduce the removal efficiency of demineralizer resin.

c. Few equipment leaks exist that contribute to radwaste inventory.

d. Chemistry management participated in development of industry guidelines for radioactive liquid waste processing and has shared the information with plant work groups. Industry guidelines were distributed to operators, radiological protection personnel, and chemistry technicians involved with radwaste processing. The information has increased awareness of radwaste challenges and potential mitigation methods.

Effective training development committees, use of subject-matter experts, and rotational personnel assignments increase the effectiveness of training. Examples include the following:

a. Line managers and supervisors actively support training development committees for each program area to determine initial and continuing training needs. They also participate in annual assessments of training programs, increasing their awareness of the overall scope of training in their areas.

b. The line organization supports the conduct of initial and continuing training by supplying subject-matter expert instructors to conduct training and assist in developing training material for revised tasks and new equipment. This increases the technical depth of training and increases the ownership of training throughout the line organization.

c. The superintendent, plant operations supports all simulator evaluations conducted for licensed operating crews to achieve consistent interpretation of operations expectations and standards.

d. Training supervisors, staff, and instructors provide real-time support of the station staff by routinely attending line management morning meetings to stay aware of plant activities and operational needs. Instructors provide just-in-time training on urgent issues assigned at these meetings. They also augment the line organization during outages to gain experience and maintain awareness of outage-related issues.

e. Rotational assignments between training and line organizations are used as development opportunities for instructors and line personnel. The mechanical maintenance lead instructor recently completed a two-year rotational assignment to mechanical engineering, and operations has made short-term rotational assignments to support nonlicensed operator training and simulator testing.

Personnel consistently demonstrate a low tolerance for equipment deficiencies, willingly respond to the needs of other departments to resolve equipment problems, and effectively prioritize emergent maintenance issues. These behaviors contribute to reliable equipment performance and good plant materiel condition. Individuals take the initiative and proactively communicate with other personnel to seek resolution of equipment performance issues. Management encourages ownership and initiative by empowering workers and establishing an environment for open communication and teamwork.

A high level of plant materiel condition is reflected by very few leaks or equipment deficiencies, a low backlog of nonoutage corrective maintenance items, and a history of reliable equipment performance. Many examples of effective and timely resolution of specific equipment performance issues were noted. These issues include reactor vessel level indication system design, air compressor performance, safeguards electrical breaker reliability, feed regulating valve operation, control room air conditioning system operation, emergency diesel generator cooling water jumper leakage, and reactor coolant pump seal repairs. Strong equipment performance and materiel condition limit plant operational challenges, supporting safe and reliable operation.

4.1.4 SUPERIOR

The performance annunciator panel program provides early detection of problems, fosters continuous improvement, communicates performance in a simple and visual manner, and allows management to focus on areas that need improvement. Examples of how this tool is used include the following:

a. The program is used to develop quarterly assessments of 31 overall performance panels with input from 151 areas using quantitative criteria. The areas include departmental performance such as maintenance and operations and cross-departmental areas such as human performance and self-evaluation.

b. Senior site managers review the quantitative data output for validity and exercise judgment to revise the window grades, which are color-coded. Managers were observed to be critical in their assessments and used their collective understanding to appropriately raise and lower the quarterly assessments to focus improvement efforts.

c. Personnel exhibited a high degree of accountability for using this tool to monitor and improve performance. Department superintendents are responsible for addressing shortfalls in performance and providing corrective action plans for annunciator panels assessed in yellow or red categories. The corrective action plans are presented to the Management Review Board for approval and are entered into appropriate tracking programs for follow-up.

d. Criteria for windows that remain green for an extended period are reviewed and, as applicable, revised with more challenging criteria. By this practice, the system is used to help guard against complacency.

e. The performance annunciator panels and the corrective actions are displayed widely in the plant, providing a visual representation of station performance for the staff.

The computer-based daily log system facilitates awareness of the current status of various work activities. Operations, maintenance, outage, engineering, and other groups maintain detailed electronic logs on daily activities. The network can be accessed by anyone on site and by management from home computers, allowing them to remain current on activities. This method of information exchange reduces control room distractions from personnel desiring to review operator logs or determine the status of plant equipment.

Personnel can readily review historical plant performance issues by viewing these chronological logs, which provide an understanding of plant activities and work performance. Also, a keyword search capability of the database allows information regarding specific equipment or tasks to be easily found.

Maintaining current outage status on the network has improved schedule execution and contributed to reduced outage duration. Additionally, access to the outage director's log from Surry station provides Superior the opportunity to be involved in problem-solving and promotes effective resource sharing.

Involvement of operators in a variety of key functions enhances interdepartmental teamwork and operational focus. Operators are assigned to multidiscipline teams as well as Operations Department staff functions. By supporting operator decisions, implementing their recommendations, and maintaining an active dialog with operators, management has effectively integrated operators into a continuous improvement process. Interest in maintaining this active involvement is evident by the number of personnel desiring to replace present volunteers in various roles. Beneficial practices noted include the following:

a. Licensed and nonlicensed operators are project coordinators for evolutions such as periodic tests or equipment upgrades that involve several shifts or require coordination among several departments.

b. On-shift procedure writers effectively augment the efforts of the procedures group by providing rapid, permanent procedure revisions while maintaining review and approval control.

c. A reactor operator is the lead for the "fix-it-now" team that provides prompt response to minor maintenance items.

d. An operations review board advocates operator concerns and areas for improvement and also evaluates operator workarounds. Operators included on committees of this board assist in root cause evaluations, screen and comment on design change packages, and participate on safety and ALARA committees.

Operations personnel performance has improved through the effective use of training and an active partnership between the operations and training organizations. This partnership has resulted in greatly improved crew performance in areas previously noted to be weak. Operations management leads comprehensive critiques facilitated by training instructors after each simulator scenario. Individual performance improvement areas are known and focused on. All operators maintain a 3x5 card with a personal list of improvement areas, which can be added to or removed through agreement with shift supervision and training. Individual areas for improvement are reinforced during training scenarios and on-shift coaching. Additionally, an on-shift training coordinator helps integrate and reinforce operations management direction for expected performance, crew communication skills, and use of station operating experience by training.

Unplanned generation losses have been maintained at very low levels because of an aggressive preventive maintenance program, experienced craft with a strong ownership of the equipment, and a redundancy of many key components. As a result, unplanned capability loss factors on both units have been less than 0.5 percent since January 1997. The following key attributes were noted:

a. Preventive maintenance receives a high management priority. Each preventive maintenance task has a well-documented basis. All preventive maintenance changes are evaluated, and nuclear oversight committee approval is required for changes to safety-related tasks. For example, preventive maintenance is performed on all important pumps, motors, and air-operated valves; all relief valves; and all 4-kilovolt and

480-volt breakers at a frequency based on environment, duty, and criticality of function.

b. A "no visible leak" policy has resulted in rapid repair and evaluation of fluid system leaks. The valve packing program requires proactive repacking of approximately 400 to 500 valves every refueling outage.

c. Highly experienced craft personnel with a strong ownership of equipment performance, detailed maintenance procedures, and an ongoing self-assessment process have resulted in a low rework rate and reliable equipment performance.

d. Redundant condensate pumps, motor-driven feedwater pumps, chemical volume control system pumps, and control room chillers allow flexibility in performing on-line maintenance and also allow the station to correct some equipment deficiencies without requiring plant or equipment unavailability.

Strong maintenance work practices have reduced containment penetration leakage to very small levels. This performance has been used to reduce the number of required local leak rate tests by approximately 50 percent. By applying the performance-based inspection option in 10CFR50 Appendix J, decreased testing requirements have reduced personnel dose and resources. Effective planning and scheduling to combine corrective and preventive maintenance activities on containment penetrations have also reduced the number of required leak rate tests. Component failures are evaluated considering past performance and service application. Adverse trends are addressed by repairing or replacing the component.

Feedwater corrosion products have been reduced to values typically less than 1 part per billion by coordinating plant modifications, changing chemistry regimes, and improving plant operations. These actions have reduced the sludge buildup in the steam generators, allowing the steam generator cleaning cycle to be extended to every other outage. Examples of steps taken to reduce corrosion product transport include the following:

a. Copper components in the secondary system were replaced, permitting system operation with a higher, less corrosive pH.

b. A secondary system amine optimization study led to reduced corrosion product transport when morpholine was replaced by ethanolamine.

c. Hydrazine concentrations were elevated to provide a less corrosive environment under all operating conditions.

d. System modifications were installed to increase steam generator blowdown capability from approximately 15 to 75 gallons per minute.

e. Makeup water systems were upgraded to accommodate increased blowdown capability.

f. Nonprecoated, pleated filters are used in the condensate system for iron removal during power operations.

Chemistry personnel accurately predicted and mitigated the effects of a higher-than-normal release of radioactive corrosion products in the primary system during the recent Unit 2 shutdown. A proactive strategy was implemented to greatly reduce the subsequent deposition of radioactive material on piping to maintain manageable radiation levels in the plant. These actions were in response to station and industry experience, which indicated that a large crud burst and higher radiation levels are expected at the second refueling outage following steam generator replacement. The goal of the shutdown strategy was to keep the isotopes soluble (ionized) to enhance removal by the ion exchangers. Using a task team approach, primary chemistry guidelines were developed and incorporated into operations and chemistry shutdown procedures. As a result, 4,185 curies of cobalt-58, 16 curies of cobalt-60, and 4,410 grams of nickel were removed from the reactor coolant system. Actions taken include the following:

a. delithiation when the unit came off line

b. continuation of a reactor coolant pump running

c. extension of the boration time, and reduction of the boration rate

d. slow degassification of the plant, keeping hydrogen around 10 cc/kg, to aim for crud that is greater than 90 percent soluble

e. delay in boron injection tank release as long as possible, avoiding high oxygen levels

f. addition of hydrogen peroxide immediately after the loops were isolated

g. draining of the loops immediately after loop isolation to prevent settlement of crud

h. reduction of coolant activity to acceptable limits prior to flooding the cavity -- Cleanup time was not significantly different from previous outages.

Effective implementation of several innovative initiatives has improved Maintenance Department performance. The maintenance "check tech" program, the maintenance review board, and the maintenance workaround program are achieving beneficial results. These programs, based on successes in the Operations Department, have identified procedure improvements, provided a focal point for addressing maintenance issues, and established a mechanism to ensure timely resolution of issues identified by department personnel. Examples of these improvements include the following:

a. The check tech program uses individuals from mechanical, electrical, and instrument and control who are dedicated to improving worker performance. The individuals are assigned for specified periods of time and form the quality maintenance team. The team's observations are summarized and presented to maintenance management. As one example, redundant calibration procedure steps required repeated opening and closing of a reactor trip breaker. As a result of the check tech's observation, the unnecessary procedure steps were removed.

b. A maintenance review board is a forum for craft personnel to become involved in plant decisions. Members include craft from the quality maintenance team and the predictive analysis group. The board discusses issues, questions, or enhancements that are submitted through information sheets. Each item is considered, and a decision is made on how to address it. For example, the board facilitated the research and procurement of a more effective boundary tape for foreign material exclusion applications.

c. The maintenance workaround program is a process that brings issues and questions submitted by craft personnel to the attention of station senior management.

Sustained strong performance in radiological protection has been achieved through self-assessments, performance monitoring, benchmarking, and use of industry and in-house operating experience. A self-critical culture was evident at all levels of the radiation protection organization. Key elements of this strong performance include the following:

a. Programmatic reviews are conducted in all functional areas of radiation protection, such that all areas are formally reviewed at least once every three years. Industry peers are used extensively in the conduct of self-evaluations. Some areas, such as trending of radiological problems and public dose, are reviewed annually.

b. Managers and supervisors frequently perform in-plant observations of radiological work and plant conditions. In addition, all radiation protection technicians perform at least one observation of another technician annually. The results of these observations are trended to identify programmatic weaknesses.

c. Frequent benchmarking and exchange visits are performed to keep current with best practices and industry issues. These include benchmarking trips to other stations, industry meetings, and visits from other stations to Superior. Approximately 24 trips have been completed in 1998 to date.

d. Strong emphasis is placed on reducing personnel contaminations and the amount of contaminated area in the plant. Currently, only one small plant area is contaminated, and usually there are no contaminated areas.

e. Radiation protection personnel review industry operating experience daily and frequently use this information in continuing training, required reading, prejob briefings, and shift orders. Industry experience with large crud bursts during the second refueling following steam generator replacements was used to anticipate the problem and develop mitigation plans.

f. Potential future candidates have been identified for critical positions in the department. Positions range from department management to first-line supervision. The readiness of candidates has been assessed, and development plans have been implemented for selected candidates.

Continued reduction in collective radiation dose has been achieved through stationwide efforts. Work groups and individual workers exhibit

strong awareness and ownership of their doses, and dose reduction is an integral part of work and outage planning. Examples of dose-saving efforts include the following:

a. Source term reduction efforts, including cobalt reduction, microfiltration, shutdown chemistry controls, hot spot reduction, and temporary shielding, have reduced reactor coolant piping radiation levels by a factor of 2.5 over a 10-year period.

b. A challenging 100 person-rem outage plan was developed based on previous best dose performance for individual outage tasks. Specific actions necessary to achieve best performance were identified, assigned, and tracked to completion. The plan is routinely updated based on lessons learned. Dose for the fall 1998 refueling outage was 92 person-rem, better than the outage goal and a significant improvement from previous years.

c. Mockups frequently are used to train work crews and to test equipment before work is performed. Examples noted include a reactor head stud test stand and a mockup of the pressurizer heater area, which is a congested area that must be accessed by welders. Also, the general employee training practical factors area uses exact replications of the plant radiologically controlled area access point and the containment personnel hatch. Instructors using these training aids challenge trainees through hands-on activities on components.

d. Radiation protection job guides that describe outage tasks and expected technician and work crew interactions are used to improve technician performance. These guides capture the experience of technicians and supervisors and prevent the loss of station-specific knowledge.

