MODULE 4

MAINTENANCE OF AN NPP

MODULE 4 OBJECTIVES

- To examine various aspects of maintenance.
- Review the optimization of a program to minimize plant deterioration.

MODULE 4 TOPICS

- Department Work Program
- Maintenance Program
- Condition Based Maintenance
- Reliability Centered Maintenance
- Major Modifications

WORK PROGRAMS

- Scope definition by department.
- Each department establish <u>what</u> work must be done during an outage.
- Plant overall performance depends on identification & resolution of problems that will cause safety or production loss.
- All problems must be clearly identified by key departments.

WORK PROGRAMS

- Effective business planning should ensure a systematic review process in departments such as:
  - maintenance
  - operations
  - chemistry
  - technical support (including major manufacturers)
  - engineering services

WORK PROGRAMS

- Areas of unreliability must be identified by each department.
- Identification of various issues establish the major scope for an outage.

WORK PROGRAMS

- Factors of Major influence will be:
  - previous experience and equipment breakdown
  - operating difficulties and upsets
  - plant corrosions and erosions
  - regulations
  - improved efficiency & production
  - product changes
  - systems and equipment revamp

WORK PROGRAMS

- Examples of issues raised by various departments shown on next 4 pages

MAJOR SCOPE SUMMARY

Boric Acid Inspections
A team of System Engineers performed a walkdown of Nuclear Steam Supply Systems (NSSS) at Normal Operating Pressure (NOP) Normal Operating Temperature (NOT) to identify boric acid leaks.

Check Valve Inspections:
As part of the program, a population of check valves must be inspected every refuelling outage. Due to advances in technology some valves in the program can now be checked by non-intrusive methods.

- 51 check valves were examined by the non-intrusive method
- 13 check valves required full disassembly for inspection

In-Service Inspection (ISI):
ISI is the process of performing non destructive testing to determine the condition of the components relative to cracks and other types of flaws. These methods include simple visual inspections, radiography, dye penetrate exams, ultrasonic and magnetic particle testing.

- 299 ISI Welds
- 83 ISI Supports

Local Leak Rate Testing (LLRT):
To meet the criteria defined in Appendix J of 10CFR50 for type B and type C penetrations, Local Leak Rate Tests were performed to measure the leakage past the isolation valves of individual containment penetrations.

- 73 penetrations were performed

GL 89-10 Testing (Motor Operated Valve Testing):
There are 151 motor operated valves within the GL 89-10 scope requiring periodic Static testing every 5 years.

- valves required lubrication and inspection
- Static "as lefts" Tests
- Dynamic Testing (DP)
- valve/actuator activities

Snubber Testing:

STP has implemented the 10% sample plan as described in Technical Specification section 4.7.9.e. 1 for each type of snubber installed.

Outage Surveillances (ST's):

- 423

Preventive Maintenance (PM's):

- 846

Outage Work Orders (WO's):

- 590

Modifications:

- Major Modifications

1. 92023 - Modify Qualified Display Plasma System (QDPS) to Reflect Implemented Modifications

2. 93018 - Replace Load Center 1W Circuit Breakers

3. 93020 - Replace Load Centers lU and 1R Circuit Breakers

4. 93030 - Install miscellaneous Cranes inside Reactor Containment Building (RCB) (saddle for one large crane)

5. 93058 - Move FWIV limit switches outside of Valve Yoke

6. 93070 - Provision to use Recycle Holdup Tank water for flushing BTRS Demineralizers

7. 93082 - Install Westinghouse Upgrade to Turbine Electro Hydraulic Control (EHC) System

8. 95-3344-4 - Provisions for Removal of Reactor Coolant Pump (RCP) Motor 1A - Mechanical Only

9. 95-3344-6 - Provisions for Removal of RCP Motor 1C - Civil Only

- Minor Modifications

1. 89-L-0019 - Allow use of new underfrequency relay for motors
2. 89-L-0059 - Allow use of new underfrequency relay for motors
3. 94-2663-12 - Alarm circuit for stator cooling water system
4. 95-4805-2 - Route High Pressure Feedwater Vents to DA System
5. 95-6698-1 - Upgrade 9V Power Supply
6. 95-6754-1 - Upgrade 9V Power Supply
7. 95-753-2 - Permanent connection on bearing lift oil piping on Main Turbine
8. 96-1323-3 - Steam Generator Feed Pump Turbine (SGFPT) Thrust Bearing Vibration Probe

<u>Main Turbine/Generator Inspection And Repairs:</u>

- Standard inspections including:

  Removal, dust blasting and NDE on low pressure rotor
  Main generator FASTGEN inspection
  Extensive modification to stationary vanes
  Turbine valve swap out
  A seal oil, lube oil and EH flush

<u>Reactor/Refuelling:</u>

- Standard refuelling activities including:

  Complete Core offload/onload
  56 new fuel assemblies
  Polar crane bearing repairs (not completed)

Bottom Mounted Instrumentation (BMI) thimble eddy current testing

Steam Generator Inspection:

- All four S/G's:
  - 100 % eddy current examination
  - Plugging of 97 tubes
  - T Slot Sludge lancing

MAINTENANCE PROGRAM

- The problem:
  - degradation and aging, every component and piece of equipment in a plant or system ages
- The result:
  - this generally invisible process can reduce capacity and reliability of equipment

MAINTENANCE PROGRAM

- The challenge:
  - If uncorrected the degradation progresses to a stage that something seizes or breaks.
- The cure:
  - Establish a maintenance program such that equipment will not fail or cause plant disruptions between one outage and the next.

MAINTENANCE PROGRAM

- The choices:
  - 'Corrective maintenance' repair after a failure.
  - 'Preventive maintenance' predetermined work to reduce the probability of equipment failure or performance degradation.

