MODULE 8

SYSTEM SURVEILLANCE

MODULE 8 OBJECTIVE

- To understand the need for and the benefits derived from a systematic review of plant equipment and performance.
- To appreciate the importance of applying lessons learned to improve future plant performance.
- To recognize the importance of observing the performance of other plants to avoid future potential difficulties.

TOPICS

- Reason(s) for surveillance
- Aspects surveyed
- Methodology for effective surveys
- Example of various cases

TOPICS

- Assessment of findings
- Link to future performance
- Effectiveness of surveillance programs

REASONS FOR SURVEILLANCE

- Good business sense, ensure systems and equipment work as required.
- Legal requirements, condition of operating license.
- Input for business planning for future work programs
- Building a data bank of the performance history of equipment and systems.

ASPECTS SURVEYED

- Overall plant performance
  - Station capacity factor
  - Scheduled incapability
  - Forced incapability
  - comparison between utilities: PWR'S ; BWR'S

ASPECTS MONITORED

System surveillance is a very extensive topic and the success of a plant rests largely with what is surveyed and more importantly what is done with the results. Equally important is what is NOT surveyed and what impact this may have on plant operation while problems may go on undetected.

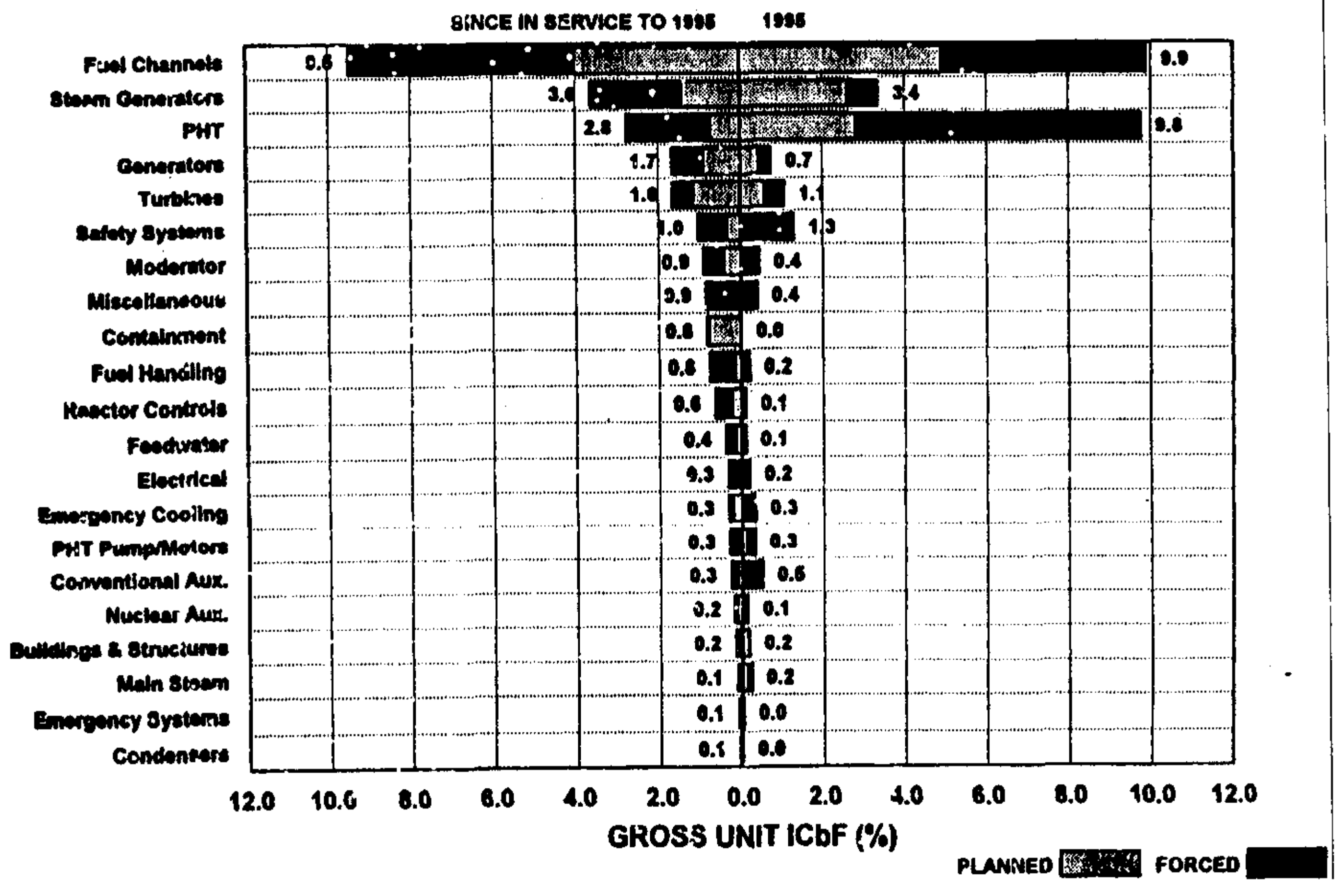
The surveillance is multi- dimensional and should address every area of plant operation ie. technical, maintenance, operations, load at various aspects of the critical systems, and examine the performance of the systems, equipment and components.

As an example typical causes of incapability are measure and reported eg. Diagram, OHN Causes Of Incapability.

The potential benefits of good surveillance are shown on 'Benefits In Capacity Factor'.
With the appropriate effort and work programs in place about 20% loss is avoidable.

Some of the major gains in capacity factor can be achieved by careful monitoring and good measurement of the main thermal cycle. Loss of MW output can readily be traced to fouling of the main condensers, air inleakage, reheater and reheater drains problem and fouling of the steam generators.