Effective use of remote monitoring techniques and a central control station have improved radiation protection monitoring of workers, reduced personnel dose, and decreased the needed level of technician support. The system uses numerous video cameras, radio communications, and telemetric electronic dosimetery to monitor both worker and area dose rates during normal operations and outages. About 1.5 person-rem of dose to radiation protection personnel is saved each outage. Key attributes noted include the following:

a. Approximately 75 workers can be monitored simultaneously from a central location for cumulative dose and dose rates during outages. Changes in worker dose rates or improper worker practices are addressed through radio communications with roving radiation protection technicians.

b. The system is used to monitor entries and exits from locked high radiation areas to provide positive control of these areas.

c. Remote video displays at the central control station are used to provide updates on job status and prejob briefings to work crews and support technicians before they enter the radiologically controlled area.

d. Remote, real-time, area dose rate monitoring with electronic dosimeters is used to reduce radiation protection personnel entries into high dose rate areas. This was effectively used to reduce personnel dose following a controlled crud burst during the outage.

The line organization and the Training Department work closely together to provide effective and timely training. Line management exhibits strong ownership of training activities, and the Training Department proactively identifies training needs to the line organization and develops applicable training to meet those needs. The following examples were noted:

a. Maintenance management initiated efforts to develop scenario training for all maintenance disciplines in a simulated plant setting and assists in conducting the training. Constructive feedback is provided to the trainees through a facilitative critique process led by the applicable maintenance supervisor and instructor.

b. During each cycle of operations requalification training in the simulator, operations line management provides the lead facilitator to reinforce management expectations and consistency among the crews.

c. Maintenance instructors work closely with their plant counterparts to improve line procedures based on lessons learned from scenario and mockup training sessions.

d. Each line department has assigned on-shift training coordinators who observe personnel performance and provide critical feedback to management. Training department personnel also actively participate in line staff meetings and are considered part of the line organization.

e. Rotational assignments from line departments into training are done on a regular basis and are viewed as career-enhancing opportunities. In addition, training personnel support outages by filling key roles, such as backshift operations manager, backshift maintenance coordinator, and outage coordinators.

Effective planning, scheduling, and implementation of refueling activities have resulted in successful outage performance and postoutage cycle operation. Goals for refueling outages during the last several years have been consistently met. These goals were for collective dose, lost-time accidents, scheduled duration, budget, and a sustained 60-day postoutage operation. Elements contributing to good outage performance include the following:

a. Craft and operations personnel actively participate in outage schedule development, giving them ownership for the outage schedule. Additionally, these people are assigned key department outage coordination roles, which allows them to use their knowledge of the schedule to improve performance.

b. Departments have assigned specific tasks to the same supervisors over the last few outages. This allows each supervisor to take ownership and pride in the job, as well as building a significant experience base in key outage activities so that these tasks can be done more effectively and efficiently. Specific examples of assignment areas include reactor vessel head assembly and disassembly, reactor coolant pump seal maintenance, containment hatch and polar crane coordination, and major motor testing.

c. Operations provides crews with a detailed narrative description of the first 10 days of the outage schedule about 1 month prior to outage start.

This allows operators to thoroughly prepare and plan for the early days of the outage by reviewing procedures and clearances that will be needed.

d. Postoutage critiques are effectively conducted, building from worker-level inputs to identify good practices and areas that need improvement. Areas for improvement are tracked, with formal assignment of responsible individuals.

4.1.5 APEX

A high degree of teamwork among plant workers, with a focus on safe operations and reliable equipment performance, has contributed to high levels of plant performance. Contributing to teamwork is an experienced work force that maintains a plantwide ownership for continued performance to high operational standards. Examples of teamwork activities include the following:

a. Control room crews effectively use teamwork to diagnose and respond to simulated transients. For example, crew teamwork prevented a premature reactor emergency depressurization and prevented a crucial immediate operator action step from being missed. In addition, crew teamwork with engineering enhances the crews' abilities to respond to plant transients. On many occasions in the simulator, crews called for engineering assistance to troubleshoot problems or to inform the engineers of relevant plant information.

b. A radwaste reduction task force, which includes members from several plant groups, has successfully developed recommendations and coordinated implementation of actions to reduce radioactive waste generation. The station is now an industry leader in achieving low levels of radioactive waste generation. (See strength RP.1-1.)

c. Teamwork within the engineering organization is used effectively to achieve solutions to engineering problems using the best available expertise. For example, plant system problems and issues are often jointly solved through discussions among system and design engineers. In addition, modification design engineers interact with other department personnel, such as operations and maintenance, through the conceptual design, the design process, and modification installation. Design engineers or systems engineers may function as modification coordinators.

d. Effective teamwork was noted among plant groups such as engineering, operations, maintenance, and chemistry. Examples include the following:

    1. Operators see the system engineers as experts in their systems and frequently seek their advice concerning operational questions.

    2. Maintenance personnel were frequently observed in engineering work areas discussing maintenance activities, and system engineers were observed in the plant and shops monitoring work activities.

    3. Chemistry personnel developed a computer program for system engineers to save engineering time performing daily calculations of plant thermal performance. In addition, chemistry personnel

have provided training to engineers and operators to use chemistry computer tools for trending and monitoring chemistry data related to plant systems.

Shift turnovers are detailed and comprehensive and provide the oncoming crew with plant status, shutdown safety criteria, and a list of shift work activities. Each member of the oncoming crew reviews all logs and equipment status sheets and then performs a detailed walkdown of control room panels and discusses the equipment status of each panel with his or her counterpart on the offgoing crew. At the start of the shift, the shift supervisor makes a presentation in the control room detailing the status of the plant and any major activities that are expected to occur during the shift. Representatives of maintenance, chemistry, health physics, security, and scheduling are at the presentation and are asked for input. The scheduling representative reviews the work activities on the schedule and, during an outage, also details the emergency core cooling systems needed to maintain shutdown safety. Systems needed to support safe operation of the plant are identified during normal operation.

A designated maintenance engineering group conducts a weekly review of all corrective maintenance work orders for potential rework and recurring events. This contributes to maintaining the safety system performance at a high level. Rework is less than 1 percent, and the corrective maintenance backlog is currently only 75 mechanical, 25 electrical, and 25 instrument and control work orders.

Corrective repair history is reviewed weekly for commonality and recurrence. This analysis includes the previous two years of repair maintenance on the component under study. Items that qualify as recurring or as rework are entered into the condition report system. Recurring items are separately placed on a "Dynamic Recurring Problem List" that is reviewed quarterly with the superintendent of maintenance and annually with system engineers and craft supervision. All pending, active, and waiting-for-closeout safety-related work orders are reviewed weekly by supervisors and monthly by engineering, operations, and warehouse superintendents.

The engineering organization effectively monitors the status of its work activities and performance using periodic status reports, integrated work schedules, and engineering performance indicators. This has contributed to the effectiveness of the engineering organization and to high equipment reliability. Examples include the following:

a. A detailed integrated schedule prepared for modifications includes scoping and authorization, design engineering activities, modification package development, material procurement, installation and test procedures development, installation, and project turnover and closeout. Additionally, an integrated schedule can be printed for individual engineers, showing all assigned activities for each engineer.

b. Engineering issues a quarterly trend report of 39 engineering effectiveness performance indicators, including indicators on human resources, work quality, and workload. Each indicator has an assigned goal.

Probabilistic risk assessment results are widely used in station activities to determine safe operating conditions and to assess risk. These activities include work planning and scheduling, operations, training, modifications, assessment of shutdown safety, and assessment of significant equipment failures. This wide use of risk assessment techniques in a variety of station activities has helped ensure prudent decisions are made regarding nuclear safety and provided early identification of potential risks. Specific examples of station use of risk assessment include the following:

a. Maintenance work planners and schedulers use an interactive computer display to determine the effect on the risk (core damage frequency) of removing various equipment from service for on-line maintenance. The model is maintained and updated by the probabilistic risk assessment group.

b. At the beginning of each outage, an outage probabilistic risk assessment report is prepared based on outage activities. The report provides a discussion of the dominant contributors to boiling and fuel uncovery risk for each day of the outage. Station managers review the reports, and the outage schedule is revised as needed to maintain acceptable shutdown risk.

c. During outages, a daily shutdown safety sheet is provided at the morning meeting and posted in the control room. It indicates the time to boiling for a loss of shutdown cooling and also lists safety systems required to be available. This information is provided by the probabilistic risk assessment group.

d. The probabilistic risk assessment group monitors a number of station design and operation activities to assess risk. Examples include the following:

   1. The risk assessment group reviews modification packages and assesses the effect of design changes on risk for the 27 systems included in the probabilistic risk assessment.

   2. Members of the risk assessment group attend the daily morning meeting, weekly planning meeting, weekly engineering staff meeting, and weekly safety assessment meeting to monitor activities affecting risk.

e. Probabilistic risk assessment results are used in operations training. Critical operator actions identified in the risk assessment model are considered for job performance measures. Results are also used in the development of simulator scenarios, and risk is discussed during simulator scenario hold points. Risk assessment results are also discussed and emphasized in classroom training.

f. The probabilistic risk assessment group reviews maintenance rule results and gives a quarterly summary of the effect of maintenance rule reportable equipment failures on core damage frequency. This summary includes a color graphic presentation that shows the severity of the risk associated with various equipment failures during the quarter.

The Operations Manual provides a comprehensive source of system information, references, and procedures in an easily used format. This controlled document, maintained by system engineering, is widely used by many groups to efficiently obtain plant equipment information and history. The manual contains separate sections for each plant system. Examples of information contained in each system section include the following:

a. a detailed discussion of the system function, description, design, and modes of operation

b. a description of each component in the system, including physical parameters, serial numbers, materials, manufacturer, and location

c. an instrument and controls section describing all alarms, switches, indicators, recorders, manual controls, and setpoints

d. a reference section providing a list of all system piping and instrumentation drawings, vendor manuals, instruction books, specifications, updated safety analysis report sections, forms and procedures related to the system, modifications made to the system, engineering evaluations, design changes, and safety evaluations

e. a system operations section containing operating requirements, general precautions, valve lists, power supply lists, startup procedures, operating procedures, special procedures, and abnormal procedures

f. a section containing simplified drawings and sketches of the system

A number of personnel commented that the Operations Manual is the starting point for answering most routine questions. It is frequently used by maintenance planners, operators, trainers, and engineering personnel.

Operator training is enhanced by comprehensive training materials, use of operating experience and probabilistic risk analysis data, and inclusion of fundamentals topics in the training. These aspects result in a high level of understanding of operator training topics and competence of the operations staff. Details of each area are as follows:

a. Training materials used in simulator and classroom training provide a proper amount of information for instructor actions, use of training resources, and appropriate teaching and questioning techniques. The materials identify references used in lesson development for instructor preparation and student use.

b. The use of industry and plant operating experience is effectively planned and appropriately included in training materials for simulator and classroom training. Simulator freeze points are identified to most appropriately illustrate the details of the operating experience. Training materials are used by simulator and classroom instructors to discuss particular aspects of the operating experience and to relate the experience to station activities, programs, and conditions.

c. Training is emphasized on operations knowledge and abilities that are determined to be especially safety-significant by the probabilistic risk analysis. Instructors have a working knowledge of probabilistic risk analysis principles and effectively include equipment failures and other faults that are most challenging to plant safety in simulator scenarios.

d. Fundamental topics such as basic heat transfer and feedwater single-element control are discussed before training, and appropriate simulator freeze points are specified at times to best apply and discuss fundamental topics related to plant systems and components. Also, fundamental information is included in lesson plans for classroom training. Operations personnel actively discuss fundamentals in training and on shift and often determine other areas in which to apply the information to their experience and to day-to-day station activities. Operators demonstrated a high level of knowledge on fundamental topics.

Improved approaches to processing low-level radioactive waste and controlling radiological work have reduced radioactive waste generation and improved worker efficiency. Resulting practices have helped maintain low-level radioactive waste volumes at levels that are among the best in the industry. Examples of these approaches include the following:

a. A task force is effectively used to identify and implement innovative approaches to reducing radioactive waste volumes. The task force has representatives from many station groups and meets once per quarter to discuss and evaluate radioactive waste issues. The task force reports directly to the plant manager and has been instrumental in initiating many of the radioactive waste reduction measures taken during the past few years. A recent example was processing waste water containing high total organic carbons through liners filled with depleted resin prior to dewatering. This aids in reducing total organic carbons in the water by getting one last use out of resin prior to disposal.

b. Radiological information is effectively communicated to workers through the use of radiation work permits and dose rate survey maps that are clear and concise. Both are available at access control and at predetermined locations within the plant. The radiation work permit format allows a person to readily determine the applicable radiological requirements. Radiation work permits contain only instructions specific to the job in question. These clear and concise radiation work permits reduce the potential for workers to misunderstand radiological work requirements. The survey maps clearly delineate radiological conditions, allowing individuals to determine radiation levels for the area being entered without the need for frequent interface with radiation protection personnel. Posted survey maps and radiation work permits were observed to be routinely used by station personnel.

c. Tools used in areas contaminated below 50,000 dpm/100 cm^2 are removed and returned to the toolroom by the workers using them, without the need for radiation protection personnel support to survey the tools for contamination. Workers wipe the tools down before removing them from the work area, bag them, and then return them to the contaminated tool storage area. This practice saves worker time and avoids the need for involving radiation protection personnel. Routine radiological surveys in the tool storage areas and the lack of personnel contaminations in 1997 attributed to this practice indicate that this method of tool control has been successful.

Resolution and response to abnormal chemistry transients are enhanced by the development and use of flowcharts. In addition, transient resolution and response, as well as annual chemistry training, have been enhanced by incorporating actual operating experience into the flowcharts. The following such enhancements were noted:

a. Chemistry technicians have promptly resolved abnormal chemistry transients using the abnormal chemistry transient flowcharts. This process has saved technician time by preventing unnecessary sampling and monitoring. It has also allowed for a faster response because of the ease of determining corrective actions for abnormal chemistry changes. For example, a chemistry technician promptly resolved a service water system radiation monitor alarm by using the flowcharts to identify a radwaste storage container that had been moved into the area near the monitor. This container had inadvertently caused the service water radiation monitor to alarm. Traditionally, technicians would have contacted chemistry supervision for direction and initiated a routine for pulling and analyzing system grab samples.

b. Use of the abnormal chemistry transient flowcharts has helped technicians to prevent chemistry limits from being exceeded. Because the flowcharts allow personnel to determine corrective actions to abnormal transients relatively easily, one chemistry technician was able to prevent exceeding a residual chlorine limit on the plant liquid effluent.

c. Chemistry abnormal transient flowcharts have also been used as a training aid during annual chemistry training. The logic and streamlined approach to problem response and resolution used in the flowcharts, along with several years of operational experience incorporated into the flowcharts, have helped improve chemistry technician knowledge and understanding. Furthermore, the flowcharts contain the basis behind the plant chemistry limits such as plant technical specifications, fuel warranty, the national pollutant discharge elimination system, and Boiling Water Reactor Owners Group recommendations.