MAINTENANCE PROGRAM

- The Maintenance Program is:
  - the process of activities performed on equipment and systems in order to assess, maintain or restore their operational capabilities.

MAINTENANCE PROGRAM COMMENTARY

DEGRADATION AND AGING

Every component, every piece of equipment in a plant or process ages. Usage, however cautious, overloads, incidents, or simply time, all take part in the degradation mechanism. This process which is generally invisible can reduce the capacity of equipment to work properly and reliably.

Aging includes a large number of different mechanisms. The most frequent involve a loss of material; wear and corrosion, and deformations, which are also the most visible and thus the easiest to pinpoint. However, there are also more insidious mechanisms such as propagation of small fabrication flaws or crack initiation, or the progressive alteration of material properties, whose effects generally weaken the resistance of a component to loads.

Even when stopped, equipment degradation can continue. Sometimes these effects can equal or surpass the result of normal use.

Failure - is the moment equipment becomes unable to perform its function
Reliability - an equipment or a system is reliable if it does not fail often, otherwise it is unreliable.
Corrective Maintenance (CM) - after a failure, the equipment needs to be repaired, the maintenance group *corrects* the failure, this is *corrective maintenance*.

Durability / Total Reliability

In both industrial and domestic life, aging is rarely seen, primarily because of maintenance that partly counterbalances it, but also because in many cases it does not exist at all, at least not in a practical sense. In fact, aging is slowed to the point that it becomes harmless to the equipment functional capability, right to the end of its normal "life".

Examples of this abound, from simple equipment like pipes and tanks.

Some degradation modes cannot be practically avoided by design. These mainly include wear caused by friction and degradation of the thin metallic walls of heat exchangers. Every friction machine wears or seizes, sooner or later. Fortunately inmost cases, lubrication can slow down or even stop the wear.
The thin metaliic walls of heat exchangers are subject to a peculiar pattern of degradation modes where mechanical loads (vibrations, fatigue) can mix with a corrosive environment created by the heat transfer mechanism, even in presence of apparently benign fluids, such as pure water.

A great percentage of industrial maintenance activities are performed to correct deteriorations that could have been avoided. Thanks to lubrication, industrial equipment has very few wear and tear parts and often operates under conditions where corrosion is not much of a risk. The most common incident (a crack or a break in a part) comes from the propagation of a local defect under the influence of stresses exceeding locally the resistance possibilities of the material in the short or long term.
"Industrial equipment does not wear out, but breaks down."

Today, project engineers can determine in advance, for any point of the equipment structure, the stress resulting from the different operating (or incident) modes. They can calculate the accumulated aging (or the resulting damage) at any specific point for a postulated lifetime, and subsequently determine the adequate design.

Economic considerations alone can justify the use of fully reliable equipment to solve the typical dilemma:
- *Use of "discount" equipment* -a cheap investment but with the related costs of high maintenance and unavailability;
- *Use of "overdesigned" equipment* -an expensive investment that is not entirely failure free.

The additional cost for fully reliable equipment result from the need for extensive preliminary projects and for increased quality control during the manufacture and assembly phases. These overcosts can be quite high but are economically justified:

- *For devices built in large series* -the individual overcosts per unit are lower than the costs associated with overdesign;
- *For major industrial equipment* -additional costs are still low when compared to the overall manufacturing costs and overdesign is not always technically feasible;

- *For equipment whose reliability has a strong impact on the productivity of the industrial unit* -overcost here can equal or even exceed the costs of overdesign but will quickly be repaid thorough the resulting increased revenue or production.

AGING: PREMATURE OR REAL

<u>REAL AGING IS CHARACTERIZED BY:</u>

1) *A continuous evolution of a variable*, which must be measurable, whose value is clearly correlated to the resistance margin, and if uncorrected would at some point lead to failure
2) *Those evolution's that can be mitigated but not totally avoided.* they are predictable at the design stage
3) Time in itself, is only an indirect factor, when compared to expected service life.

* Wear, easy to measure and to compare with a minimum acceptable size, is a simple example.
* Deformation (of a building, a dam) is another example easy to monitor, not always easy to relate to the risk of sudden failure.
* Material properties, such as tenacity, hardness, sometimes vary with time for high performance parts. They can be measured and compared to acceptable limits. All these phenomena's belong to real aging.

* Overload or flaw induced cracks initiations and propagation, and most types of corrosion (except cases like general oxidation) are not aging, they are accidents that can and should be prevented by careful design and operation within a design envelope.
  Fatigue cracking is an example of a finite case, clearly an aging phenomena, with its number and severity of stress cycles, but also an accident because it is often the result of a local degradation which can be avoided by simple stress limitation measures

From a designers point of view, the problem of equipment reliability boils down to two complementary approaches:

* Identify real aging mechanisms that will take place because of the components environment, predict the resistance reduction rate associated to the severity of the situation, and size the component to allow it to keep a good margin at the end of its postulated life, for each of these aging modes.
* Size and build the component in a way that would avoid overstressing any part of it and would limit fabrication flaws, these two phenomena's are the main sources of premature failure of an otherwise perfectly sound component.

From a maintenance point of view, reliability is the result of:

* A close follow up of identified aging mechanisms to check the resistance reduction rate at the beginning, versus the residual resistance margin at the end of life.
* A surveillance of places in the component whose stresses are not very well known or exceed design values, or where fabrication flaws are likely to occur, thus preventing a premature failure by a early recognition of its symptoms.