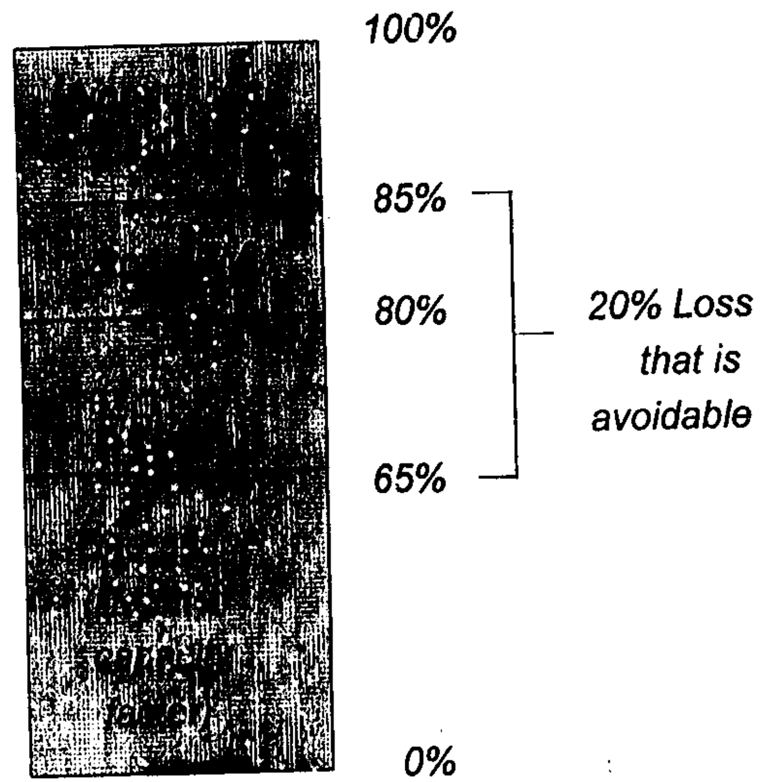
OHN CAUSES OF INCAPABILITY



BENEFITS IN CAPACITY FACTOR

Valves, Pumps
Motors, HX's

Pressure tubes,
boilers, piping
calandria,
containment,



ASPECTS SURVEYED

- Overall plant performance
  - Station capacity factor
  - Scheduled incapability
  - Forced incapability
  - comparison between utilities: PWR'S ; BWR'S

SYSTEMS SURVEYED

- Service systems
  - – Capacity of D.C. batteries
  - – Instrument air tank capacities
  - -- Chiller system performance

SYSTEMS SURVEYED

- Key process systems control systems
  - Reactor regulating system
  - Control computer reliability
  - Liquid zone system
  - Heat transport pressure inventory and control
  - Boiler level control
  - Boiler feed water system

ASPECTS MONITORED

- Major economic influences
  - Thermal performance of power train.
    - » Boilers
    - » Steam system
    - » Turbine
    - » Condenser
    - » Feedwaters
    - » Electrical output

ASPECTS MONITORED

- Key items within systems
  - Electrical relays
  - Ground faults
  - Instrument calibration drift
  - Reference leg plugging
- System chemistry
  - H_2 in PHT
  - O_2 in feedwater

METHODOLOGY OF EFFECTIVE SURVEYS

- Much work has been done in the nuclear industry in efforts to optimize the surveillance process.
- It is generally accepted that organizations have to be selective in the choice of the systems which will provide the greatest pay back.
- The initial step of selecting which system to monitor and why is crucial to the success of an optimum program.

METHODOLOGY OF EFFECTIVE SURVEYS

- Once the systems have been selected for survey, the following general review should be carried out on each system:
  - Define performance goals / indicators for system
  - Define the importance of system function and components

METHODOLOGY OF EFFECTIVE SURVEYS

- Define system motoring requirements
- Identify the data required
- Identify actions required
- System monitoring documentation

METHODOLOGY FOR EFFECTIVE SURVEYS

- In carrying out the system review, it is vital that the various views of system strengths and weakness be identified.
- A team approach is required and should be made up of knowledgeable staff from
  - Technical
  - Operation
  - I & C / electrical maintenance
  - Mechanical maintenance
  - Manufacturer - where available

"Guidelines for System Monitoring by System Engineers"

(a discussion of an EPRI-PSE work in progress)

Carol LeNestour - Ontario Hydro, BAND

The challenge facing many of us today in systems engineering groups appears to be how to accomplish more with less. In our industry, daily, we face increasing standards, both regulatory and internal; increasing economic pressures resulting in efforts to maximise system efficiency, reliability, and safety; on going consolidations; downsizing and increased individual responsibilities.

One of the key roles of a plant system engineer is to ensure that their systems contribute to the overall high reliability of the plant. Engineering system surveillance, the tracking, trending, walkdowns and general system monitoring performed by the system engineers, provides a foundation on which to build an effective system engineering program. But currently little industry guidance exists to aid system engineers in determining what is an appropriate level of system monitoring in order maximise the system performance obtained for the engineering resources invested.

Faced with these issues in his station, Bob Waselus of South Carolina Electric and Gas, V.C. Summer, submitted this topic as a candidate task to Plant Support Engineering at EPRI during their annual meeting in June 1995. As their mission statement states: "PSE is a utility driven support resource, whose objective is to support utilities in reducing O&M costs related to engineering while improving or maintaining technical quality." Based on this mandate, the PSE subcommittee approved this task, and a System Monitoring by System Engineers task group was formed. Members of this task group included Bob Waselus - our chairman, Leonard Loflin - the EPRI program manager, the task contractor - Duke Engineering Services, and industry and utility representatives (system engineers, supervisors and managers, including a representative from INPO).

The challenge that we were handed at that first meeting in February, our charter, was to, by the end of the year:

"Produce guidance useful to individual system engineers and system engineering organisations in accomplishment of their responsibility to monitor system and component performance to achieve appropriate system performance.

The Task Group is to search the industry for best practices and lessons learned that would be of immediate benefit to system engineers. Particular emphasis is to be given key parameters and indicators, proven processes, techniques and technologies that are specifically effective in obtaining ***appropriate*** *system performance, while minimising the consumption of engineering resources."*

In short - to optimise a system surveillance program by balancing the engineering effort expended and the value of the resultant performance improvement.