Reduction of feedwater iron concentration has resulted in reduced radioactive waste generation and improved equipment performance. In addition, reduced feedwater iron has eliminated some decontamination tasks during refueling outages.

The reduction in feedwater iron from 1.8 to 0.5 ppb was achieved by installation of pleated filter septa in the condensate polisher filter demineralizers. Use of the pleated filter septa design has eliminated the need for a body feed cellulose-based overlay and has reduced the amount of resin necessary to precoat the new septa. It is estimated that radioactive waste volumes will be reduced by approximately 15 percent. Elimination of the cellulose-based filter septa overlay has also lowered the average feedwater silica concentration. This reduction has increased reactor water cleanup filter demineralizer run lengths by approximately 50 percent.

A lower feedwater iron concentration has contributed to a decrease in radiation dose rates from primary system piping. The reduction in radiation dose rates has been instrumental in the decision to suspend extensive primary system decontamination activities during refueling outages.

4.1.6 ACME

Station management has effectively fostered an environment that promotes a strong willingness to work together to improve station performance. Cooperation among work groups and departments is exemplary. Individual managers, supervisors, and team leaders are quick to support each other to expedite important work when it is required.

The station uses cross-functional teams and includes employees at all levels of the organization to address issues important to station performance. For example, as a result of a recent health physics self-assessment recommendation, a cross-functional team was formed to develop an action plan for attaining strategic dose reduction goals. Initiatives resulting from this team effort included design and procedure changes, new equipment, and process improvements. The success of this team effort is reflected in the reduced total dose during the most recent refueling outage. The total dose was the second lowest on record for the unit. Another team was assembled to address industrial safety issues before the last refueling outage. Initiatives identified by this team contributed to reductions in severity and frequency of personnel injuries during the outage.

Management promotes behaviors that support station and corporate values, including ethical behavior, customer service, shareholder value, teamwork, superior performance, and citizenship. A comprehensive employee survey is used to assess the degree of success in instilling these values and behaviors and to identify needed follow-up actions. Feedback from the survey is provided to all levels of management. Follow-up actions include implementation of individual performance improvement plans for workers, comprehensive training on the business challenges that face the station, and the use of the station values as core competencies in the candidate selection and promotion process.

A strong operational focus has contributed to plant safety and high levels of equipment reliability. Industry experience has shown that a strong operational focus is a prerequisite for high levels of plant safety and reliability. The station has experienced no significant events during the past two years. High levels of performance are reflected in the overall performance indicators. Contributing to the operational focus are the following:

a. The station makes extensive use of senior reactor operator licenses to fill top- level manager positions. Nine of these 10 positions are filled by licensed or previously licensed individuals. The operations knowledge and on-shift experience of the management team have contributed to a strong and effective management focus on safety and reliability.

b. The large number of managers with operational experience has given the leadership team a common frame of reference in decision-making. Plant leadership has effectively communicated the resulting common set of values and priorities throughout the organization. Support organizations understand and work to operations priorities, as evidenced by the low maintenance backlog and relatively low number of operator workarounds. This common focus has effectively eliminated departments working to different goals and priorities.

c. While maintaining a proper balance with the need to oversee shift activities, the shift superintendents are actively involved in management decisions affecting operations. This is accomplished in the following ways:

    1. attending the daily briefing of off-site management at which significant plant issues are discussed

    2. attending the plan-of-the-day meeting and establishing priorities for newly identified work

3. leading the discussion of plant status at the daily management meeting

---

During simulated transients, reactor operators demonstrated their ability and willingness to advocate their positions and contribute to team decision-making. The operators maintained respect for supervisory command and control functions while providing important comments.

The operations manager holds operators accountable for crew decisions. For example, errors during transitions in emergency procedures are considered team failures. The following examples are typical:

a. A reactor operator correctly suggested that a failed-open power-operated relief valve be deenergized in an attempt to close the valve, thereby decreasing the loss of reactor coolant. The unit shift supervisor initiated actions to remove power from the solenoid valve for the relief valve.

b. During an emergency boration lineup restoration, a reactor operator noted that the unit shift supervisor had incorrectly stated which valves were to be aligned. The supervisor directed an operator to close the refueling water storage tank to charging pump suction valves while the volume control tank to charging pump suction valves remained closed. The operator addressed the supervisor and stated that the alignment should be performed per the procedure. The unit shift supervisor then directed an operator to follow the procedure for valve restoration.

c. When a shift superintendent directed a crew to proceed with a unit power increase, a reactor operator recognized that adjustment of power range nuclear instruments would be required and this was not permitted with an out-of-service pressurizer pressure channel. As a result, the shift superintendent and the unit shift supervisor agreed to hold power at the present value until the pressurizer pressure channel could be restored to service.

d. On several occasions during transitions in emergency operating procedures, operators checked the procedure being addressed by the unit shift supervisor and conveyed their agreement with the transition.

Operator monitoring and diagnostic skills contribute to timely identification of problems and conservative response actions. Examples of adverse conditions that have been recognized and mitigated by in-plant and control room operators include the following:

a. In June 1997, a plant equipment operator noticed that the supply line to the motor coolers of one safety injection pump was warmer than the others. The temperature difference could not be explained, so a work order was written to investigate. When the safety injection pump was disassembled, gasket material was found to be blocking the cooler tubesheet.

b. In October 1997, an inaccurate boron sample resulted in an unplanned boron dilution condition. A reactor power increase was noted by the reactor operator when power had increased 1 percent. Compensatory actions were taken immediately to restore power to the previous value. The crew had been performing a blended makeup to allow a mixed bed demineralizer to be flushed. The boric acid storage tank was at a lower concentration than the previous sample indicated.

c. In June 1997, a control room operator questioned the reduced frequency of normal dilution of the reactor coolant system. The operator reviewed the volume control tank level indication using the integrated plant computer and discovered an increasing trend for tank level. Troubleshooting activities revealed that a dilute water valve was leaking past the seat, causing a slight in-leakage.

d. In June 1997, an instrument failure caused an atmospheric relief valve to fail open. The crew promptly detected the condition and took actions to mitigate the associated power increase.

e. In May 1996, a Unit 1 feedwater regulating valve failed closed because of a blown fuse. The operating crew promptly recognized the inadequate feed flow to a steam generator and the change in valve indication. A manual reactor trip was initiated in response to this unrecoverable condition.

Effective outage risk assessments improve personnel awareness of outage risk, avoid inappropriate combining of outage activities, and improve schedule quality through lessons learned. Preoutage risk evaluations identify evolutions that should not be combined, protected train components, and corresponding contingency plans. During the outage, risk evaluations and walkdowns include evaluation of schedule changes for risk impact prior to the change being implemented and verification that actual performance is consistent with scheduled activities. Postoutage activities include a comparison of the actual risk versus the scheduled risk evaluation, for identification of lessons learned. The following activities are used in the outage risk evaluation process:

a. Preoutage risk evaluations include a detailed schedule review conducted by a multidiscipline team of station personnel and peers from other utilities. In addition, a computer review of the schedule is performed based on outage activities at the component level. This provides a means of identifying improper logic ties. These reviews are conducted approximately two months before the outage starts, prior to the initial outage schedule being issued.

b. Risk evaluations during the outage include periodic risk assessment walkdowns during periods of increased risk as determined from the preoutage review and changing plant conditions. The walkdowns verify existing plant conditions are consistent with scheduled activities and identify potential challenges to shutdown safety functions and protected components by unscheduled activities. Personnel who conduct the walkdowns communicate the risk message to craft and operators, resulting in increased awareness of protected equipment.

   Demonstrating the benefit of the walkdowns, several have identified plant conditions that had not been sufficiently analyzed for impact on risk. For example, the walkdown identified that reactor coolant loops were not completely filled. This could have resulted in the steam generator not being available as a heat sink.

c. Daily outage risk assessment reports provide a three- to five-day look-ahead that identifies higher-risk tasks, protected equipment, contingency plans, and items to monitor and address.

d. Computer risk profiles are prepared during the outage for evaluation of emergent work activities during the daily plan-of-the-day meetings. The risk profiles identify which safety functions and equipment are at reduced defense-in-depth conditions, the impact the situation had on the plant, and equipment to be protected. These evaluations help determine acceptability of proposed emergent schedule changes.

e. The computer risk profile generated for the initial schedule and the risk profile generated for the actual outage schedule are compared after the outage. Differences are evaluated for potential lessons learned for implementation in future outages. For example, one lesson learned from the past Unit 2 outage identified the potential for losing two trains of safety-related equipment if surveillance testing failed. Maintenance had been started on one train of a diesel generator while the other train was in surveillance testing. This lesson was incorporated into the 1997 Unit 1 outage, thus decreasing the risk of losing protected equipment or affecting two trains at the same time.

Improved parts availability, improved equipment reliability, and reduced costs have been achieved through material evaluations of commercial-grade parts for safety-related applications. Material analysis is also performed to verify proper materials and troubleshoot component deficiencies. In addition, reviews are completed for parts and materials supplied by vendors that no longer are maintaining proper quality assurance programs for safety-related components. The following examples were noted:

a. Some commercial grade gaskets, O-rings, capacitors, resistors, nuts, screws, and terminal lugs have been generically qualified for use in safety-related applications. This reduces time and costs locating suppliers for these parts.

b. Material analysis laboratory tests are performed for critical parameters of parts to determine equivalency with commercially available items. The laboratory equipment has the capability to test mechanical, hydraulic, electrical, and combustible characteristics. These commercial-grade parts are used in applications for which the supplier no longer maintains a safety-related quality assurance program.

c. Material analysis equipment is used during troubleshooting of material deficiencies on installed equipment. During the recent Unit 1 outage, electrohydraulic system O-rings for main steam isolation valve fittings were identified to be leaking. A laboratory analysis determined that the vendor-supplied O-rings were incorrect, even though labeled as the required O-rings. The correct material O-rings were installed, resolving the leak.

d. Critical parameters of receipt material are periodically verified. Problems with receipt parts were detected during the Unit 1 outage, thereby preventing the wrong material from being installed. Two receipt inspections identified that both the flash point of some hydraulic fluid and the gasket materials for some chiller parts were incorrect. These items were returned to the vendor for the proper material specification.

Engineering has demonstrated a proactive approach to improving plant equipment reliability. Reliability improvements have been achieved on key balance-of-plant equipment, including feedwater heater level control and electrohydraulic controls. Engineering has initiated actions to prevent potential problems by applying industry experience. Contributing to this proactive approach are a highly qualified engineering workforce, active supervisory involvement in managing engineering work, and use of long-range action plans to address equipment issues.

a. The following are examples of proactive actions to improve equipment reliability:

1. In response to industry experience, an action plan was implemented to refurbish all reactor coolant pumps on both units to ensure that loose reactor coolant pump turning vane cap screws did not reduce reliability.

2. The Unit 1 feedwater heater level control system was upgraded from pneumatic to solid-state electronics, resulting in more precise level control and eliminating valves and fittings prone to leaks. Modification of the Unit 2 system is scheduled for the next refueling outage.

3. The reliability monitoring of the turbine-driven auxiliary feed pumps was upgraded to include pump starting data. The collected data has been used to fine tune pump controls, contributing to a high system availability.

4. Electrohydraulic control system reliability has been improved by several modifications, including addition of a pulsation dampener, valves for component isolation to allow on-line maintenance, and redundant filters, and upgrading of pressure instrumentation and pump internals.

5. Although steam generator sludge buildup is low, latest available techniques were adapted for use at the station to visually inspect and clean areas of the tube sheet previously inaccessible and to confirm tube sheet sludge buildup profiles. Similar techniques were adapted to allow inspection of the steam generator upper bundle.

b. The following contribute to engineering's proactive approach:

1. Many system engineers have had their assignments since startup, and most of the staff has been at the station since startup. In addition to attending engineering support personnel training, the engineering support group has initiated a special biweekly technical training program to improve engineering skills and system knowledge. For example, all members of the nuclear steam supply system group are working on reactor engineering qualifications.

2. The station has established, and reports quarterly on, a major problem list that includes a "top 10" list. These problems are worked on aggressively by all work groups. The station has been proactive not only in solving its own known problems but also in seeking out industry issues that may adversely affect continued safe operation.

3. Engineering supervision provides continuous oversight, coaching, and counseling on workload and priorities. Engineering management sets goals for backlogs that are typically 50 percent of station goals. Having a low engineering backlog has helped maintain a more balanced approach to operation and maintenance support and has improved equipment reliability.

Training personnel are routinely involved in line department initiatives. These initiatives have resulted in improved equipment reliability, testing efficiencies, and technical guidance, as well as improvements in training. Support for these initiatives includes roles as project leaders, subject-matter experts, and technical reviewers. This support develops training ownership of station performance and contributes to improved teamwork between training and line departments. The quality of training is also enhanced because the instructors incorporate their knowledge gained into training materials. Additionally, this training support improves instructors' credibility with students and promotes effective use of station resources. The following are examples of effective training personnel involvement in resolving problems:

a. During support of outage activities, an electrical instructor recognized indications of hardening grease inside electrical breakers as part of preventive maintenance. The instructor subsequently met with industry working groups, the manufacturer, and corporate engineering to determine the extent of the problem. The instructor also worked with line engineering personnel to revise procedure guidance and to develop and conduct breaker maintenance training on this identified problem.

b. The station's response to new industry requirements for testing ASME Code pressure relief valves was led by a mechanical maintenance instructor. The instructor worked together with industry working groups, vendors, and other nuclear utilities to obtain related information. The instructor shared this information with maintenance personnel, developed an innovative pressure relief valve test stand, and provided training on the testing. The instructor also acts as the lead to revise procedure guidance for pressure relief valve testing.

c. Training personnel led a project to improve technical specifications by extending out-of-service times on some equipment and offering a more consistent approach to applying technical specifications. They also developed related training. Since training personnel provided the technical expertise to lead this effort, line departments did not have to divert resources from the day-to-day operation of the plant.