MAINTENANCE PROGRAM

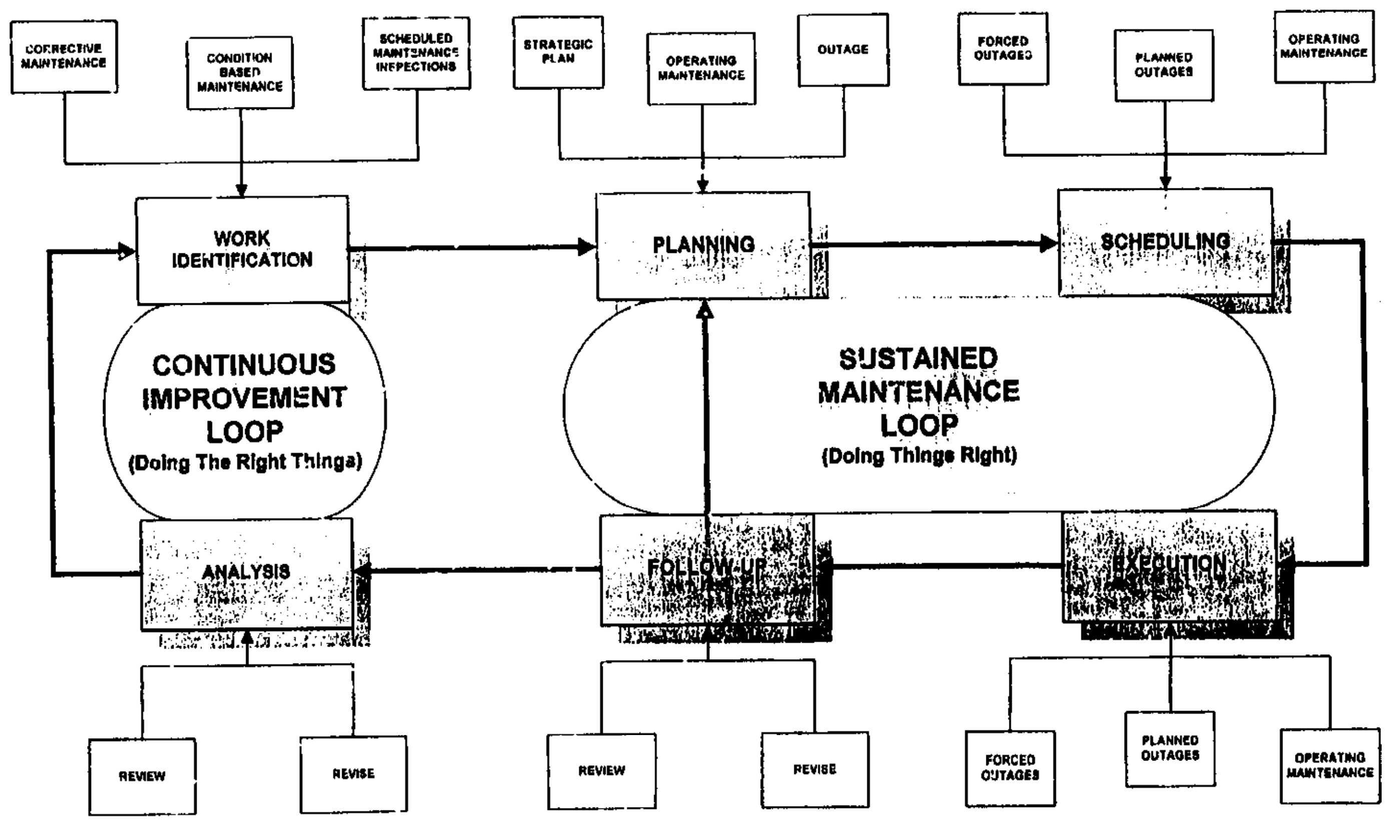
- A good maintenance program has an effective interaction between operations, maintenance and design/technical
- A good maintenance program will identify what equipment must be worked on and what must be done to preserve performance

MAINTENANCE PROGRAM

- An effective maintenance and revamp outage will have all the vital components and system identified - 'doing the right thing'
- An effective major maintenance and revamp outage will ensure that the proper repairs and revamps are carried out in all the required areas - 'doing things right'