Our first task was to determine the "State of the Union" so to speak. We did this by developing a survey which EPRI-PSE sent out to 87 member utilities. With this survey, we attempted to find out, not only what the utility was currently doing for system monitoring, including any best practices that they would like to share, but also, what form of guidance that they would like to see.

In the first meeting, some of us had envisioned that a large part of the guideline could be obtained from stations who were doing surveillance well, and that through discussions, site visits and survey results, we would find what the current industry best practices were. We discovered that:

- Most stations are performing some level of system monitoring. However, most stations indicated that their programs needed improvement.
- There are many inconsistencies within a plant, within a multi-site utility, and within the industry in general. No identical programs were uncovered. Some stations may be monitoring 100% of their systems; others may not be monitoring any systems.

- It was difficult to correlate the scope of the system monitoring program and the overall performance of the plant. For example, those stations with good SALP ratings, low O&M costs, or high capacity factors do not always have the most extensive system monitoring programs.

Based on input received from the survey, along with INPO and SALP ratings in the engineering categories, two plants (Byron and Limerick) were chosen for on-site interviews. These on-site visits, combined with results from the survey led us to the conclusion that we needed to develop our own process for system monitoring, a process that would integrate the comments from the surveys, the results of the site visits, and the knowledge and experience of the task group members to provide guidance that could be used to develop, improve or validate system surveillance programs.

What we have arrived at to date, is an 8 step process focusing on the critical elements of an effective program. In order to provide some validation for the process, it was tested on five different systems at four nuclear stations. The fact that three of the systems were completed by system engineers who were not involved with the task group, helped to provide a grass roots, cold body review.

__System Monitoring Program Development Process__

Step 1 - Program Scope Definition

Since not all station systems will require monitoring at the systems level, this step is just an initial decision as to whether or not a system will be included in the program, the actual level of monitoring will be determined later. In making this decision certain criteria such cost, production goals, reliability requirements, industry experience, and as regulatory requirements (e.g. NRC's Maintenance Rule 10 CFR 50.65 "Requirements for monitoring the Effectiveness of Maintenance at Nuclear Power Plants") must be considered.

Step 2 - Define Performance Goals/ Indicators for System

In this step, we are looking for parameters that will measure the effectiveness of the system monitoring program - a key element in ensuring continuous improvement. These indicators could be direct indicators such as system availability, or indirect indicators such as maintenance cost for the system. It is essential to note here the relationship between the system goals, and the overall plant goals (such as production, cost and safety targets), since knowing the impact of the system on the plant will help to achieve the appropriate level of system monitoring.

Step 3 - Define Importance of System Functions and Components

This is the critical step in focusing monitoring efforts - the system functions, failure modes and failure effects are defined, as well as critical interfaces to other systems. This determination of failure modes and effects is used to prioritise the monitoring effort. This information is available from such sources as design basis documents, reliability centred maintenance assessments, and probabilistic assessments as well as plant experience.

Step 4 - Define System Monitoring Requirements

In order to determine "how" and "what" to monitor, degradation mechanisms and indicators for the failure modes of critical system functions are determined. For example, at the component level, a degradation mechanism for a heat exchanger is fouling, degradation indicators could include increased pressure drop and a decreased temperature change. Here is where the generalist nature of a system engineer comes into play, since this step requires a thorough knowledge of system functions; system equipment, including its physical, mechanical and electrical properties; as well as both short term and long term ageing and wear processes. The guideline will provide support in these areas by containing sample surveillance plan shells for approximately 5 generic systems, as well as references to other sources of information.

Step 5 - Identify the Data Requirements

In this step, the system engineer defines the data type, acquisition frequency, and precision required to monitor degradation mechanisms. Analysis of system performance may require integration of several different component trends to determine the cumulative effect on a system. For example, you may have a system where all the individual parameters are operating in a degraded state, but within the tolerable levels, but the system as a whole may have unacceptable performance. (e.g. a valve slow to stroke, combined with low flow from a pump, and heat exchanger fouling)

The majority of the data required to monitor system performance is being collected at most nuclear stations by various different departments. the key is to interface efficiently with these departments. and effectively integrate the data. Another key point, and a trap that many system engineers fall into, is to avoid reviewing and trending data that does not support the monitoring for degradation of critical system functions.

Step 6 - Identify Actions Required

Setting appropriate action levels, and understanding and documenting the action to be taken when these are exceeded should allow proactive intervention to prevent failure. There were many examples in the industry where data was being trended, but acceptable limits, either absolute values or rate of change, had not been established, and action plans did not exist. Action plans may contain such activities as increased trending, monitoring or testing; root cause analysis; design reviews; routine maintenance; or operational adjustments.

Step 7 - Establish Communication Methods

Although it is clear that the system engineer must define all communication channels in order to keep the required technical information flowing, management reporting of surveillance results is also essential in order to ensure that system problems receive the appropriate level of attention. One of the best practices that we found in the industry, was the use of a "system report card", or a "system health sheet". Most systems are assessed in several areas, including performance (reliability and availability); deratings; maintenance backlog; physical condition; operator work-arounds; and design issues, and a "window" or annunciator colour is usually assigned. These report cards are used as a tool for focusing plant resources, since every issue contributing to a window alarm requires an action plan.

Step 8 System Monitoring Documentation

It is essential that the system engineer document the decisions made in the development of the program. This document, which should become a living document, will provide a current and a historical technical basis for the program, and an invaluable tool when transferring system responsibility to another engineer.

Future Plans

The final meeting of the task group is in December. At this point in time, the report should be finalised, and concurred with by the entire group. Copies should be available in February next year. Plant Support Engineering has obtained funding to produce approximately 40 generic "shells" of system surveillance plans - similar to the few provided in the guideline. Although these will focus on PWR and BWR technology, there may be some valuable information in these plans that can be applied to CANDU. Work will start on these in January.