Training and line managers encourage instructors to take ownership for plant performance and readily accept comments from instructors on topics outside the traditional training area. Line managers look for opportunities to integrate training personnel into routine operations and special projects, fostering collaborative work relations between line and training departments and enhancing the capabilities of the instructors.

The use of a centralized monitoring system has improved health physics monitoring of workers, thereby reducing dose to health physics staff and decreasing the level of technician support needed during outages. Outage management and maintenance supervisors also use the system to monitor work in progress, and some in-service inspections have been done totally using the video system. Workers can use the system to request specialized tools and to avoid job delays when quality control hold points are approached. The system uses video cameras, wireless headset radio communications, cellular telephones, and telemetric electronic dosimetry to monitor workers in both the auxiliary building and the containment building.

Over 100 outage workers have been monitored simultaneously using the system, which consists of up to 22 video cameras and 7 color monitors, communications equipment, and teledosimetry operated from a remote location outside the radiologically controlled area. As a minimum, work groups entering the containment building are provided with cellular phones, and roving health physics technicians have wireless headset radios. Changes in worker dose rates or improper worker practices are addressed through direct communications with either roving health physics technicians or individual workers. In addition, satellite video monitors are set up for operations and outage personnel during refueling outages. Also, system wiring and camera mounts permanently installed inside containment have reduced both equipment installation time and dose.

Some recent successes of the system include the core barrel lift for the 10-year in-service inspection and removal of a damaged lower guide tube. The core barrel lift used the centralized monitoring system with the polar crane operated from a pendent behind a shielded area. The core barrel lift and associated activities were completed with a total dose of only 75 millirem. Also, a damaged lower guide tube was remotely removed from the refueling cavity to a shipping cask through use of the centralized monitoring system, for only 4 millirem. Radiation fields during the lift were as high as 730 rem/hour.

The system has evolved over the past five years from temporary installations during outages for steam generator and other dose-intensive tasks to a permanent centralized monitoring system. The system was designed and built by plant personnel with extensive use of existing equipment to minimize cost. Increased manpower efficiencies have allowed cost savings that exceed the total system cost each outage. Over the past five years, use of the system is estimated to have saved about 125 person-rem and reduced the percentage of outage dose attributable to health physics from 17 to 8 percent.

Reductions in collective dose have been achieved through the use of job-task and long-term planning, plant modifications, and changes in the conduct of work. A cross-section of workers and supervisors from several departments was tasked with developing an effective dose reduction plan. This strategic plan for dose reduction identified over 80 short- and long-term action items. All items were evaluated for cost benefit, and owners with due dates were assigned. While the health physics department tracks these action items, most action items are owned and implemented by personnel outside the health physics department. Examples of dose savings include the following:

a. Increasing the number of running reactor coolant pumps during shutdown and use of reactor coolant microfiltration has improved the effectiveness of controlled crud bursts. During the recent refueling outage, two trains of residual heat removal were placed in service to allow three reactor coolant pumps to be operated during cleanup of the controlled crud burst. This shutdown lineup, in conjunction with the use of 0.1 micron filtration and good operating chemistry, is credited for a reduction in containment building dose rates.

b. The method used to drain refueling cavity sludge after cavity decontamination was changed and a permanent modification made to allow draining through the cavity emergency drain directly to the containment sump. This modification has reduced the number of hot spots caused by reactor cavity draindown and the need for subsequent flushing to remove these hot spots. An estimated 4.5 person-rem is saved each refueling outage.

c. A detailed review of snubber work scope by size and location was used to optimize crew size and the sequence of snubber work. This resulted in an estimated saving of 2.3 person-rem during the 1997 refueling outage. Similarly, an evaluation of outage scaffold work resulted in the purchase and use of quick- erect, modular-type scaffolding. This saves approximately 6 person-rem of dose per outage.

Effective teamwork between the Chemistry Department and the Outage and Planning Department has minimized the impact of shutdown chemistry practices on critical path outage time without compromising shutdown chemistry goals. Highlights of the activities reflecting this teamwork include the following:

a. The reactor coolant hydrogen removal and hydrogen peroxide addition processes have been effectively managed for transition into the oxidizing phase of shutdown chemistry without schedule delays.

b. The length of the oxidizing phase of shutdown chemistry has been gradually reduced under controlled conditions and the effects analyzed. This has reduced the time required for this phase from 48 to 24 hours of reactor coolant pump operation, with no adverse effect on shutdown dose rates. This improvement has also reduced the scheduled outage time.

c. Many maintenance activities, including some inside containment, are being performed in parallel with chemistry activities with minimal impact on dose received.

Effective integration of shutdown chemistry activities with the outage schedule has contributed to their successful implementation. In addition, a critical review of the schedule uncovered inefficiencies to implementation of parallel work activities during early boration, hydrogen peroxide addition, and reactor coolant cleanup phases of the shutdown.

Proactive implementation of chloride injection for steam generator molar ratio control has decreased the severity of alkaline crevice conditions in steam generator tubes. To minimize the potential for future tube cracking, chloride injection is implemented as a preventive rather than a reactive measure. The following examples highlight the chloride injection program:

a. Through an aggressive source term identification process, steam generator blowdown sodium concentrations were reduced to less than 0.4 parts per billion before the chloride injection program was implemented. This is consistent with industry guidelines to minimize impurity ingress before molar ratio control.

b. Before chloride injection, the Unit 1 cation-to-anion molar ratio was 50:1 as measured during hideout return studies. Following chloride injection, the ratio was reduced to 1.2:1 as measured during shutdown for a forced outage, and 2.1:1 going into refueling outage 1R7. This reduced the calculated crevice pH from 10.5 to 8, indicating lower alkaline conditions in the steam generator crevices.

c. Potassium in the condensate storage tanks was identified as an impurity resulting from degradation of the tank bladders. Consequently, the bladders were replaced, and the molar ratio control program was adjusted to offset the effects of potassium entering the system. Potassium contributes to alkaline crevices in the steam generators.

4.1.7 TOPS

Management fosters a high level of ownership and initiative by station personnel that contributes to the consistently strong materiel condition, equipment performance, and cleanliness of the plant. Personnel frequently take ownership of tasks and are proactive in communicating with other personnel and supervisors as needed. Individuals take the initiative to identify and seek resolution to equipment performance issues. This results in an effective and efficient teamwork approach to maintaining plant performance and cleanliness. Management encourages ownership and initiative by empowering workers; maintaining simplified and easy-to-use work processes; consistently communicating a message to take the time to do it right; and establishing a vision of safe, long-term plant operation.

A high level of plant materiel condition is reflected by very few leaks or equipment deficiencies, a very low backlog of nonoutage corrective maintenance items, and strong long-term equipment performance and reliability as indicated by the World Association of Nuclear Operators performance indicators. Strong equipment performance and materiel condition limit the challenges to operators, supporting safe and reliable operation. Additionally, the plant is uniformly clean, including out-of-the-way areas. Tool storage and lockers are well organized. The cleanliness of the plant allows equipment problems to be more readily identified and addressed.

Operations management has made many operations-related improvements in areas such as outage conduct, work planning, personnel sick leave reduction, and human performance through the use of monthly operations management meetings. Meeting participants include operations management, operations training management, shift managers, and shift supervisors. Improvements made as a result of these meetings include the creation of a new outage position known as the "shift outage coordinator" for maintaining consistent, effective outage management from one shift to the next and the implementation of a sick leave incentive plan. Areas routinely addressed in the meeting include operational, performance, organizational, personnel, and regulatory concerns; emerging issues; and policies and standards. Unresolved issues are assigned and tracked to closure. Teamwork, involvement, and ownership are major factors in the effectiveness of this forum.

Extensive operational training is provided to engineering personnel to increase their integrated plant knowledge and operational perspective. Engineers participate in the nuclear certification training program that provides 19 weeks of licensed operator-level fundamentals, systems, and simulator training. Continuing training consisting of quarterly systems refresher training is also provided to maintain the knowledge level and proficiency attained through the initial certification training. Engineers participate in simulator training once per year. This training has contributed to engineering personnel maintaining a strong operational focus in their work activities.

Training program advisory committees are effective in the systematic determination of training program content, which has enhanced worker and station performance. Training program advisory committees are the primary decision-making bodies for training issues at the station. All committees have a commensurate mix of line managers and supervisors, job incumbents, and department training personnel. Each program advisory committee is chaired by a line manager.

The committees use a systematic process to analyze training needs. This includes training requests, performance indicators, and reviews of changes to job scope to identify needed task additions or deletions. Additionally, the committees analyze student and line manager feedback, industry experience, and human performance trends that may indicate changes to the training programs are needed.

Ownership of the training program advisory committees by the line management team has been enhanced as a result of the training supervisors and instructors reporting directly to the line managers.

The nuclear manager-supervisor training program is effective in providing management personnel with the position-specific knowledge needed to perform assigned responsibilities. The program consists of 25 position-specific qualification areas. Each qualification area consists of a group of common and position-specific training topics and a job familiarization section. A continuing training program is provided to present current information on major program changes and to address any areas for improvement in business and professional skills.

The common topics of the training program are similar to those included in the accredited shift manager and maintenance supervisor training programs. These topics are enhanced by job-specific items included in the various qualification areas of the training program. Examples include topics on work-site cleanliness, job briefings, postmaintenance testing, and regulatory requirements.

The job familiarization section gives the new incumbent an opportunity to discuss the responsibilities and support functions of several plant departments with members of the management team. Additionally, the new incumbent develops an understanding of the interrelationships among the plant departments.

A continuing training program is based on recommendations of the manager-supervisor training program advisory committee. The committee uses feedback from plant performance, employee survey results, plant modifications, and administrative procedure revisions.

The station consistently achieves low collective radiation dose. In addition, the collective dose for the recent Unit 1 refueling outage was about 25 percent lower than the previous refueling outage dose. These results have been achieved by a plantwide focus on the basics of dose reduction. Key aspects of the dose reduction efforts include the following:

a. An elevated pH and coordinated lithium primary system chemistry have been maintained for many years. In addition, fluctuations in lithium concentrations are reduced. As a result, the radiation source term is decreased.

b. Temporary shielding is effectively used to reduce personnel dose. For example, during outages, temporary shielding is installed between the reactor coolant pump motors and the steam generators, for a dose savings of about 2 person-rem.

c. When possible, work is moved to lower dose rate areas. For example, the upper internals lifting rig was painted outside the reactor cavity.

d. Workers perform tasks efficiently and reduce time in higher dose fields. Also, maintenance crew sizes are optimized for the work to be performed.

e. During the recent Unit 1 refueling outage, incentives were used for meeting weekly goals. If weekly goals for radiation, industrial, and nuclear safety were met, prizes were raffled off. Both plant and contract workers were eligible for these prizes. Also, the Radiation Protection Department increased use of both prejob and job site radiological briefings. As a result, workers were more aware of area dose rates and low-dose areas.

Filtration of lubrication oil prior to use reduces the potential for damage to plant equipment. Plant personnel have frequently detected that drums of new lubricating oil supplied by vendors contained particulate impurities and, in some instances, sludge. The station purifies this oil by using a dual filtering technique (a 40-micron filter followed by a 10-micron filter). The filtered oil is placed in dispensing drums in the oil storage room. Each dispensing drum has a strainer on its spigot to remove any large foreign material. The clean oil dispensed in the oil storage room is transported to the equipment in dedicated, clearly marked safety cans.

The concentration of lithium, boron, and sodium is accurately analyzed using improved ion chromatograph techniques. This provides more accurate measurements at low levels and avoids the interference of boron found in reactor coolant samples. The typical industry method is to analyze lithium on an atomic spectrophotometer with multiple standards containing boron and lithium. The concentration of boron is also determined by using the ion chromatograph. Since the ion chromatograph is also used for postaccident boron analysis, this provides an opportunity for the technician to practice with the instrument each day. Steam generator sodium concentration is also measured using the ion chromatograph technique to a very low concentration, 0.1 parts per billion.

Table 3
Symptom Classification for High Performing Plant Strengths

Core attribute	**Strength**
	Summit
Teamwork to solve a plant problem	A multidisciplined team has developed effective actions to minimize the effects of heavy influxes of ocean debris at the intake structure.
Teamwork in the control room, peer checking	Control room operators effectively use peer-checking practices for routine component operation, verification of expected alarms, and reduction of human errors.
Fixing the equipment, keeping the backlog low	Timely repairs and reduced work backlogs have resulted from effective implementation of the Fix-It-Now team.
Investing in the expertise of the people	Strong management emphasis and support are developing a high degree of health physics technical expertise.
Teamwork to reduce radwaste volume	The generation of low-level radioactive waste has continued to be reduced as a result of plantwide support and innovative volume reduction approaches.
Learning organization	Chemistry personnel routinely conduct extensive benchmarking of industry chemistry programs, resulting in program enhancements such as improved use of primary coolant demineralizers for lithium and impurity control and detection of chlorides in closed cooling water systems by ion chromatography.