PND MAINTENANCE PROCESS MODEL - Level 1

PND Maintenance Processes



MAINTENANCE PROGRAM

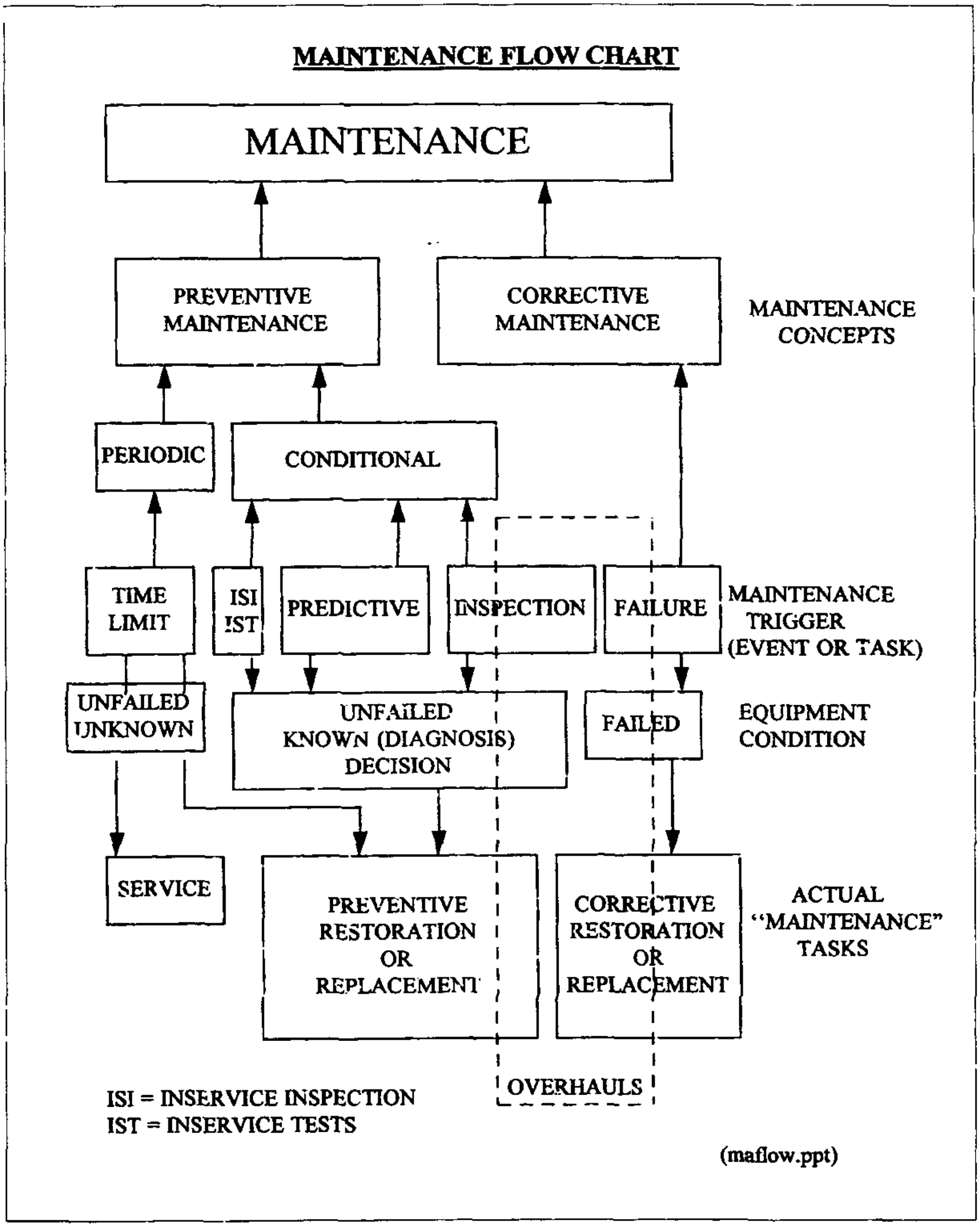
- A good maintenance program is one that is based on a systematic review of equipment and systems with a conscious application of various maintenance techniques:
  - corrective maintenance
  - periodic maintenance
  - reliability centered maintenance
  - condition based maintenance

MAINTENANCE PROGRAM

- Corrective maintenance: all the tasks performed to restore the functional capabilities of failed equipment (restore or replace).
- Preventative maintenance : activities performed on non-failed equipment

MAINTENANCE PROGRAM

- Periodic maintenance: actions to restore part or all of the failure resistance of non-failed equipment. Initiated as a function of time or production, regardless of the actual condition of the equipment.
- For an overview of the various aspects of maintenance see chart, 'Elements of Maintenance'& following 10 pages



MAINTENANCE FLOW CHART
MAINTENANCE
PREVENTIVE MAINTENANCE
CORRECTIVE MAINTENANCE
MAINTENANCE CONCEPTS
PERIODIC
CONDITIONAL
TIME LIMIT
ISI IST
PREDICTIVE
INSPECTION
FAILURE
MAINTENANCE TRIGGER (EVENT OR TASK)
UNFAILED UNKNOWN
UNFAILED KNOWN (DIAGNOSIS) DECISION
FAILED
EQUIPMENT CONDITION
SERVICE
PREVENTIVE RESTORATION OR REPLACEMENT
CORRECTIVE RESTORATION OR REPLACEMENT
ACTUAL "MAINTENANCE" TASKS
OVERHAULS
ISI = INSERVICE INSPECTION
IST = INSERVICE TESTS
(maflow.ppt)

MAINTENANCE

All activities performed on equipment and systems in order to assess, maintain, or restore their operational capabilities

Maintenance has two and only two major subclassifications:

Corrective maintenance, which is performed after the failure of an equipment and;

Preventive maintenance (PM), which is performed according to predetermined criteria, to reduce the probability of equipment failure or of performance degradation.

This distinction is the most (and perhaps only) important one, because corrective maintenance measures the failure of the organization to control degradations, while preventive maintenance measures the volume of efforts devoted to that goal.

PREVENTIVE MAINTENANCE:

All activities performed on nonfailed equipment or systems to avoid or reduce the probability of failure. This typically includes restoration or replacement of degraded but unfailed equipment or components. However, when during the implementation of a preventive task, such as a scheduled overhaul of equipment and an internal item if found or judged failed, the restoration or replacement cost for this item should be considered corrective maintenance. If it is found unfailed but degraded beyond potential failure, the restoration or replacement is preventive in nature. (Note that a degradation which does not reach the potential failure point does not mandate restoration since the component will live through the next inspection interval without failure).

Preventive maintenance can be divided in a variety of ways, each with a different objective in mind. We will use the distinction between time directed and condition directed PM when dealing with the establishment of the preventive maintenance program.

PERIODIC PM:

Actions to restore part of all of the failure resistance (of unfailed equipment or systems) initiated as a function of time or production, regardless of the actual condition (degradation status) of the equipment or system. It includes systematic replacement of critical components after some life limit, replacement of inexpensive components to avoid noneconomical condition assessment, and most of servicing (replacing fluids, filters, etc...). This type of action has at least the advantage of a simple decision scheme, time has or has not expired.