EPRI is also planning workshops in May and August of next year- to "roll - out" the guideline, to provide some additional background and insight into the "Hows and Whys" of the process, and to discuss operating experience with the program to date. Currently there are three utilities implementing the draft process, and their feedback, along with others, will be discussed at these workshops.

The acid test of the program will be proven over time, however I think that it is very encouraging to hear the comments of some of the system engineers who were involved in the original trials of the process. "With about the same effort, I can now monitor things that are more consequential", and " Now I have a better understanding of why I'm doing what I'm doing" - all keys to a successful system monitoring program.

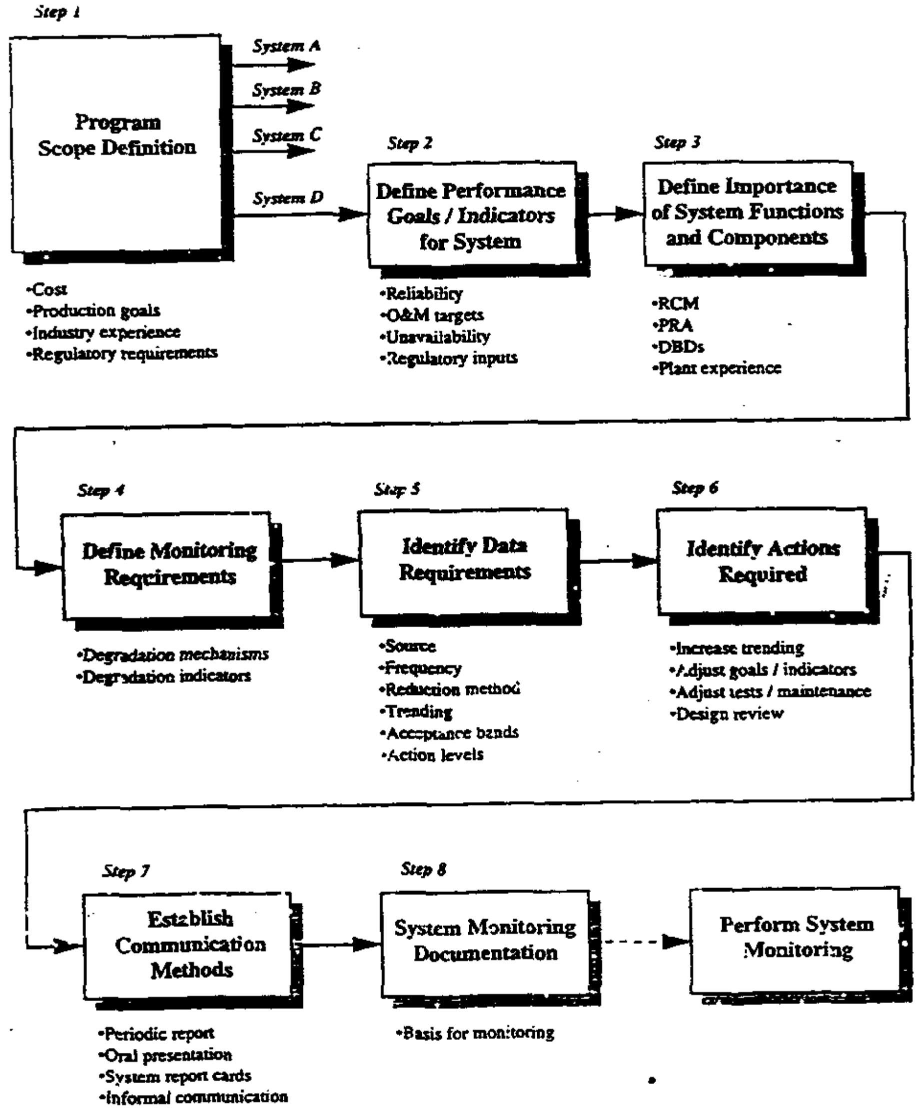


FIGURE 3-1. SYSTEM MONITORING PROGRAM DEVELOPMENT PROCESS OVERVIEW

EXAMPLES OF VARIOUS CASES

- A case study on the implementation of an integrated maintenance management program
- Darlington equipment aging management
- Pickering thermal performance : Low tech VS High tech surveillance - practices.
- Reactor noise analysis application in Ontario Hydro.
  - A statistical technique used for surveillance -

EXAMPLES OF ONE CASE

The Darlington experience showed regular weekly and monthly routines on critical areas is essential. Sources of problems found to be:

- Leaking blowdown valves
- Leaking CSDV's
- Reheater drains flow
- Condenser performance
- Calibration of instruments for reactor powers

Darlington Equipment Aging Management

Nuclear Plant Life Assurance (NPLA)

Abstract:

The program has two major thrusts:

a) Monitoring degradation of expensive/not easily replaceable pieces of equipment such as Pressure tubes/boiler, etc., and,

b) Preventative maintenance of critical pieces of equipment (replaceable) such as valves, pumps and so on.

The first group is well underway for routine inspection every four years. The difference between Darlington and previous OH stations is that baselines are done within five years of operation with an emphasis on detecting small changes so that a rate will be determined by year 10. This means going beyond regulatory requirements and doing inspections with more scope and more precise tooling. For example, several boiler tubes are removed to detect degradation < 5% through wall. This accuracy is not possible with eddy current inspections. A comprehensive program in this NPLA area is judged to contribute 10% reduction in incapability in later plant years.

The second group of equipment involves about 2,000 items, each one, if failed, either causes a loss of production or requires a unit shutdown to repair or replace. System engineers have identified these items and callups are being put in place to inspect and overhaul as required. The typical time frame for these are 4 - 8 year intervals. Several tools have been purchased to provide effective maintenance such as valve monitoring devices (FLOWSCAN/MOVATS), thermography, elastomer tester tool, vibration monitoring, HX tube cleaner, generator/turbine inspection tools requiring no disassembly. We are also considering a portable skid for nuclear HX shell side chemical cleaning. We believe this equipment maintenance will achieve 5% reduction in incapability.