Core attribute	Strength
Effective use of training to improve expertise	Significant improvements in nonlicensed operator continuing training have resulted from effective line ownership of the training program.
Effective planning results in better mode transistions	An effective tracking system automatically and easily identifies reactor mode change constraints during outages. As a result, mode changes performed over the past several outages have been effectively executed.
Effective planning allows more equipment to be worked on during forced outages	Detailed planning has contributed to well run unscheduled outages.
Preventive instead of corrective maintenance, monitoring of equipment	The chromium content of carbon steel piping is monitored to aid in determining appropriate inspection intervals for flow accelerated corrosion.
	Pinnacle
	Management use of the Independent Safety Engineering Group (ISEG) in day-to-day activities has promoted a station culture focused on nuclear safety.
Learning organization	Strong management support of benchmarking activities has resulted in several process enhancements.
Operations focus on station activities	Shift operating crew members exhibit effective communication and conduct activities in a way that minimizes control room distractions. Clear written standards and consistent reinforcement of expectations by managers, supervisors, and trainers contribute to the effectiveness of these practices.
Operational focus	The shift turnover process results in an accurate exchange of important information.
Procedures facilitates equipment repair and return to service	Response to degraded instrument and controls equipment conditions is improved through the development and use of preapproved troubleshooting procedures.
Preventive	Three-phase breaker testing has increased 480-volt AC

Core attribute	Strength
instead of corrective maintenance	breaker reliability.
Preventive instead of corrective maintenance	The development and use of effective methods for monitoring motor-operated valves have resulted in improved valve reliability.
Monitoring to improve plant performance	Implementation of an improved fuel loading strategy has reduced in-core neutron flux tilt and increased operating margin.
Teamwork to reduce exposure	Low dose rates in the plant, effective contamination control, and intensive planning and work coordination have been effective in maintaining low collective radiation exposure.
Teamwork to reduce radwaste volume	Continuing efforts at reducing the generation of low-level radioactive waste have resulted in significant reductions in both solid and liquid waste.
Teamwork to reduce radiation exposure	Chemistry and operations personnel maintain a high degree of control over reactor coolant pH, contributing to low radiation levels in the steam generators and reduced radiation exposure.
Training to improve performance	Licensed operator continuing simulator training effectively corrects identified crew and individual performance weaknesses.
Training to improve performance	Continuous improvement efforts, varied and effective training methods, experienced instructors, and effective line and training supervisor involvement in training have resulted in improved maintenance, health physics, and chemistry performance.
	Peak
Understanding each others job, focus on priorities	Engineering use of a simple, but effective work management process facilitates the timely completion of important engineering work. The process prioritizes and balances workload and has resulted in a sitewide understanding of engineering priorities and activities.
Training used to improve performance	Radiological protection and training worked together to develop training scenarios that have been used to improve technician understanding and performance of infrequently performed, complex radiation protection tasks.
Innovation reduces radiation	Use of a valve location guide that references valves to radiological survey map grid coordinates has contributed to a

Core attribute	Strength
exposure	reduction in collective radiation dose.
Teamwork to reduce radiation exposure and radwaste	Aggressive station actions have resulted in reduced activity of liquid radioactive waste and low usage of waste processing ion exchange resin.
Training to improve performance	Effective training development committees, use of subject-matter experts, and rotational personnel assignments increase the effectiveness of training.
Teamwork to improve plant performance and material condition	Personnel consistently demonstrate a low tolerance for equipment deficiencies, willingly respond to the needs of other departments to resolve equipment problems, and effectively prioritize emergent maintenance issues. These behaviors contribute to reliable equipment performance and good plant materiel condition.
	Superior
Performance indicators used to communicate progress versus established goals	The performance annunciator panel program provides early detection of problems, fosters continuous improvement, communicates performance in a simple and visual manner, and allows management to focus on areas that need improvement.
Promoting teamwork via improved communication, also knowing each others jobs	The computer-based daily log system facilitates awareness of the current status of various work activities.
Teamwork, knowing each others jobs, and operational focus on station activities	Involvement of operators in a variety of key functions enhances interdepartmental teamwork and operational focus.
Training used to improve performance	Operations personnel performance has improved through the effective use of training and an active partnership between the operations and training organizations. This partnership has resulted in greatly improved crew performance in areas previously noted to be weak.
Equipment reliability high	Unplanned generation losses have been maintained at very low levels because of an aggressive preventive maintenance

Core attribute	Strength
due to knowledgeable staff and preventive maintenance versus corrective maintenance focus	program, experienced craft with a strong ownership of the equipment, and a redundancy of many key components. As a result, unplanned capability loss factors on both units have been less than 0.5 percent since January 1997.
Preventive versus corrective maintenance results in better performance and reduced workload	Strong maintenance work practices have reduced containment penetration leakage to very small levels. This performance has been used to reduce the number of required local leak rate tests by approximately 50 percent.
Preventive versus corrective maintenance	Feedwater corrosion products have been reduced to values typically less than 1 part per billion by coordinating plant modifications, changing chemistry regimes, and improving plant operations.
Use of industry operating experience to improve plant performance	Chemistry personnel accurately predicted and mitigated the effects of a higher-than-normal release of radioactive corrosion products in the primary system during the recent Unit 2 shutdown. A proactive strategy was implemented to greatly reduce the subsequent deposition of radioactive material on piping to maintain manageable radiation levels in the plant.
Use of in-house operating experience to improve performance	Effective implementation of several innovative initiatives has improved Maintenance Department performance.
Use of operating experience (benchmarking) to improve performance	Sustained strong performance in radiological protection has been achieved through self-assessments, performance monitoring, benchmarking, and use of industry and in-house operating experience.
Teamwork to reduce radiation exposure	Continued reduction in collective radiation dose has been achieved through stationwide efforts.
	Effective use of remote monitoring techniques and a central control station have improved radiation protection monitoring of workers, reduced personnel dose, and decreased the needed level of technician support.

Core attribute	Strength
Training to improve performance	The line organization and the Training Department work closely together to provide effective and timely training.
Planning improves outage and post-outage performance	Effective planning, scheduling, and implementation of refueling activities have resulted in successful outage performance and postoutage cycle operation.
	Apex
Teamwork to achieve high levels of performance	A high degree of teamwork among plant workers, with a focus on safe operations and reliable equipment performance, has contributed to high levels of plant performance.
Good communication among operating crews	Shift turnovers are detailed and comprehensive and provide the oncoming crew with plant status, shutdown safety criteria, and a list of shift work activities.
Focus on preventive maintenance over corrective maintenance	A designated maintenance-engineering group conducts a weekly review of all corrective maintenance work orders for potential rework and recurring events.
Control and manage work to focus on priorities like equipment reliability	The engineering organization effectively monitors the status of its work activities and performance using periodic status reports, integrated work schedules, and engineering performance indicators.
	Probabilistic risk assessment results are widely used in station activities to determine safe operating conditions and to assess risk.
Process innovation allows information to be easily retrieved to support equipment reliability	The *Operations Manual* provides a comprehensive source of system information, references, and procedures in an easily used format.
Training used to improve	Operator training is enhanced by comprehensive training materials, use of operating experience and probabilistic risk

Core attribute	Strength
performance	analysis data, and inclusion of fundamentals topics in the training.
Reduced radwaste volume and radiation exposure through teamwork	Improved approaches to processing low-level radioactive waste and controlling radiological work have reduced radioactive waste generation and improved worker efficiency.
Use of operating experience to improve response to plant events	Resolution and response to abnormal chemistry transients are enhanced by the development and use of flowcharts.
Focus on preventive maintenance to improve equipment performance	Reduction of feedwater iron concentration has resulted in reduced radioactive waste generation and improved equipment performance.
	Acme
Teamwork to achieve high levels of performance	Station management has effectively fostered an environment that promotes a strong willingness to work together to improve station performance.
Operational focus to plant safety	A strong operational focus has contributed to plant safety and high levels of equipment reliability.
Training used to develop and reinforce good teamwork skills	During simulated transients, reactor operators demonstrated their ability and willingness to advocate their positions and contribute to team decision-making.
Operational focus	Operator monitoring and diagnostic skills contribute to timely identification of problems and conservative response actions.
Use of risk management tools to improve plant safety	Effective outage risk assessments improve personnel awareness of outage risk, avoid inappropriate combining of outage activities, and improve schedule quality through lessons learned.
Innovation to assure quality parts are available for equipment	Improved parts availability, improved equipment reliability, and reduced costs have been achieved through material evaluations of commercial-grade parts for safety-related applications.

Core attribute	Strength
Monitoring and fixing equipment, using operating experience	Engineering has demonstrated a proactive approach to improving plant equipment reliability.
Use of training to improve performance, in this case the improvement of the trainers	Training personnel are routinely involved in line department initiatives. These initiatives have resulted in improved equipment reliability, testing efficiencies, and technical guidance, as well as improvements in training.
Innovation to reduce radiation dose and improve radiation protection technician productivity	The use of a centralized monitoring system has improved health physics monitoring of workers, thereby reducing dose to health physics staff and decreasing the level of technician support needed during outages.
Teamwork to reduce radiation dose	Reductions in collective dose have been achieved through the use of job-task and long-term planning, plant modifications, and changes in the conduct of work.
Teamwork to improve outage performance	Effective teamwork between the Chemistry Department and the Outage and Planning Department has minimized the impact of shutdown chemistry practices on critical path outage time without compromising shutdown chemistry goals.
Focus on preventive activities to improve equipment performance	Proactive implementation of chloride injection for steam generator molar ratio control has decreased the severity of alkaline crevice conditions in steam generator tubes.

	Tops
Teamwork to achieve high plant and equipment performance	Management fosters a high level of ownership and initiative by station personnel that contributes to the consistently strong materiel condition, equipment performance, and cleanliness of the plant.
Operational focus	Operations management has made many operations-related improvements in areas such as outage conduct, work planning, personnel sick leave reduction and human performance through the use of monthly operations management meetings.
Training used to improve performance, knowing each other's jobs, and operational focus	Extensive operational training is provided to engineering personnel to increase their integrated plant knowledge and operational perspective.
Training used to improve performance	Training program advisory committees are effective in the systematic determination of training program content, which has enhanced worker and station performance.
Training used to improve performance, including managers	The nuclear manager-supervisor training program is effective in providing management personnel with the position-specific knowledge needed to perform assigned responsibilities.
Teamwork to reduce radiation dose	The station consistently achieves low collective radiation dose.
Focus on preventive maintenance to improve equipment reliability	Filtration of lubrication oil prior to use reduces the potential for damage to plant equipment.
	The concentration of lithium, boron, and sodium is accurately analyzed using improved ion chromatograph techniques.

4.2 Executive Interviews

To gain additional perspective on the core attributes that are necessary to achieve long-term high levels of safety and economic performance, the chief nuclear officer for each of the high performing stations was interviewed. Other executives who had previously worked in a long-term high performing station or were known to have other unique insights for example, experience in significantly improving station performance (turnaround managers) were also interviewed.

Each executive was contacted in advance of the interview, the thesis objectives discussed, and were sent the following question:

> As part of an executive exchange program, you suddenly find yourself working at a different utility. Your first thought is, "They brought me here to improve their performance, I'd better get started." What are the first few things that you look to be in place and functioning properly? What are the <u>core attributes</u> that you think must be in place for the station to achieve a sustained high performance level? Why?

Each executive was then interviewed by telephone for approximately one hour. Notes taken during the interviews are shown below and the symptom classification analysis is shown in Table 4, Symptom Classification for Executive Interviews. The names of the executives, utilities, and stations have been changed to protect the confidentiality of the interactions between INPO and its members.

4.2.1 Nuclear Executive Interview 1

Who: Vice President, Nuclear Operations and Chief Nuclear Officer, Progress Power Corporation

When: April 5, 1999

Key Points: Executive 1 said that there are four main aspects to running a high performance nuclear power station. These are:

1. Communication – There should be no major separation between the management and the staff, management cannot be isolated. Further questioning revealed that Executive 1 meant that manager needed to have a detailed, clear, objective understanding of what was going on in the plant. He said that indicators may be helpful but too often do not contain the detailed information necessary and the input to the indicator is sometimes too easily manipulated. He said that the key to good communication is an environment where people challenge each other in a healthy way, erroneous or overly optimistic information is challenged. The main goal is for management and staff to truly understand and appreciate what is happening at the plant.

2. People with broad and deep knowledge - People under how the power generation business works from multiple perspectives. A good technocrat only is no longer good enough. The plant staff must have more people with operations and engineering knowledge than just those who work in operations and engineering. This is because many problems are subtle and diverse input and perspectives on problem resolution are needed. Also, (gets back to challenging, see above) who can question what engineering (or operations) is doing if no one else on site understands their job? Rotational job assignments help achieve this but are generally not sufficient. Other activities must be pursued, like getting an engineering manager a license or certification or providing cross-training to achieve the desired knowledge. The goal is an organization that can challenge each other because they understand each other.

3. A well-maintained plant – All decisions about plant maintenance or repair must be made from the perspective of what is best for the long-term operation of the plant. This applies to big items like repair of dents in the steam generator to daily little items. Must actually fix the technical problem, not just temporarily fix it, but fix it for the long-term. It is OK to perform an analysis that says that a repair is not necessary now but at the same time a plan needs to be made for when the repair will be made. Don't just put things off, leads to always being in a reactionary mode, responding to plant failures in a crisis mode.

4. Focus on simplicity in everything that you do – There is a tendency to change the process, the procedure, or to provide training every time a problem occurs. If these changes are not necessary then more complex processes, procedures, and training results. This is frequently caused by a lack of focus on individual accountability. Sometimes a person just makes a mistake and needs to be spoken to, changes to procedures, processes, or training are not necessary.

4.2.2 Nuclear Executive Interview 2

Who: Senior Vice President, Nuclear, Generation, Superior Power

When: April 7, 1999

Key Points: Executive 2 made the following points:

1. People capable of doing their jobs are absolutely fundamental. However, even when there are capable the may not know the standards of performance. These are provided through a unifying vision – people all pulling together in the same

direction. Superior Power's is "Safe, competitive, world-class nuclear operator." The world class says that we don't want to just get by, sets the standard. One example, we were in the bottom quartile in radiation exposure, not world class. Everyone owned the goal of reducing radiation exposure, not just health physics.

Need to make the long-term investments to support the goals. For example, to reduce leaks and reduce radiation exposure we cut out the RTD's (resistance temperature detectors), an expensive job, but necessary if we were to reduce leaks and reduce radiation exposure during outages.

To support the vision, long-term goals need to be set and sometimes targets need to be set as intermediate points to reach the long-term goals. Setting goals recognizes the fact that standards change and the goals need to change with them, prevents us from becoming complacent. Finally, we need to hold each other accountable to the goals and we have accountability systems (goal review sessions) that help us do this.

2. Communication – Communicate the obvious things like vision, standards, and expectations. But also, the entire management team needs to be walking around talking with people, listening for details of what is happening, and getting the message through. Other methods include monthly newsletter, weekly staff meeting, meetings with first line supervisors, frequent visits to the stations, go out and look at specific jobs. Additionally, need to encourage communication up, down, and sideways, especially sideways to avoid silos in the organization.

3. Teamwork – Comes from first, have a commonality of goals, see point number 1. But the goals and rewards need to be structured such that all succeed or

none succeed. Can't have one group meeting goals at the expense of another group not meeting their goals.