CONDITION BASED MAINTENANCE

- All types or activities of restoration on unfailed equipment as a result of condition assessment and comparison with a defined acceptance criteria (potential failure)

RELIABILITY CENTERED MAINTENANCE

- Known by all, misunderstood by most. it is an approach to maintenance, a philosophy, integrating rigor and common sense

CONDITIONAL PM

All types of restoration (of unfailed equipment or systems) initiated as a result of condition assessment and comparison with a defined acceptance criteria (potential failure). It is immediately apparent that this type of PM requires additional tasks to measure the degradation level. Those initial tasks are also considered a part of condition directed maintenance since they are the core of the decision process, even though they are generally scheduled at regular time intervals.

To understand the value of condition directed maintenance it is important to see the assessment and the subsequent restoration tasks as different.

In most cases, only the first one is made because there is not enough degradation to undertake a (preventive) restoration. As those inspection tasks are scheduled at regular intervals, they are often misclassified as periodic maintenance, which of course they are not. The benefit is evidently to delete a useless (and costly) restoration.

The most common types of assessment tasks include:

In Service Inspection (ISI)

Visual or non-destructive examination used to assess the condition of metallic structures such as massive pressure vessels and pipes or mechanical components.

In Service Testing (IST)

Tasks that measure equipment readiness and / or performance levels in normal or emergency operations. Examples include: a battery endurance test, a sensor calibration, etc.

Monitoring and Diagnostics (Predictive Maintenance)

Tasks that rely on variations in operation perameters as a sign of ongoing degradation, which then triggers preventive inspections or restorations to avoid failures.

MONITORING

The most basic type of monitoring is performed during operator rounds. This cyclic activity is performed by the field operator who makes visual and sound checks, and reads the gauges installed directly on the equipment. In this case, the field operator judges whether or not the equipment is operating "normally". In effect, operating personnel do not just "start, run and stop" equipment, they play an important role in maintenance particularly by discovering impending failures, stopping the equipment and preventing its total destruction.

Operator rounds must be complemented by walkdowns performed by maintenance personnel. Maintenance checks performed by these experts are one of the best ways to detect deterioration before it leads to actual equipment failure. Maintenance checks take a close look at any parameters outside the norms whereas, often, operating personnel mainly ensure that alarm or shutdown criteria are not exceeded and that "last chance" indicators (flames, smoke, sounds) are not perceptible.

This type of surveillance also includes equipment / system monitoring at a distance performed by the operators from the control room, using all indicators, annunciators, and recorders. It also includes the internal equipment protection devices that are frequently installed; these are often considered as part of the system proper, and result from a compromise between the desire to protect the function and the desire to protect the equipment. In fact, a piece of equipment and its internal protection devices should be considered as one, and their set points determined by a maintenance specialist. It is up to the system designer to take into account these constraints globally when designing the functional system, for instance by the use of redundancy to obtain a given functional reliability.

PREDICTIVE MAINTENANCE

This is the fashionable word, if you want to look good you should be doing a lot of predictive maintenance; but what exactly is predictive maintenance? Most people would agree that this is a technique which uses precise trends in operating parameters to monitor and assume (predict) equipment internal condition. The idea is to initiate a (preventive) inspection task only when an excessive degradation does exist and warrants restoration.

Now this is more or less what I have called monitoring, a technique that has been known for a long time, so what is the difference?

Well, basically there is little difference if any between the two concepts, but from an understanding, predictive maintenance is seen as the package of recent advances in monitoring techniques, a kind of "smart" monitoring with a higher goal than usual.

Monitoring is often mainly targeted to avoid failures or accidents, while predictive maintenance is looking for the same goal plus the goal to reduce unnecessary inspections.

What people do when they look for smoke or listen to the sound of their automobile engine is called monitoring. We do not intend to skip the next inspection if it sounds good, we simply try to guess if the whole thing is going to self destruct in the next hour.

Predictive maintenance needs a smarter diagnosis because its goal is to delete the next inspection, if the equipment condition is good enough to do it safely.

An immediate difference is that we need to do more than decide if it sounds OK or not. We need to remember what it sounded like the last time and six months before that and decide if there is a change and what it means.

So the main difference between monitoring and predictive maintenance is that the latter needs an expert opinion, or its modern equivalent, a computerized expert system.

REVAMPS & MODIFICATION

- Integral part of restoring or prolonging plant performance.
- A means of re-establishing equipment and system reliability.
- Correction of the design, directed to root of failure.

RELIABILITY CENTERED MAINTENANCE (R.C.M.)

This section is devoted to that well-know and extensively discussed maintenance methodology.
We will not cover in great detail what *exactly* RCM is, instead we will comment on RCMs' application to industry.
First of all, we will recognize the merit and the influence on modern maintenance of T. Matteson and Stan Nowlan of United Airlines who were major players in the group of individuals who invented the concept, and were the ones who made it known and accepted worldwide in the exceptional book by Nowlan and Heap.

Before and after them, most specialists have approached maintenance from the theoretical side, mathematics and statistics. Their approach was instead a mixture of intelligence and practical solutions, perfectly suited for the very difficult problem of mass air transport.

RCM, THE HISTORY AND METHODOLOGY

RCM was developed by the airlines companies, manufacturers, and regulators because between 1960-70, they were confronted with some disturbing facts:

-The discovery that traditional overhauls were unable to control the failure rate of big complex radial engines, whatever the periodicity (infant mortality).
-The complexity of new jets systems increased maintenance costs to levels incompatible with airline competitiveness.
-The arrival of jumbo jets whose crashes could no longer be considered as "accidents", but national or even international disasters.

In the early sixties, a working group produced a document "FAA -Industry Program for Airliners Reliability" and launched a series of experiments on the capabilities of preventive maintenance.