Darlington Equipment Aging Management

Introduction

As a new station, we had to take stock of what OHN stations have done in the past and decide if those approaches would work for us. A review was done of the causes of incapability at those sites and Figure 1 was our conclusion. We believe an annual capacity factor above 80% after 20 years may not be achievable. In the early days of Pickering A, we posted 90% capacity factor but after a dozen years, 80% was demanding. When pressure tubes came to the forefront, capacity factors plummeted. Many of the older stations are suffering from steam generator problems. Point Lepreau, which had an admirable record of production achievement, appears to be experiencing some surprises after 15 years.

We decided here when the first unit went into service to aim for an annual 80% target and do the required inspections and predictive maintenance to get an early trend of equipment performance.

1.0 NPLA

We have three units in Engineering Services that devote themselves to equipment issues. The first unit is Nuclear Plant Life Assurance (NPLA) and focuses on the expensive, hard to replace items. The other 2 units devote themselves to I&C, and mechanical equipment.

We have programs in place for periodic inspections of Steam Generators and Pressure Tubes. Every year we inspect one unit with an accent on more tubes or channels and utilization of techniques that find smaller defects. We use both UT and tube removals on SG's to characterize early signs of degradation. For pressure tubes, we have 3 devices that are Fuelling Machine delivered: a camera for liner/end fitting internal inspection, an ultrasonic tool for pressure tube defect detection (PIPE), and a laser detector (OPIT). These last 2 devices enable better characterization of flaws at the inlets.

Plans for next year are Calandria internal inspection and cable monitoring. We see Calandria problems as the next major issue facing the older CANDU units and want to get an early start on a program.

Our piping programs are deficient in that we do not have piping surveillance for corrosion nor do we have fatigue monitoring for high energy piping system. A "new" approach is being pursued with Ontario Hydro Technologies to develop mechanical fatigue probes for use next year. These devices existed 40 years ago but have been obsolete for 10 years with really no replacement. We have secured the manufacturing capability from a defunct company and will make our first batch next year.

2.0 <u>Significant Equipment Maintenance</u>

This is a far more difficult subject. It is never clear where to draw the line because one gets the sense of we can "recover" if equipment is falling apart in later years. The NPLA issues have "buy in", but an increase in maintenance either by overhauls, or pre-empted replacement is generally resisted because of restricted resources. Fire fighting takes a higher priority over long term issues. OM&A and staff numbers are fixed; in fact there is an expectation that it must trend downward to be economically competitive in a changing marketplace.

Before maintenance staff are consumed with corrective maintenance, we consciously filled their plate with a high preventive maintenance workload. The following programs are in place by the Production Support Unit, and the other two units in Engineering:

1. Heat Exchangers and Steam Generators.
   - nuclear HX inspections, and a possible chemical cleaning of a S/D cooling HX.
   - cleaning of conventional HX's a minimum of every 4 years.
   - SG water lancing every 4 years and chemical cleaning every 10 years.
2. Major Pump Motor Sets.
   - disassembly/inspection of a sample of pumps and motors beginning at year 12
3. AOV/MOV program doing routine MOVATS and flowscanner testing (specialist function) on critical valves.
4. Routine overhaul of critical switchgear.
5. Routine thermography of mechanical and electrical equipment (specialist function).
6. Vibration Monitoring of 1200 pieces of rotating equipment (specialist function).

7. Elastomer Testing.

Currently this is an Engineer part time. In the longer term, we see it as a maintenance specialist tool

The above techniques are applied to equipment, that in the Engineering-Maintenance community are commonly considered to be cost effective; ie, not necessarily on critical equipment, but on equipment judged to fail soon if a little effort is not put in to diagnosis and repair/adjust.

2.1 Critical Equipment

The following describes the approach:

1. 170 systems evaluated for risk of Unit/Station incapability. Expert judgment used combined with history of similar plants. About 35 systems highlighted.

2. System Engineers/Coordinator evaluate key components in each system by using flowsheets. Single failure resulting in downtime results in designation as "highly critical". Single failure resulting in significant loss of redundancy was considered "medium critical".

3. Control Maintenance/Mechanical Maintenance personnel evaluate critical list on each system and determine likely modes of failure from experience at other sites on similar equipment. Preventive Maintenance tasks recommended.

4. Call-ups put in place, spare parts ordered, support documentation initiated.

5. On-going surveillance review by Engineers of success of program.

NOTE: 1) In addition to above, a parallel review is done across all systems on key components - Heat Exchangers, AOV's, MOV's, Pump-Motor sets. Most important equipment given "predictive" maintenance.

2) A separate process is used for station "life threatening" equipment. Steam Generators, Cabling, Pressure Tubes, Piping, Major Civil Structures, TG, etc. (> 50 M$ or > 6 months to repair). Each is assessed for degradation mechanisms and a periodic inspection plan put in place.

The review described above has identified about 2,000 pieces of equipment for which callups are being put in place. The normal time frame is about 4 - 8 years for first inspection. This program is scheduled for completion in 1997 after which the monitoring for success/failure begins and adjustments made on an ongoing basis.

2.2 Balance of Plant Equipment

To prevent unreliable operation in the 25-40 year range, we need to replace classes of equipment which is either difficult to maintain (fails often), or costly to maintain (long repair times), or simply cannot be fixed because of no parts (obsolescence).

Appendix A provides a best guess of the materials and staff needed to do it. We presently are understaffed to do bulk changeouts and cannot see that this will ever change. However, what can change is an increase in efficiency in maintenance. Wrench time is low here as in other OHN stations for many reasons and outside the scope of this evaluation. Because it is so low, it presents a realistic opportunity. What the reasoning shows in Appendix A, is that a doubling or tripling of staff to effect such refurbishment is uneconomic. We either accept a lower capacity factor (3-5% realistic, 10% upper bound) or we must increase maintenance productivity.