4. Accountability – Not an ugly thing, it is a matter of pride to be held accountable for your actions. Don't forget that praise is the positive part of accountability. Write notes or in some other way don't neglect to acknowledge good performance.

5. Encourage differences of opinion, differences need to be expressed, we say that squawking is good.

6. To prevent silos need to develop broad expertise in many different people. Accomplish this by training (for example, provide license certification training to engineers to give them an operational perspective) and by rotational assignments. This is slow to accomplish and takes a long-term commitment. Superior Power has lots of people in key positions with operational experience and SRO licenses.

7. Leadership – Key attribute is to keep everyone pulling in the same direction and having the energy to keep at it. Need to know what is going on, people need to know you and to trust you. Trust is primarily consistency, doing what you say and being consistent in what you say and do.

4.2.3 Nuclear Executive Interview 3

Who: Senior Vice President and General Manager Nuclear Power Generation, Summit Power

When: April 8, 1999

Key Points: Executive 3 made the following key points:

1. Clear sense of mission and direction – This is needed on paper, but it must also be known and understood by the people. The organization's goals must then be consistent with the mission and direction. Finally, the resource allocation (both people and dollars) must be consistent with the goals. Every decision that is made must be in the context of the goals and mission, the leader must look to make sure that this is happening. He must listen to hear whether people are speaking about the mission and direction when they are in the process of making decisions.

2. Given number 1 above, the mission and goals must be balanced. Can not have only emphasis on safety when the reality is that the business must also be economically competitive. If competitiveness is emphasized, it is real risk that people will begin to think that nuclear safety has taken a back seat to economics, which is wrong. At our plant we use a triangle to talk about balance. Safety is at the top of the triangle because it is the most important. The other two vertices are cost and generation. We keeping stressing balance of these three and integration of these three in everything that we do. Everyone on site must be aligned with the mission and goals but also the corporation (corporate office support and CEO for example) must be aligned to the same goals.

3. Long-term investment in the resources – Need a long term focus on both the people and the plant. For the plant, need a budget and decision process that supports the long-term investment in the quality of the plant and equipment. Can not always be cutting the budget and eliminating plant projects that are needed for long term superior operation of the plant.

For the people, need talented and capable people. Need to know and not be blind to the quality of key people and the depth of talent for key positions. Succession planning is a must.

To develop talented people, training programs that focus on improving performance are needed. Need to develop the technical and soft skills of the workers. Training to improve performance is also needed for the managers.

4. Operating experience – Need to be outward looking so that our people are exposed to the "best in class" ideas. Need to seek and use the operating experience of others. Learn from others and do not be isolated.

5. Self-assessment – Need to know our own strengths and weaknesses. Thorough, honest, self-critical appraisal of our own strengths and weaknesses.

6. Be good at planning – Need to manage the processes to produce good results. We are good at dealing with crises but not so good at doing detailed planning to get the results that we want, this is something that we are working on. Need to emphasize forward looking and not being reactionary.

7. People working together to solve problems – People jointly own problems, not working in silos to try to solve problems. Look for people asking for help and offering assistance.

8. Stretch goals – Does the organization strive on stretch goals? Look for willingness to always improve, willingness to strive to do better, avoids complacency.

9. New ideas – Looks for healthy debate on issues and a willingness to try new ideas. Does not like to see people locked into ideas because that is the way it has always been done. Looks for flexibility because things change over time (used the example of deregulation and retail competition in California).

4.2.4 Nuclear Executive Interview 4

Who: President, Nuclear Generation, Tops and Apex Power

When: April 8, 1999

Key Points: Executive 4 made the following key points:

1. Consistent, constructive decision-making, across a variety of decisions, not just decisions that affect nuclear safety. Need to have predictable management that works through a process to come to a predictable outcome. One example is decisions made regarding personnel discipline. People at the plant watch these decisions very closely. Can not have one decision where the worker is fired and another decision where the worker is given a slap on the wrist for apparently similar offenses. The organization and the people need to know what to expect from management. Predictability helps communication.

2. Lateral integration – Everyone knows everyone else's job. Poor performing stations resolve issues in silos. Lateral integration is achieved by, for example the System Engineering group. The system engineers are the hubs of small teams that are formed to solve problems. They integrate operations, maintenance, and other groups together to solve the problems.

Training also helps to achieve this lateral integration. For example, we have an active certification process (primarily for our system engineers) to give them an operational perspective and knowledge. Once certified, they participate in annual requalification, much like the operators.

3. Teamwork – Lateral integration also leads to teamwork. It takes the whole staff to be successful, no one takes pride or comfort in another's failure.

4. Leadership – Encourage leadership at all levels. It doesn't have to be the boss who is the leader all the time. Leadership is situational.

5. Self-sufficiency – Internally focused, work together to solve our problems, resist bring in contractors or consultants to solve our problems. The expertise to solve the problems the next time, and the problem solving skills are then resident in our organization and do not leave when the contractors leave. There is a downside to this, we do not use the operating experience of others well, we do not do benchmarking trips well, it is something that we are aware of and are working on.

6. Focus on making the equipment work – The equipment is the customer. Fix the equipment right the first time, so you do not constantly have to fix it over and over again. Fix the equipment with a view toward long-term operation of the plant. Plan for the future when deciding on equipment fixes, design changes, or upgrades.

   Need to have a simple, effective process for getting the equipment repaired. This is aided by keeping the maintenance backlog low, that way you can spend your time fixing the equipment not managing the backlog.

Add value to the equipment through preventive maintenance. We replace parts before we really need to, this helps to keep our corrective maintenance to preventive maintenance ratio low. We do 80% preventive maintenance and 20% corrective, other stations do the opposite. This helps us to plan our work and not to be in a reactionary mode due to equipment failures.

7. Planning – Thorough planning is helping us to improve our performance. Planning on a daily basis and also for outages. Schedules are used as a lateral integration tool, many groups review and provide input, results in a believable, achievable schedule that everyone is committed to (because they had a part in developing it).

4.2.5 Nuclear Executive Interview 5

Who: Formerly President of Generation, Century Power

When: March 24, 1999

Key Points: Executive 5 made the following points:

1. Individual accountability – Need to stress this at every level. Resist the temptation to blame and change the process, the procedure, or the training. Make it clear that it is everyone's responsibility to make things work, make it clear that if the process, procedure, or the training is not right, it is the individual's responsibility to get it right before it causes an event.

2. Self-critical (to avoid complacency) – Genuine, self-critical examination of performance, to look for weaknesses and areas for improvement. Self-assessment for large programs and small activities. Look at activities done

daily and critique, make it part of the culture that we talk about what we just did, what went well and what did not go so well so we can improve it.

3. Leadership – The leader needs to understand the nature and characteristics of his organization (regional culture, work ethic, stability of the workforce) and communicate and lead in a style suitable to the workforce, not necessarily his own style.

4.2.6 Nuclear Executive Interview 6

Who: Formerly CEO of Superior Power

When: March 24, 1999

Key Points: Executive 6 made the following points:

1. Teamwork – Teamwork is needed at the plant level and also teamwork between the corporate office and the plant. Successfully operating a nuclear power plant is a complex undertaking that requires everyone working together to accomplish, hence the need for teamwork. Teamwork is promoted by the management team paying attention to all the details, prescriptively if necessary (like at a detailed 0700 meeting), this promotes working together to solve not only the daily problems but also the longer term problems. Teamwork is based on knowledge of the people you work with. Good equipment performance is an outgrowth of good teamwork.

   The reason too many or too frequent change-out of people does not work is because it takes too long for individuals to get to know one another and to get used to working with each other.

2. Support from senior management (CEO) – Management team needs full support of senior managers (CEO) both publicly and privately.

3. Clear lines of accountability – Each person needs to clearly know what they are responsible for and be absolutely clear on their chain of command. To this end, it is helpful to have all the activities that support the nuclear division the responsibility of a single manager.

4.27 Nuclear Executive Interview 7

Who: Executive Vice President Acme Power

When: April 9, 1999

Key Points: Executive 7 made the following points:

Philosophy

- Problem-oriented in a proactive way. A strong desire to uncover problems when they are small or prevent them before they occur.
- Conservative decision making is pervasive.

Organization

- Internally focused on the day-to-day operations of the plant as a first order of business. Externally influenced and influential
- Corporate support works for the plant.

Knowledge

- All line managers through the CEO should have experience in an SRO position as well as managerial capability.

Open Environment

- Employees trust each other and look out for each other and the plant.
- Discipline is reserved for willful misconduct and gross negligence.

Leadership

- Leadership development, performance management and succession planning processes exist that are maintained, utilized and related to each other.
- Leaders are built from within the organization.

Owner

- Financially sound and knowledgeable in plant operations to such a degree that the proper long- term and short-term decisions can be made and supported.

Continuous Improvement

- All employees must understand that continuous improvement is essential to the success of a competitive business.
- Each employee must contribute.
- This transition from a regulated to competitive is very difficult to manage.

Indicators

These critical indicators are high and improving:

Performance

- INPO performance indicators

Material Condition

- Internals, heat exchangers, turbines, generators, etc.

Behavior

- Human performance: industrial safety events, mispositionings, etc.

Attitude

- Surveys, forums, management involvement. We must work on more ways to measure.

Appearance

- Employee conduct, plant and grounds cleanliness and orderliness.

Principles for Nuclear Operations

We are America's best nuclear operations. Our successful employees exhibit the behaviors and values of *Acme Style*. Our approach to nuclear operations is guided by the principles outlined below.

Safety

As a matter of personal and moral responsibility, we take conservative measures to safeguard the health and safety of our employees and the public. This responsibility is never compromised in the interest of production or cost.

Continuous Improvement

We are dedicated to the optimum operation, maintenance, engineering, and support of each of our nuclear plants, hour-by-hour, day-by-day, to ensure safe, reliable and economical performance. We strive to achieve simple and standard work practices. We maintain open and candid relationships with each other, regulatory agencies and others with whom we interact. We build upon our past achievements and experiences, as well as those of others, to achieve continuous improvement.

Problem Focus

We recognize that the methodologies used in the design, construction, and operation of any large, complex production facility, such as a nuclear plant, are a less-than-perfect application of knowledge and skills. We also recognize that we are not infallible in the application of knowledge and skills. These imperfections may evolve into problems that we must be prepared to overcome in order to accomplish our mission. Therefore, we are "problem-oriented." We maintain our day-to-day -- as well as long-term -- focus on detecting existing and potential problems before they become significant. We take action to resolve these problems safely and cost-effectively, taking into consideration the relative importance and priority of every aspect of our work.

Responsibility and Accountability

We recognize that our success depends on each individual's performance. We set high goals for ourselves. We accomplish our goals through teamwork, with each individual having assigned work and the authority, responsibility and accountability for performance of that work. We act with speed and professionalism, and we dedicate our individual initiatives and unique capabilities to the achievement of our personal, team and company objectives. Each of us will be independently responsible for our professionalism.

Spirit

We will be mutually and collectively supportive to maintain a strong, positive team spirit in striving to achieve our goal as "America's Best Nuclear Operations."

Ethical Behavior	We tell the truth. We keep our promises. We deal fairly with everyone.
Customer First	Our business is customer satisfaction. We will think like customers...
Shareholder Value	... and act like owners. We work to increase the value of our investment.
Great Place to Work	We are a first-name company. We enjoy our work and celebrate our successes. We seek opportunities to learn. We do not compromise safety and health.
Teamwork	We communicate openly and value honesty. We listen. We respect all opinions and expect differing viewpoints as we work together toward common goals. We emphasize cooperation -- not turf.
Superior Performance	We continue to set high goals for ourselves. We take personal responsibility for success. We act with speed, decisiveness, and individual initiative to solve problems. We use change as a competitive advantage.
Citizenship	We are committed to the environment and to the communities we serve.

4.2.8 Nuclear Executive Interview 8

Who: Engineering Programs Manager, Sunshine Nuclear

When: March 24, 1999

Key Points: Executive 8 made the following points:

1. Physically fix plant problems. Be very reluctant to analyze problems away. Fix plant problems so they stay fixed for a long time. The staff concentrates on fixing the plant, not on doing analysis to make problems go away (when this is not really appropriate). Sometimes the most important aspect of fixing the plant is getting the design basis adequately reconstituted so that there is no question about how the plant is supposed to operate and what the safety basis is.

2. The organization is a learning organization. The station corrective action and self-assessment programs find real problems and solutions are generated that fix the identified problems. Resist changing procedures, training, and processes if they are not what needs to be fixed, done way too often.

   Also as part of a learning organization, the station uses the operating experience of others effectively.

3. Training is important. Training includes technical training, soft skills training, and business training.

4. The organization is outward looking. People in the organization seek input and ideas from outside sources like the NRC and INPO.

5. Continuous focus on what they are trying to accomplish, the best plants talk about station focus areas daily.

6. The management team is very involved and knows the details of everything that is going on at the station. This does not mean that they micromanage the details but they know and monitor to make sure the standards are being met.

7. Continuous long-term investment is made in the plant. The plant staff continually looks ahead to manage obsolescence and aging. The plant has a good replacement and upgrade program.

8. Department heads and first line supervisors know and do their jobs – which is to coach and train their subordinates. The department heads and supervisors also take the corporate direction and focus and translate it into meaningful actions for their subordinates. Also, the station needs a senior management team that can teach the department heads and supervisors how to do the above and monitors to make sure they are doing it.

4.2.9 Nuclear Executive Interview 9

Who: Vice President, Nuclear Operations Pinnacle Nuclear Station

When: April 15, 1999

Key Points: Executive 9 made the following points:

1. Leadership

Station leaders must know how the station works in detail. This knowledge is developed by experience for the leaders in the Operations Department, Senior Reactor Operator license or certification, degree programs for operators (to prepare them for leadership positions) or rotational assignments.

First line supervisors are encouraged to work among themselves to resolve issues instead of pushing issues up to manager. Executive 9 said that this approach has developed a sense of teamwork among the supervisor and also increased their sense of responsibility and ownership for the solution of station problems.

Managers must have a high level of involvement in station activities and know and understand the station issues. This includes managers up to including the Nuclear Vice-President.

A monthly performance meeting is held for the entire management team in order to help all managers keep track of what is going on stationwide. Helps managers work together as a team to identify problem areas and solve them.