In 1965, the results of the programs were incorporated in a logical standard for designing PM programs under the name of MSB (Maintenance Steering Group), which was first applied by the team in charge of the new Boeing 747 jumbo jet.
Its successful application, a combination of safe operation and reduced maintenance costs led to several refinements of the initial concepts, as well as generalization of these methods. Today, MSG 3 has been applied worldwide to the most recent airliners, the Airbus and Boeing 767 and a revised version is planned. RCM concepts are also generalized for military systems like combat aircrafts and nuclear submarines.

Strangely enough, the diffusion of RCM to other industries has been somewhat slow. The initial evaluations for the nuclear industry began in 1984, at EPRI, followed by limited experiments mostly in France and the U.S.A. Today, there is no utility whose PM program is fully built according to RCM logic; Frances' EDF being very close, but development is rapid.

WHAT IS RCM

Surprisingly, RCM is known by everybody and misunderstood by most. It is perceived as a complex and sophisticated logical methodology to build and drive an optimum PM program, which in fact is the product of RCM, but very few people know that RCM is more than that. It is an approach to maintenance, a complete philosophy, integrating rigor and common sense and in fact not requiring fancy modeling.

RCM is based on both technical and policy principles

RCM TECHNICAL PRINCIPLES

1. Failures are undesirable conditions, with the following important distinctions:
-Functional failures are discovered by flight crews
-Potential failures are discovered mainly by maintenance teams.

2. RCM is not equipment oriented, but system oriented.
Functional failure consequences define maintenance priorities, from top to bottom:
-Safety related and hidden failures (that may lead to common mode failures) influencing the risk of loosing aircraft and lives
-Operational consequences, including only direct repair costs

3. Modern Preventive Maintenance is predictive or condition-directed rather than periodic.

4. Design directs failure consequences, they can only be changed by design changes.
-Safety consequences can often be reduced to operational by using redundancy.
-Hidden failures can be revealed by specialized instrumentation.
-P.M. cost effectiveness vary with equipment inherent reliability and maintainability.

5. Inherent (intrinsic) reliability of equipment is the field value observed with an effective (optimum) PM program.
This value is fixed by design and cannot be surpassed, whatever PM is implemented.

The policy principles included in RCM have even more value.

RCM is not only a Decision Logic but a complete approach to maintenance, founded on maintenance engineering, a follow up of the design engineering activities, directing the collection and analysis of a dedicated "age exploration program" (a large view of what we call operating experience).

Design and Maintenance working together
A PM program cannot approach optimum if built alone by vendor or operators. Only team work can do it. If both organizations have consistent capabilities, are understanding of each others needs, and place on the table the unique inputs that they own and that are the basis of the decision process.

MAJOR MODIFICATION

- Implications of major revamps:
  - result from unacceptable plant degradation and product changes
  - high capital costs
  - complex job, removing existing equipment, installing new equipment
  - contract work groups beyond normal plant staff

REVAMP & MODIFICATION

- Implications of major revamps:
  - contract workers must be integrated with normal plant work and practices
  - different tools, facilities, skills and personnel must be accommodated
  - new operating and maintenance procedures
  - additional staff training, materials, spare parts
  - new testing commission work
  - new problems not previously experienced

REVAMP & MODIFICATION

- Aspects requiring careful consideration by outage manager:
  - most of the work done by staff beyond the normal company organization
  - outage critical path often through the revamp work
  - if not well prepared 'surprises' may emerge expanding the scope and time for the work
  - 'designers' may not be part of the company, further removed

REVAMP & MODIFICATION

- Aspects requiring careful consideration by outage manager:
  - planning capability of the contractors
  - contingencies considered by the contractor, design support, material quantities, spare parts, oversights
  - division of responsibilities of respective organizations must be clear
  - one totally integrated outage plan must be prepared and agreed to by all parties

REVAMP & MODIFICATIONS

It is tempting to consider equipment modification as the natural extension of the design activities that "fine-tune" the product, and indeed it is true that no modification of any consequence should be achieved without the contribution of the manufacturer's design office. However, it must be recognized that operators also play a major role in initiating and implementing a modification, using it as a maintenance alternative.

Equipment modification is maintenance's natural 'technical' answer to a failure, and especially to a flaw, that is found to be rooted in design or manufacture. A well designed modification protects equipment from a recurrence of the incident. Modification is thus one of the best means of re-establishing equipment reliability with "normal" (ie reduced) maintenance needs, for equipment subject to this kind of fault.

Most people would not agree with that statement, because they are aware of the potential problems (including the cost) associated with modifications.

I should emphasize that most changes are hardly modifications but instead a simple correction of the design, directed to the very local root of a failure mechanism, to correct a stress concentration point of a faulty manufacturing process, are usually inexpensive and effective.

Equipment that is insufficiently reliable should not be repaired at infinitum, regardless of whether design is a fault or whether the equipment was poorly chosen for the function at hand.

However, this approach should not be followed to excess. Studies for a modification and also its implementation can be very costly, particularly in terms of the indirect costs of outages. Modifications must therefore be carefully analyzed beforehand for cost-efficiency. It is also important to keep in mind that modifications do not always have the success expected, and that they can also cause negative secondary effects. Furthermore, the well known tendency of engineers towards perfectionism should be watched with a keen eye.

Accepting the reoccurrence of a failure is always an option when comparing the various responses to the problem and is sometimes the best economically.

One needs a powerful organization for mastering modification proposals, studies, and follow up. The aims of the organization are:

- To assure the quality of the modifications through careful redesign and analysis of all possible negative effects.

- To check modification cost-efficiency by obtaining different opinions, including that of the manufacturer.

- To convince the manufacturer to redesign his product. One can make a nice living selling services for a bad product and not all of the vendors are comparing long term customer relationship to short term benefits (in fact, in today's difficult economic environment, some cannot afford to do it).