If we go back to Figure 1, we need to identify what equipment requires maintenance. This has been arrived at in two ways:

a) Critical equipment evaluation which was described in 2.1, and,

b) A tabulation of the most numerous equipment types in the plant. This is shown in Figure 2.

From this follows assigning engineering resources to monitor these types. It is not surprising that we are targeting hiring of at least one person with specialty in each of these areas. We are also developing staff to cover these areas. These are not today's problems but there is a good chance that they will be in future. (To complete the picture of what today's problems are, Figure 3 and Figure 4 are provided).

Summary

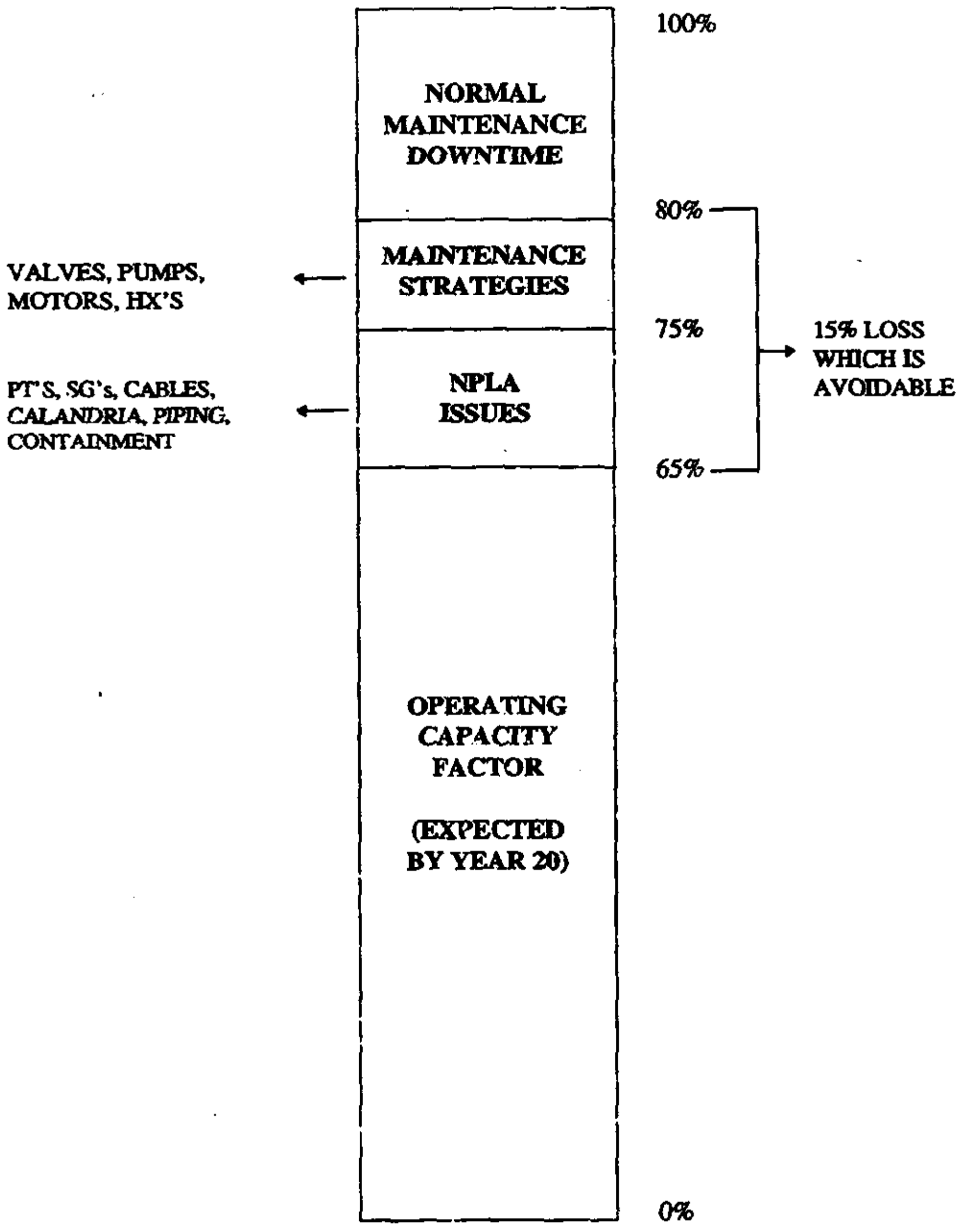
The success of an NPLA program is measured by the lack of major equipment surprises. Not surprisingly it is, therefore, a managed maintenance program and not some obscure back office exercise. It is field work on the right things, the right amount, and occurs at the right time

Darlington is putting in the effort to try to get their maintenance plans in place early in life before a reactive mode sets in due to surprises. Figure 5 is a summary of where we are today. It is incomplete in that the discussion above highlights other component classes that should be added. (Our assessment is that it will take a few more years to complete). It also encompasses other issues deemed important by an OHN team reviewing this subject (eg. system surveillance).

In the end we will get there with perseverance and a bit of luck.

Figure 1

OPPORTUNITIES



THERMAL PERFORMANCE SURVEILLANCE AT PICKERING ND

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SUMMARY

PND has three leading indicators of thermal performance, each independent of the other. These are:

TPE	Thermal Power Error	[%]
CVE	Condenser Vacuum Efficiency	[%]
TPI	Thermal Performance Indicator	[%]

Summing the deficit of each of these from its nominal value (0%, 100%, and 100%, respectively), the total quantifies how far away we are from the entire secondary side's design-level of operation. Allowing 0.5% latitude (and counting negative TPEs as zero) on each measure, we are targeting performance within a 1.5% deficit from design-level of operation. This cumulative deficit from design-level operation has been nicknamed the "TPI_{dex}" by Generating Units staff, and has been incorporated into the Generating Units Managers' performance contracts.