Of all the leadership attributes, integrity is the most important. Must do what you expect others to do and keep promises.

2. Safety zealots

Everyone must put reactor safety first in all his or her activities. Additionally, a few people on site must be "safety zealots." These people always put safety before schedule pressure and keep others focused on safety too. Managers must go out of their way to reinforce the safety zealots.

3. Communication

Executive 9 judges the health of communication in the organization by listening for those who ask the difficult questions. He wants an atmosphere where everyone feels comfortable asking questions about reactor safety, no one should feel intimidated or worry about being chastised for asking a reactor safety question. Managers must be overt in their support of those who speak up and ask the difficult questions. Also, people must feel comfortable bringing bad news to the boss. Executive 9 listens for issues that are "watered-down" instead of being presented frankly.

Deal with facts, not opinions and keep everyone in the organization informed. Executive 9 has found that communication with the first line supervisors particularly important. The supervisors are considered part of the management team and are informed before the individual contributors so they have an opportunity to ask questions and are better able to answer their subordinates questions.

4. Outward Looking – Constant Improvement

Executive 9 stated that he is always seeking improvement. The two ways this is most frequently done is benchmarking trips to other facilities (nuclear and non-nuclear) and self-assessment. He tries to get individuals from other nuclear stations to participate on every self-assessment team, they have an agreement with three other utilities to exchange individuals on self-assessments. He finds the outside perspective particularly insightful.

5. Long-term perspective

There has been a recent effort at the station to recover some of the safety margin that has been eroded over the years. Preservation of the margin helps assure that the station will be able to successfully operate for many years (hopefully beyond its currently licensed lifetime). Some margin was recovered when the new steam generators were installed.

Engineers are encouraged to take a long-term perspective when installing plant modifications and fixing equipment problems. Executive 9 said that life at the plant gets better when the equipment problems are solved and not allowed to recur.

6. Teamwork

Executive 9 encourages teamwork and said that a nuclear power station can only be successfully run if everyone works together. At Pinnacle, everyone on site receives training on teamwork and on how to effectively communicate. This has helped people communicate their ideas and improved problem solving at the station.

7. Plant Changes

The plant is able to changes faster than the people are able to adapt to the change. When a plant modification is made now, they take the time to discuss the change, provide detailed training on the change, allow people to ask questions about how the change will affect them, and pay special attention when an evolution involves the plant change. This very careful approach has reduced the number of problems introduced by change.

8. Training

The focus in providing training is to add value, not to just go through the training motions. The emphasis in training is on interpersonal skills and on technical fundamentals.

9. Human Performance Problems

Keep a balanced perspective on when to solve a human performance problem with a physical change (either to the plant or to a procedure) and when to counsel the individual. Executive 9 said that it was equally easy to make a mistake either way.

Table 4
Symptom Classification for Executive Interviews

Interview Comment	Core Attribute
Executive 1	
A healthy environment where people challenge each other Managers know in detail what is happening in the plant	Communication
People in key positions need to not only know the technical details of the plant but must know other's jobs, helps with healthy challenging Training to achieve broad experience	People with broad and deep plant knowledge
Fix the technical problem with the equipment Focus on long-term solutions Plan for equipment upgrades and repairs when possible, avoid always having to react to equipment failures	A well-maintained plant
Continually strive to simplify processes Focus on accountability, resist the temptation to change the procedure or process when individual accountability should be exercised	Focus on simplicity
Executive 2	
Communicate direction and standards through a unifying vision	People capable of doing their jobs

Interview Comment	Core Attribute
Make long-term investments to support people and plant goals Hold each other accountable to meet the goals	
Communicate vision, standards, and expectations. Also, the management team needs to really know what is going on, find out by talking to people at all levels.	Communication
Structure goals and rewards such that all must succeed for one to succeed	Teamwork
Personal accountability at all levels in the organization	Accountability
Culture where one is expected to express their opinion, goes with knowing each other's jobs	Encourage differences of opinion
Broad experience of plant staff. Long-term commitment is needed, achieved by training and rotational assignments.	People with broad expertise
Attributes of a good leader; keep everyone pulling in the same direction, consistency to develop trust, and know details of what is going on.	Leadership
Executive 3	
Goals and budget consistent with organization's mission and direction Managers must know what is going on and that it is consistent with mission and direction	Clear sense of mission and direction
	Balance of safety, economics and generation
Long-term view on maintenance of equipment with adequate budget to support Develop talented people, using training to improve performance. Train for both technical skills and soft skills.	Long-term investment in the people and equipment

Interview Comment	Core Attribute
Must be aware of capability of people, good succession planning	
Outward looking, expose people to best in class ideas	Use of operating experience
Need to know own strengths and weaknesses	Self-assessment
Plan to get desired results, avoid just reacting to crises	Good planning
Teamwork, not working in silos, knowing each other's jobs, asking for and offering help	Teamwork to solve problems
Avoid complacency by setting and achieving stretch goals	Stretch goals
Healthy debate on issues, willingness to listen to and to try new ideas	New ideas
Executive 4	
Processes that support predictable management decisions	Consistent decision-making
Knowing each other's jobs, solve problems as a team, not in silos. Training and rotational assignments to achieve and to also develop an operational perspective throughout the organization	Lateral integration
Lateral integration and no one taking pride unless everyone succeeds	Teamwork
Set expectation and provide training so that people other than manager can assume leadership when appropriate	Leadership
Develop expertise to solve own problems, do not rely on consultant or contractors	Self-sufficiency
Fix the equipment with the long-term operation of the plant in mind Need to have a simple, effective process for getting equipment repaired Focus on preventive maintenance	Focus on making the equipment work

Interview Comment	Core Attribute
instead of reacting to failures (corrective maintenance), allows for planning instead of reacting	
Use planning as a lateral integration tool also, plan for results instead of reacting	Planning
Executive 5	
Individual accountability at all levels, resist temptation to blame (and subsequently complicate) procedures or training	Accountability
Thorough self-critical examination of performance	Self-critical
Know what is going on in the organization	Leadership
Executive 6	
Work together to solve problems. Good equipment performance is a natural outgrowth of good teamwork.	Teamwork
CEO and corporate office needs to be aligned with and support the nuclear organization	Support from CEO
Each person needs to know what they are responsible for and their chain of command (clear organizational structure that promotes this understanding)	Clear lines of accountability
Executive 7	
Proactive solution of problems	Philosophy
Focused on day to day operation of the plant. Outward looking, use of operating experience and advice	Organization
Operations knowledge and experience	Knowledge
People look out for one another	Open environment
Leadership development, performance management, and succession planning	Leadership
Self-critical, striving for continuous	Continuous improvement

Interview Comment	Core Attribute
improvement	
Executive 8	
Fix equipment problems with long-term solutions in mind, be reluctant to analyze problems away Design basis must clearly define safety basis of the equipment	Physically fix the equipment
Self-assessment and corrective action processes find and fix real plant problems Use operating experience is used effectively	Learning organization
Training is used to improve both technical and soft skills	Training
Seek and use input from outside organizations	Outward looking
Continuous focus on organization's goals	Focus
Management team is involved and knows the details of what is happening at the plant	Involved management team
Continuous long-term investment in the plant, replacements and upgrades are made	Long-term investment in the plant
Department heads and first line supervisors coach and train their subordinates	Department heads and first line supervisors
Executive 9	
Station leaders must know the plant in detail and have operational experience or at least knowledge	Leaders know how the plant works in detail
First line supervisors encouraged to work among themselves to solve problems	Teamwork
Key leadership attribute is integrity	Integrity
Open challenging of ideas, airing of problems and concerns	Communication

Interview Comment	Core Attribute
Deal with facts in making decisions, not opinions. People must feel comfortable bringing bad news to the boss.	Communication
Use self-assessment and operating experience to foster continuous improvement	Outward looking
Fix equipment problems with a long-term perspective in mind. Recover lost safety margin to assure margin exists at the end of plant life.	Long-term perspective
Use training to improve interpersonal skills, results in improved teamwork.	Training to improve teamwork
Plant is easier to change than the people. When making plant changes make sure the people fully understand the changes before they have to be used.	Change management
Use judgement in deciding if a physical plant change is needed to solve a human performance problem, every case is different.	Human performance problem corrective actions

5. CORE ATTRIBUTES OF HIGH PERFORMING STATIONS

The purpose of this chapter is to present and describe the core attributes that resulted from the analysis of the high performing plant strengths and executive interview. Of the many activities at a commercial nuclear power station, they represent the programs, processes, and practices that contribute most significantly to sustained high performance. The core attributes are interrelated and mutually supportive. Some attributes are part of and contribute to the success of other attributes.

Teamwork

Each executive interview and INPO evaluation report identified teamwork as the most important core attribute for sustained success in operating a commercial nuclear power station. Executives stated that successfully operating a station is a complex undertaking that requires all employees working together as a team. Teamwork was described as the willingness to help others accomplish their tasks and goals. One executive said that teamwork was taking pride in helping others succeed. For teamwork to contribute to station success it must occur at many different levels within the organization. Individuals within a department must help each other but must also willing to help those in other departments. Executives also stated that the teamwork extends beyond those on the plant site to include corporate office employees and employees at other sites in the same utility.

Several factors contribute to teamwork. The executives stated that the most important element to good teamwork was a common set of goals that were well understood by all station employees. Effective goals encompass a broad set of objectives including reactor safety, personnel safety, production, financial performance, and environmental stewardship. Meaningful incentives must be awarded for goal attainment. Additionally, the incentives must be structured to further enhance teamwork. For example, achievement of one goal should not be able to be accomplished at the expense of not achieving another goal. Several executives stated that they no longer provide incentives for meeting department specific goals. The executives found that incentives for department specific goals resulted in competition for resources and discouraged teamwork. Although department specific goals still exist, incentives are awarded only if the station-wide goals are achieved. This approach promotes teamwork and station-wide ownership of the goals.

Executives said that teamwork is also enhanced when there is an understanding of integrated plant operations by many people in the organization (including members of the management team), communication among work groups and between workers and management is effective, and management is involved in the daily operation of the station. Each of these items is more fully discussed below.

Intolerance for Equipment Problems

An extreme intolerance for equipment problems was identified at each of the high performing stations. Corrective maintenance activities are considered failures too expensive to be tolerated. Upgrades and preventive maintenance can be planned and scheduled, but corrective maintenance often "schedules the station." Corrective maintenance causes perturbations and inefficiencies for the maintenance shops, operations, and engineering, but also was mentioned by several managers interviewed as being a significant potential impact on their time. The managers stated that the time spent reacting to preventable equipment failures was time taken away from more important management tasks like monitoring, long-term planning, and being available for their subordinates. Most corrective maintenance is completed quickly without complex systems like a large work control organization. The stations have low equipment failure rates and low corrective maintenance backlogs.

Managers emphasized the need for extensive preventive maintenance to preserve equipment performance. The primary emphasis at the high performing stations is placed on time-based tasks implemented during station outages. Complete replacement of components, at conservative intervals, is used as one means to achieve superior equipment performance and to decrease schedule variability. Interchangeable spare parts, often used as complete replacements for station equipment, play an important role in preventive maintenance programs. For example, a complete condensate pump and motor assembly is purchased as a spare part. During a refueling outage, one of the installed condensate pump and motor assemblies is removed and replaced as a unit with the spare. After the outage is completed, a detailed overhaul of the removed pump and motor is completed in the maintenance shop. This process is then completed on another condensate pump and motor assembly during the next refueling outage. The benefits of this method include:

- Improved preventive maintenance quality is achieved as the used component is overhauled in a controlled environment (the maintenance shop or at the vendor). The component can be disassembled and detailed inspections can be more easily performed with reduced schedule pressure.

- Better control of outage scope and duration as the number of "open and inspect" items is significantly reduced. The planned activities (for example, condensate pump and motor replacement) are of known duration as they have been performed many times using the same methods.

- Reduced expediting fees and a smaller inventory of spare parts are required because parts are ordered during the overhaul process or on an as needed basis with little schedule pressure.

Component failure data and operating experience are effectively used to enhance equipment performance and reliability. The stations maintain equipment failure databases and use industry failure databases effectively. Stations frequently had a well-functioning feedback mechanism between craft personnel performing preventive maintenance tasks and the system engineers controlling changes to the task scope or frequency. The feedback is used to further improve the preventive maintenance applied to the equipment to improve its reliability or to maintain its material condition. Several stations use the system engineers as the focal point for collecting, analyzing, and disseminating equipment reliability information.

Communication

Several aspects of communication were identified as core attributes to long-term high performance. Many executives stated that good communication among work groups at the station was important because it allowed the best resources available to be applied to station problems. When work groups do not communicate or do not clearly communicate their problems, the problems usually remained within that group. The group with the problem then attempted to solve it without input from other groups and frequently developed solutions that did not meet critical needs of other groups. The executives referred to this phenomenon as "silo-ing."

Executives also sought clear and accurate communication up and down the chain of command. The fear of bringing bad news to the boss was a frequently mentioned shortcoming in upward communication. They felt that in order to sustain a high level of performance they needed to know accurate information about the station, information that was not filtered to remove or minimize its negative aspects.

Executives said that communication to their subordinates needed to be consistent with station goals and standards. The most frequently mentioned shortcoming in downward communication was not considering first line supervisors to be part of the management team. Fist line supervisors must have access to information before the same information is communicated to the station staff enabling the supervisors to be better prepared to convey the information to the staff or to answer staff questions. The executives regarded first line supervisors as the most important link in the communication chain between themselves and the plant staff. Supervisors have daily contact with the plant staff and are the management team member most likely to be sought out by the plant staff when information is needed.

Outward Looking

The long-term high performing stations constantly seek advice, input, good suggestions, new ideas, and even criticism in order to improve their performance. Through this process of constantly looking outward they avoid becoming isolated from others in the industry. The outward looking helps them discover better ways of running the station and thus also helps them avoid overconfidence and complacency.

The high performing plants successfully manage their relationships with outside agencies like the NRC and INPO. They attempt to minimize the adversarial nature of the relationship and strive to use constructively the input provided. The stations seek to understand outside agency comments and concerns and appropriately use the information to improve the station without overreacting to information provided.