MANAGED APPROACH

- The following must be considered, before during & after outage:
  - all departments have a major contribution to the overall outage
  - any one group failing to integrate their efforts may render the outage ineffective
  - the 'cost model' should be appreciated by all
  - management should establish where the plant costs are relative to the model

MANAGED APPROACH

- An outage plan should recognize the three phases of an outage
  - preoutage and shutdown preparations: developing a clear integrated plan
  - outage critical path and other work: co-ordinate team work
  - post maintenance and revamp testing & plant restart

MANAGED APPROACH

- Management must consider communication:
  - make emplcyees and equipment safety #1 priority
  - learn from the best - look at plants who consistently have good outages
  - set strict limits for outage duration & challenge employees and contractors
  - plan & schedule every detail of the outage
  - communicate outage expectation to ali involved

MANAGED APPROACH

- Accountability & authority:
  - Give outage directors authority & responsibility for keeping on track.
  - Assign team leaders to 'make it happen' to key outage events.
  - Hold contract workers accountable to schedule.
  - Effective work control of day to day management.
  - Learn from mistakes, celebrate success, incorporate and apply lessons learned.

MANAGED APPROACH

- Team work & deadlines:
  - Integrated outage team with one visible head.
  - Scope, responsibilities and targets for each team. Prepare an 'outage guide.'
  - Prepare pre-outage plan for revamp preparation and prerequisites.
  - 'Drop dead' date plan must be established.

MANAGED APPROACH

- Documentation:
  - Prepare comprehensive plant shutdown plan and include application of work protection isolations.
  - Prepare comprehensive outage plan with clear critical path(s).
  - Prepare comprehensive start up plan.
  - All information, documents, materials, procedures must be in place at 'drop dead' date.

MANAGED APPROACH

- During the outage, management must:
  - Conduct daily planning monitoring.
  - Key teams including contractor to provide accurate progress and identify potential problems.
  - Track all work - initiated, in progress and completed.
  - Outage manager and team adjust resources to ensure planned target met.

MANAGED APPROACH

- Outage manager and team, adapt to contingencies as they develop.
- Outage manager ensure the optimum co-ordination and cooperation of all teams.

MANAGED APPROACH

- After the outage, management must ensure:
  - Outage manager and team ensure controlled testing to meet requirements.
  - Outage manager and team ensure controlled restart of plant as per startup plan.
  - Outage manager and team prepare report on; target versus actual; what went wrong and what went well and why.
  - Lessons to be applied to next outage.

OUTAGE GUIDE

1.0 MESSAGE OUTAGE MANAGER

2.0 OUTAGE GOAL

3.0 OUTAGE SCOPE

1. Final Scope
2. Key Diagrams
3. Critical Path Work
4. Other Major Work

4.0 ORGANIZATION, RESPONSIBILITIES, AUTHORITY

1. Organization Charts:

   Operations

   1. Operations Execution Organization
   2. Boiler Recovery Organization
   3. Steam Generator Life Management Organization

   Construction

   1. Boiler Chemical Cleaning and Water Lancing
   2. Construction Communication Chart

   NOCD

   1. Inspection, Maintenance and Metallurgy Department
   2. Chemical Operations Department

   B&W

   1. Chemical Clean Organization Chart
   2. Waterlancing Organization Chart

2. Contacting Outage Personnel:
   1. Operations Boiler Recovery Team Telephone List
   2. Water Lancing / Flushing Contacts
   3. Pencon Construction, Design & Engineering Contacts
   4. Chemical Cleaning Contacts
   5. Operations
   6. NOCD Contacts
   7. Safety Services Department (SSD) Support
   8. Health Physics Approval for Radiological Work Plans
3. Responsibilities and Authority
   1. Project Manager, Steam Generator Program
   2. Business Team

3. Strategy Team
4. Regulatory Coordination Team
5. Outage Superintendent
6. Operations Coordinator (OC)
7. Outage Safey Coordinator (OSC)
8. Reactor Building Coordinator (RBC)
9. Operations Execution Group
    1. RB Supervisor (RBS)
    2. Assistant RB Supervisor (ARBS)
    3. Authorized Nuclear Operator (ANO)
    4. Chemical Clean Dedicated Supervising Nuclear Operator (SNO)
    5. Operations Greenperson Duty Crew
    6. Dedicated Operator Support Group
10. Water Lancing Team
    1. Project Manager
    2. Site Manager
    3. B&W Lancing coordinator (BWLC)
    4. Lancing Engineer
    5. Lancing Supervisor (LS)
    6. OH Lancing Coordinator (OHLC)
11. Chemical Cleaning Team
    1. Task Leader
    2. Senior Supervisor
    3. B&W Senior Process Engineer
    4. NOCD Chemistry Support Coordinator
    5. OH Senior Process Engineer
    6. Shift Process Engineer
    7. Shift Laboratory Supervisors
    8. Boiler Recovery Team (BRT)
12. Inspection and Tube Plugging Team
    1. Inspection and Maintenance Coordinator
    2. Results Coordinator
    3. Inspection Work Group Supervisors
    4. Maintenance Work Group Supervisors
    5. Boiler Recovery Team (BRT)
13. Site Chemistry Support Team
    1. Superintendent Engineering Sciences
    2. Supervisor Chemistry Maintenance

14. Construction Execution Team
    1. Team Leader
    2. Perform Work Person
    3. Planning / Engineering Person
    4. Safety / Training Person
    5. Workface Coordinator
15. Site Execution Staff Training Requirements
    1. Chemical Cleaning
    2. Water Lancing and Flushing
    3. Inspection and Maintenance Staff
    4. Plant Site Staff
16. Engineering Services
17. Waste Management
18. Program Integration