At Pickering ND, a dedicated program of thermal performance improvement has been in place since 1989. Available performance data goes back at least 6 years, eg:

Year	TPI_{dex}
1990	2.59%.
1994	2.01%.
1995	1.75%

The effect of a 0.5% improvement has the following potential impact:

0.5% ⇒		(2.72 MWe per unit)
	x	(8760 hours/year)
	=	23.85 GWh/unit/year

The 0.84% improvement of 1995 over 1990 is worth 4.6 MWe/unit. Assuming a station Capacity Factor of 80%, this works out to approximately, 257 GWh/a, or about 5.1 M$/a.

TPI_{dex} is calculated for each unit, as well as for the station-average.

THERMAL PERFORMANCE

Thermal performance measurement at PND is broken down into three components, each of which addresses a major aspect of secondary-side operation, and each of which has its own measure and target:

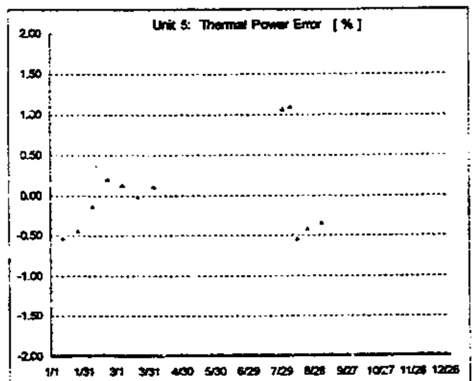
- the cycle source — TPE
- the cycle sink — CVE
- the turbine cycle (ie: everything between) — TPI

CYCLE SOURCE

Goal:	Maximize power transferred to secondary side.
Measure:	Thermal Power Error (TPE)
Target:	-0.5% ≤ TPE ≤ +0.5%
Current:	TPE = +0.03 %

Discussion

Close control of TPE means close control of the turbine cycle heat source. It essentially involves ensuring that we are delivering from the HTS to the secondary coolant every MegaWatt of power which we are - by license - permitted to transfer. This involves routine calculation of each unit's calorimetric, and occasional adjustments to the Digital Control Computers' Reactor Regulating System subprogram, in order to maintain close agreement between indicated and actual reactor thermal powers.



Current Status

We have optimized this by means of a rigorous program of testing, Q/A, fine-tuning of FPTRs, and minimizing unnecessary primary coolant loads. TPE is afforded highest priority, because of its potential safety impact. In the last 5 years we have satisfied the targets. TPEs in 1994 and 1995 have been near-zero. However, the current process is paper-intensive and labour-intensive, involving data collection by operators from computers, Control Room, and field instrumentation, followed by off-line analysis by Thermodynamics staff. This paper process is as streamlined as can be reasonably achieved.

unit. Otherwise, differences in operating intervals and power levels could bias the results. Explanation is best done by way of an example.

In the following table are illustrated - from left to right - the following information.

Unit	[-]	The PND Unit number
TPI_{dex}	[%]	"Thermal Performance Index" (this is the deficit from design-level of operation, and is calculated directly from TPE, CVE, TPI.
ΔTPI_{dex}	[%]	The improvement in TPI_{dex} from 1994 to 1995
NET	[GWh]	Net electrical output for each unit, in 1995
SAV	[GWh]	The energy saving in 1995, based on the difference in TPI_{dex} between 1994 and 1995. This is calculated by: $SAV = NET \times (\Delta TPIdex)/100$

Unit	1994 TPI_{dex}	1995 TPI_{dex}	ΔTPI_{dex}	NET	SAV
1	2.77	2.87	-0.10	1982.407	-1.982
2	2.65	n/a	n/a	n/a	n/a
3	1.47	2.06	-0.59	2681.461	-15.82
4	1.92	2.05	-0.13	2773.857	-3.606
5	2.13	1.02	+1.11	3357.866	+37.27
6	1.67	0.89	+0.78	3483.656	+27.17
7	1.86	1.70	+0.16	4049.065	+6.479
8	2.54	2.46	+0.08	4003.404	+3.203
Avg	2.01	1.75	+0.26		
Total				22331.726	+52.72

CONCLUSIONS

- No matter how cost-effective initiatives in thermal performance improvement are shown to be, they are still discretionary. When resources are limited and Production priorities involve minimizing outage time, continued operation, and safety-related issues, thermal performance initiatives will be shelved.
- Consequently, engineered changes which involve significant blocks of time-commitment by various station work groups will evolve over extended periods of time.
- In a multi-unit environment, projects involving significant engineering changes can all be in different stages of implementation. Tracking progress and providing support is not so much difficult, as it is awkward and time-consuming.
- Station-engineered changes are often installed by unit-responsible crews. This means that separate Work Plans/Packages, materiel management, pre-job orientation, and support must be provided for each unit.
- As such engineered changes can stretch over years, personnel changes mean that job briefings may have to be conducted several times.
- The result of the issues described above is that significant engineered changes can take a great deal of time to show any return on investment. During the time of installation, the process is a significant drain on engineering resources.

- The low-tech approach stands a much better chance of being completed quickly and effectively.
- Since it gets off the ground very quickly, a low-tech solution begins to show results and reduce productivity losses while more ambitious programs await long-term implementation.
- The PND "cycle isolation/steam trap" project was fully configured by unit-specific crews within days, and was done on a pick-up basis. The underlying analysis was done by a central service organization, and so was not affected by station resource constraints. Overall secondary-side surveillance is similarly being instituted on a KISS basis.
- By keeping surveillance requirements quick and simple, the success rate for the routine execution of the callups for the surveillance by Generating Units staff is high.
- Analysis of cycle isolation/steam trap surveillance is performed by the Thermodynamics group. By completing the analysis quickly and feeding it back to GU staff for prioritization of repair, they have more or less instant gratification, as well as the correct perception that we are providing them a service. This further adds to their level of involvement and satisfaction.