The operating experience of other stations is actively sought and used by the high performers stations to evaluate and improve their own operations. One source of this input is NRC and INPO products like Information Notices, Significant Event Reports, and Significant Operating Experience Reports. The station resists the temptation to explain why the shortcomings described in the operating experience information can not happen at their station. Rather, the high performers critically review their programs and practices in light of the information contained in the operating experience and seek ways to prevent a similar occurrence.

Benchmarking is used to improve programs and practices. Domestic and foreign nuclear power stations are visited and non-nuclear facilities are also benchmarked. Executives stressed that these benchmarking trips can not be just "nuclear tourism" but must yield ideas for improvement that can be implemented. The most common pitfall in benchmarking trips cited by the nuclear executives was the tendency of those on the trip to seek to explain why their operation at home was superior and nothing could be learned from the host facility. This tendency results from a natural sense of pride in the success of their station and therefore a reluctance to admit someone else might have a better way.

High performing stations conduct self-assessments for a wide range of activities. These assessments are conducted in the spirit of genuinely trying to improve how activities are accomplished as opposed to assessments conducted with the intent of trying to verify that what is currently being done is satisfactory. Several executives stated that the most effective self-assessments are those that have outside participants, for example, employees from other stations, INPO employees, or consultants. Outsiders are typically more objective, bring the experience of accomplishing similar tasks in different ways, and ask more fundamental questions as they seek to understand how business is conducted at the station being assessed. Several executives said that they have arrangements with other utilities to temporarily exchange employees to participate in each other's self-assessments.

Involved Management

Nearly every executive interviewed said that all station managers, up to and including the senior nuclear officer (typically the Nuclear Vice-President) must have integrated plant knowledge. This knowledge can be the result of a Senior Reactor Operator's license, time spent in the Operations Department, or as a result of training (senior reactor operator certification). The executives also stated that several members of the management team should have direct operational experience either as a Senior Reactor Operator on shift or in a management or supervisory position in the Operations Department. This level of knowledge of plant design and operation enables managers to understand quickly the significance of technical issues as they arise in the daily operation of the plant, to make sound long-term judgements regarding plant investments and capital improvements, and to communicate believably and effectively with the plant staff.

Executives stated that executives and managers must know what is going on in the station every day. This includes knowing about equipment problems, human performance issues, the status of backlogged and overdue items, budget, and issues of potential interest to outside agencies. The executives said that they are careful to ensure that this level of involvement is not viewed as usurping the authority or responsibility of their managers (micromanaging).

Training Used to Improve Performance

The high performing stations strive to use training to correct identified performance shortfalls and to improve both the technical and interpersonal skills of their employees. In contrast, some lower performing stations seek only to do the minimum training required to maintain the accredited status of their training programs. Within the context of improving known shortfalls and striving for further improvement, training is used primarily in three ways.

First, training is provided to increase the depth of a person's knowledge for their existing position. This can be training on a specific technical topic for engineers, refresher on operational fundamentals for operators, or operating experience from other stations. Training to improve soft skills like oral and written communication is also included in this category.

Second, training is provided to broaden the knowledge and perspective beyond a person's current area of responsibility. This includes degree programs for staff member without a college degree, senior reactor certification programs for engineers to introduce them to plant operations and to provide integrated plant knowledge, and management development programs for prospective supervisors and managers.

Third, training is provided for a broad set of skills that enhance teamwork and communication. This training is provided in an appropriate way to nearly everyone on site, not just the management staff. The high performing stations recognize that these skills are fundamental to success at their current level of performance and also for continuous improvement to reach a higher level of performance.

Operational Focus

The entire management team and station staff's first priority is always the safe operation of the plant. Reactor safety is the foremost consideration in all daily and long-term decisions. Distractions from this operational focus are minimized for the management team, station staff, and especially for the operations staff.

Station management fosters an operational focus by frequent, clear communication of high operational standards. These high standards include expectations for rigorous monitoring of plant parameters, clear and unambiguous procedures, strict procedure adherence, clear communication, and operating the plant within the safe operating envelope. The station managers demonstrate high standards by their actions and are conscious of their responsibility as role models for the station staff. Special attention is paid to verifying that standards are being met during important plant evolutions like startups, shutdowns, reactivity manipulations, or during simulated casualties in the plant simulator.

Decision making authority, responsibility, and accountability are absolutely clear within the operations chain of command. Committees or other ad hoc groups maintain their advisory role and are not allowed to become part of the operations chain of command.

Knowing Each Other's Jobs

Professional development of people that know their job well and also understand (and may have done) other's jobs is a long-term commitment to training and development of station staff. This is achieved by providing training (see above) and is also provided by rotational assignments, career planning and careful management of the succession planning process.

Executives said that a group of people that were broadly knowledgeable of a wide variety of station activities enabled several other core attributes to be performed more successfully. For example, this broad level of knowledge enhanced teamwork because people, by understanding another's job, were able to make helpful suggestions or spot potential errors in another's activities. This knowledge also enhanced communication because the broadly knowledgeable people understood the terminology, procedures, and practices of a variety of station work groups.

Long-range Focus

Well-developed, long-term planning is used to ensure effective and efficient allocation of resources. Each of the stations uses detailed planning for key activities several years in advance. Executives stated that this level of detailed planning also resulted in refueling outages that were well executed and completed within the predicted duration. Benefits of long-range detailed planning were stated to include reliable in-service intervals for equipment and decreased operating costs (mostly due to a reduced number of forced outages and shorter duration refueling outages).

An on-going capital investment is made to improve continuously safety margins and unit reliability. The focus at the stations is to have all components support long-term operation. Plant equipment is often upgraded, rather than performance problems being tolerated. Replacement or modification of components is sought after just the second or third time an equipment problem occurs. Several executives stated that their stations relied on good teamwork and communication between the system engineers and the operators to identify troublesome equipment and to determine appropriate repair, modification, or replacement solutions. The components that cannot be replaced in the short term are scheduled for future replacement and resources committed for the replacement. Several managers stated that the strategy of scheduling future replacements, committing resources, and following through with the replacement (instead of constant deferral) minimized unscheduled equipment repair.

Sufficient capital budget is allocated and spent. Two executives estimated that approximately one-half to one percent of the capital cost of the plant should be budgeted and spent each year. Long-range plans and budgets for equipment material condition improvement are in place for both upgrades and major maintenance activities. For example, several stations produce and maintain a living 10-year plan for all major components (down to the valve level) and update it yearly.

Highly Skilled, Experienced, and Motivated Workforce that Exhibits Good Teamwork

Workers understand their roles and responsibilities, exhibit strong teamwork, and use excellent communication and collaboration to prevent or solve equipment problems. Workers, supervisors, and managers also understand the roles and responsibilities of other station work groups and station processes like work control, outage planning, and operating experience. Typically, the following very clear definition of roles and responsibilities was observed. The Operations department operates the equipment and monitors its performance to identify degradation. Maintenance focuses on preventive maintenance and outage preparation. Engineering takes a long-term view of the station and its equipment, focusing their efforts on equipment upgrades and equipment life cycle.

Station personnel, including technicians and craftsmen, are empowered and expected to carry out their roles and tasks with little oversight. Management philosophy is to have an involved and empowered staff that is capable of operating and maintaining the station. Managers and supervisors know in detail station problems, activities, and plans. They recognize that one of their most important functions is to coach their subordinates to maintain high standards in all their activities. The high performing station continually work to simplify processes to further empower the staff, improve efficiency, and allow for relatively small staffs.

Efficient and Effective Processes

Equipment repairs and refueling outages are well planned and executed, resulting in excellent equipment and station performance. Planning and preparation are the most frequently noted keys to successful equipment and outage performance. Many of the plants use a simple work control process to schedule work with an emphasis on timely completion of maintenance activities. Low equipment failure rates have resulted in low corrective maintenance backlogs, permitting the use of simple work control processes. Significant management emphasis is placed on maintaining low corrective maintenance backlogs. Managers stated that when corrective maintenance backlogs begin to grow, increased time is spent on prioritizing or otherwise managing the backlog list, diverting time from more important management tasks and reducing the time available to spend with their subordinates.

6. A STRATEGY FOR IMPLEMENTING THE CORE ATTRIBUTES

The purpose of this chapter is to suggest ways for stations to identify the core attributes that may be missing or not functioning as necessary to support strong station performance. Also, other possible uses for the core attributes are suggested.

In order to achieve high levels of safety and economic performance, a commercial nuclear power station in the U.S. must perform many activities to a very high standard. The core attributes identified above are not sufficient to guarantee success. However, results of the analysis of station strengths and interviews with executives from the high performing plants suggest that the core attributes constitute a minimum set of programs, processes, and practices that must function well for success to be possible.

Each station that has not achieved a high performance level has a unique set of causes for their shortcomings. No two NRC SALP reports, INPO plant evaluation reports, or station self-assessments are alike. While most lower performing plants have frequent unplanned shutdowns, unreliable equipment performance, and planned outages that last longer than expected, the causes of these problems are unique to the station and are dependent on many factors. Therefore, the path to improve the shortcomings and achieve sustained high performance, to achieve excellence, will be different for each station.

Central to each of the following strategies is a focus on reliable equipment operation. Executives stated, and INPO evaluation experience shows, that reliable equipment performance is fundamental to long-term success in the operation of commercial nuclear power stations. When equipment breaks down unexpectedly and frequently the entire station organization is stressed. For example, when the maintenance, engineering, and operations departments are forced to deal with frequent equipment malfunctions, the routine work does not get done and their backlog of work grows. As the backlog of work grows, the time spent managing, sorting, and prioritizing the backlog increases, leaving even less time for routine work. There is a risk that important work will be inappropriately postponed, possibly further effecting reliable equipment performance. Frequent equipment failures are also likely to attract the attention of the regulatory agencies. This attention will result in an increased demand on managers' time and a decrease in the time that they are available for their staff. This decreased management availability due to attention paid to both repairing the failed equipment and to the regulator will decrease staff productivity and result in further increases in backlogged work.

These stresses can also negatively effect teamwork, communication, and time available for training. Therefore, in considering the suggested uses and implementation strategies below, the overriding goal should be to achieve extremely reliable, long-term equipment performance. The improvement in personnel issues like good communication and teamwork and the process issues like use of benchmarking and operating experience will result from actions taken based on a broad view of the necessary enhancements and corrective actions to achieve excellent equipment performance.

A station can elect to implement any or all of the following suggestions. Although not proven, it is likely that the more of the core attributes that are being performed well, the more benefit the station will realize. It is expected that the benefit of the core attributes taken in the aggregate will be greater than the benefit realized by the sum of the attributes separately.

Self Assessment

A station interested in using the identified core attributes to improve performance should conduct self-assessments to reveal shortcomings in each of the core attribute areas. Senior station management must sponsor and support the self-assessment activity for the results to be accepted and acted upon by the station staff. Further, the self-assessment teams must have a clear understanding of the scope and schedule for their assessments. Teams with a broad knowledge and detailed understanding of station design, operation, and station processes should conduct the self-assessments. The teams should also include participants from other stations, preferably with a strong performance record in the area being assessed.

The self-assessments should begin with a retrospective assessment of equipment performance at the station. The self-assessment team should determine the frequency of failure of important station equipment and compare this frequency with stations that have superior equipment performance. The team should then examine the causes of the failures to determine what actions can be taken to minimize future failures. This analysis is likely to point to shortcomings in many of the core attributes. For example, there may be weaknesses in the station's inspection and test programs; the quality of preventive or corrective maintenance may not support reliable equipment operation; there may be inadequate funds available for needed upgrades; or station personnel may be insufficiently knowledgeable about the design or operation of the equipment. Corrective actions should be implemented for the identified weaknesses and after an appropriate time has elapsed, follow-up assessments should be performed to determine the effectiveness of the corrective actions.

This retrospective assessment is important and will help put the station on the path to improvement. However, the station must also investigate selected equipment failures as they occur to identify actions to prevent recurrence. Few stations have the resources to perform a detailed root cause analysis for every equipment failure. Criteria based on the importance of the failed equipment to safe or reliable station operation, and the frequency of the equipment failure, must be established to guide the station in determining the depth of root cause analysis to be performed.

Station Core Values or Priorities

For long-term success, the executives stressed the importance of having a team of people working together with a common, well-understood purpose. The core attributes represent key elements to sustained high performance and therefore represent a set of core values and activities. The core attributes could be used to develop a set of station principles that would provide a vision to the station staff. Many stations already have a well-publicized set of beliefs or principles that are used to provide broad guidance to station personnel. These established principles could be compared to the core attributes to ensure that the principles support sustained high performance.

Management and Supervisory Training

Stations could use the core attributes as a module in their management and supervisory training courses. The purpose of this training would be to make the managers and supervisors aware that there are programs, practices, and activities that are fundamental to sustain high performance. Additionally, courses that discuss individual core attributes could be developed as supervisors and managers express the need or as the need is identified by self-assessment activity.

INPO Evaluation Teams (a suggestion for INPO)

INPO teams evaluate every commercial nuclear power station in the U.S. at least once every two years. The performance objectives and criteria used to guide the evaluation process contain all the core attributes. The performance objectives and criteria also contain many other programs and activities. Training could be provided to INPO teams during the preparation for the evaluation to make them aware of the core attributes. This awareness would help in at least two ways. First, due to their importance, any problems found in core attribute areas would be subject to a more thorough and detailed investigation. Second, core attribute weaknesses could be brought to the attention of the Chief Executive Officer during the evaluation exit meeting to alert him to their potential importance.

REFERENCES

1. Institute of Nuclear Power Operations, *INPO 1984 Performance Indicator Report for the U.S. Nuclear Utility Industry*, May 1994.

2. Nuclear Energy Institute Fact Sheet, *Restructuring the U.S. Electric Power Industry*, April 1998.

3. Institute of Nuclear Power Operations, *Policy Note on Operating Station Performance Assessment Process*, February 12, 1999.

4. Institute of Nuclear Power Operations letter to Executive Points of Contact, *Performance Indicator Index*, October 20 1994.

5. World Association of Nuclear Operators, *WANO 1997 Performance Indicator Report for the U.S. Nuclear Utility Industry*, May 1998.

6. Nuclear Regulatory Commission Management Directive 8.6, *Systematic Assessment of Licensee Performance (SALP)*, 1996.