REACTOR NOISE ANALYSIS APPLICATIONS IN ONTARIO HYDRO: A STATISTICAL TECHNIQUE USED FOR SYSTEMS SURVEILLANCE

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ABSTRACT

Reactor noise analysis is a non-intrusive statistical technique regularly used in surveillance and diagnostics tasks. The paper concentrates on some of the recent applications of reactor noise analysis in Ontario Hydro's CANDU stations, related to the dynamics of in-core flux detectors (ICFDs) and ion chambers. These applications include (1) detecting anomalies in the dynamics of ICFDs and ion chambers, (2) estimating the effective prompt fractions of ICFDs in power rundown tests and in noise measurements, (3) detecting the mechanical vibration of ICFD instrument tubes induced by moderator flow, (4) detecting the mechanical vibration of fuel channels induced by coolant flow, (5) identifying the cause of excessive signal fluctuations in certain flux detectors, (6) validating the dynamic coupling between liquid zone control signals. Some of these applications are performed on a regular basis. The noise analysis program, in the Pickering-B station alone, has saved Ontario Hydro millions of dollars during its first three years. The results of the noise analysis program have been also reviewed by the AECB with favorable results. The AECB have expressed interest in Ontario Hydro further exploiting the use of noise analysis technology.

INTRODUCTION

Reactor noise analysis is a statistical technique for extracting information on reactor system dynamics from the fluctuations of instrumentation signals measured during steady-state operation. The small and measurable fluctuations of process signals are the results of stochastic effects inherent in physical processes, such as heat transfer, boiling, coolant flow turbulence, fission process, structural vibrations and pressure oscillations. The goal of reactor noise analysis is to monitor and assess the conditions of technological processes and their instrumentation in the nuclear reactor in a non-intrusive passive way. The noise measurements are usually performed at steady-state operation, while the availability of the signals in their respected systems (e.i. shutdown systems, regulating system) is not interrupted. Although reactor noise analysis techniques usually offer an indirect way of diagnostics and require expert knowledge, often they are the only diagnostic indicators of processes inaccessible to direct plant testing.

In 1992 an extensive program of reactor noise analysis was initiated in Ontario Hydro to develop noise-based statistical techniques for monitoring process and instrumentation dynamics, diagnostics and early fault detection. Since then, various CANDU-specific noise analysis applications have been developed and validated. The noise-based statistical techniques are being successfully applied as powerful troubleshooting and diagnostic tools to a wide variety of actual operational I&C problems. The dynamic characteristics of certain plant components, instrumentation and processes are monitored on a regular basis. A comprehensive "noise survey" of detector signals from the standard instrumentation of Pickering-B, Bruce-B and Darlington units have been carried out in the past four years at various operating conditions. Also, recommended standards and procedures for regular station noise measurements have been developed. In these measurements the feasibility of applying noise analysis techniques to actual operating data has been clearly demonstrated. The results indicated that the detection and characterization

OTHER APPLICATIONS OF NOISE ANALYSIS

Noise analysis has been successfully used in pressure and flow measurements of the primary heat transport (PHT) system too. The application includes the following areas: (1) estimating the response time of pressure and flow transmitters and validating their dynamics, (2) identifying the resonance frequencies of pressure sensing lines, (3) validating FINCH flow and SDS1 safety flow signals, and (4) characterizing anomalies in flow, such as signal dips and oscillations [13,14]. Noise analysis also provides a non-intrusive method for monitoring and estimating the dynamic response of RTDs installed in the process, and for isolating the cause of RTD signals anomalies (spikes induced by ground fault detectors). Boiling in FINCH fuel channels can be also detected by noise analysis. The detection of coolant boiling in FINCH fuel channels is based on the measurement of inlet and outlet flow fluctuations. Noise measurements in Darlington showed strong correlation between the occurrence of boiling (indicated by fuel channel outlet temperature) and the coherence and phase functions of inlet and outlet flow fluctuations in the frequency range of 0-1 Hz [3].

CONCLUSION

CANDU noise measurements carried out in the past four years proved that fault detection and validation of process/instrumentation dynamics can be based on the existence of multi-channel complex patterns of statistical noise signatures. The technique is being successfully applied now in a wide variety of actual station problems as a powerful troubleshooting and diagnostic tool.

ASSESSMENT OF FINDINGS

- From the examples given and the topics covered to this point it is obvious that managing the various requirements is a major managerial challenge.
- For running plants much of the data and trends required are not readily available. Changes are expensive and discretionary.

ASSESSMENT OF FINDINGS

- In addition to the types of information that can be taken from an instrument or a location there is a vast amount of 'corporate memory and experience' that is spread over many disciplines and people.
- 'Maintenance records' - if well recorded can provide vital insight into system and equipment performance.

ASSESSMENT OF FINDINGS

- The majority of the instrument monitoring is indicated in the main control room but it is mainly instantaneous and only available to the control room operators.
- Maintenance staff 'give up' feeding back information because 'nothing ever gets done' - sub performance is accepted.

ASSESSMENT OF FINDINGS

- Historically system surveillance has been subjected to severe budget restraints, however there is evidence of change as the benefits become more evident.

LINK TO FUTURE PERFORMANCE

- Considerable effort is currently underway to apply technology to system surveillance to make it more effective and improve productivity.
- Various elements eg. vibration monitoring are quite advanced and the integration with other monitoring such as chemistry is starting to show promising results.
- There is no 'magic bullet' for surveillance.

LINK TO FUTURE PERFORMANCE

- The intellect and experience of the staff is where the greatest 'value added' is obtained.

EFFECTS OF LACK OF SURVEILLANCE

- Dropping capacity factor
- Increasing unplanned forced outages
- Rising OM & A
- Increasing threat of institutional shut down
- Suggests that the systems run management; management are not running the systems