4. Rules for Non-Station Personnel
    1. Accounting When Arriving on Site
    2. Access To Site
    3. Parking
    4. Use of Telephones
    5. Protective Clothing
    6. Food Restrictions
    7. Bioassay Samples
    8. Maternity Guidelines
    9. Smoking
    10. Reporting of Occupational Accidents
    11. Medical Services
5. Roles and Responsibilities For Bringing Non-Station Personnel On-Site to Perform Radioactive Work
    1. System Responsible Engineer
    2. Reactor Building Coordinator (RBC)
    3. Security
    4. Radiation Data
    5. Non-Station Personnel
    6. Work Unit Coordinating Supervisor
    7. Reactor Building Supervisor (RBS)
    8. Operations Greenperson
6. Responsibilities of Health Physics
7. Responsibilities of Radiation Control

5.0 OUTAGE CONTROL

1. Scope Control
2. Work Control / Work Authorization / Work Protection
    1. Controlling Authority
    2. Work Authorization / Work Protection
    3. Main Boiler Work Permit
    4. Work Control Administration
3. Quality Control
4. Procedure Control
5. Change Control Systems and Equipment
6. Verification

6.0 COMMUNICATIONS

1. Meetings
    1. Reactor Building Supervisors
    2. Project Safety Coordination
2. Status Information
    1. Outage Information Board

7.0 CONVENTIONAL SAFETY

1. Hazards
    1. Hazardous Agents
    2. MSI
    3. Heat
    4. Noise
    5. Heights
    6. Work Coordination
2. Controls
    1. Chemicals
    2. Chemical Spill Protective Clothing
    3. Waste Handling
    4. Heat
    5. Environmental Factors
    6. Noise
    7. MSI
    8. Scaffolds
    9. Work Coordination
3. ERT Information

        1. First Aid Instructions
        2. Air Sampling Instructions
        3. Material Safety Data Sheets
    4. Accident / Incident Notification
    5. Project Safety Coordination

8.0 RADIATION SAFETY
    1. Operating Memo
    2. Radiation Protection
        1. Greenpersons
    3. Nuclear Operations Branch Procedure 137
        1. Radiation Protection Assistants (RPAs)
    4. Mid-Term Agreement
        1. Radiation Protection Assistant
    5. Radiation Safety Guide
        1. PIP of Boilers and HTS Components
        2. Cigar Inspection - Fuel Channels
        3. Adjuster Rod Replacement
        4. Moderator Hear Exchanger
        5. Shutdown Cooling Hear Exchanger
    6. Radiation Protection Facilities
        1. Dose Desk
        2. Surveys
        3. Descriptive Log
        4. Radiological Log
        5. Shift Turnover - Greenpersons
        6. Dosimetry
        7. Radiation Work Plans (RWP)
        8. Radiation Work Application
        9. Radiological Hazard Signs
        10. Greenperson Routines
        11. DMS/PF - 59s
    7. Dose Management System (DMS)

9.0 HOUSEKEEPING AND MATERIAL CONDITION
    1. Governing Policy
    2. Housekeeping Standards
    3. Housekeeping Responsibilities
    4. Rubber Area Standards
    5. Rubber Area Responsibilities

6. Material Identification
7. Material Condition
8. Structure Restoration
9. Reactor Building Laydown Areas
10. Reactor Auxiliary Bay Laydown Areas
11. Space Coordination
12. Initial Reactor Building Inspection
13. Breathing Air Hoses

10.0 RESOURCES

Pre-refuel Outage

Develop/issue plan	12 months
Freeze DCP scope	12 months
Freeze non-DCP scope	9 months
Define outage organization/DCP eng. complete	6 months
Issue summary schedule/ preliminary budget	6 months
Work packages complete	5 months
Issue draft detailed schedule	3 months
Outage organization in place	2 months
Issue final refueling outage schedule	1 month

PLANT A PRE-OUTAGE MILESTONES

MILESTONE	DESCRIPTION
11 Months	Transfer known work scope to schedule
10 Months	Develop logic schedule based on defence-in-depth requirements (done by operations)
9 Months	Load modification work scope into schedule
8 Months	Publish Revision of schedule
6 Months	Complete design changes engineering and work packag
3.5 Months	Complete clearance tagging; finalize contracts
3.5 Months	Freeze and publish final schedule

PLANT B PRE-OUTAGE MILESTONES

MILESTONE	DESCRIPTION
24 Weeks	List of modifications that will be done during outage is fixed
16 Weeks	Maintenance department work scope verified by the maintenance departments. ALARA needs identified
13 Weeks	All work orders for outage are ready
12 Weeks	Modification files are available in the control room
10 Weeks	Proposed outage plan (schedule) is complete
8 Weeks	ECO revises outage plan based on feedback for departments
6 Weeks	All planning complete. Work orders for secondary systems sent to operations
4 Weeks	Work orders for the system are sent to operations

PLANT C PRE-OUTAGE MILESTONES

MILESTONES	DESCRIPTION
20 Weeks	Issue preliminary manager schedule
12 Weeks	Departments provide work scope
8 Weeks	Work planning
8 Weeks	Update standard networks
8 Weeks	Work scope and logic discussion meeting
8 Weeks	Make preliminary outage plan
8 Weeks	Check preliminary outage plan
7 Weeks	Send preliminary plan to regulator
7 Weeks	Start network planning
4 Weeks	Make final managers schedule
4 Weeks	Make final outage plan
2 Weeks	Check final outage plan
2 Weeks	Company approval of final outage plan
2 Weeks	Send final outage plan to regulator
0 Weeks	Outage start date

CONCLUSION

- By paying attention & improving the business practices in the topics discussed the overall costs in the business will come down.
- By encouraging staff to look for & recognize improvements & apply these to future outages, each successive outage will be more successful that the previous.

CONCLUSION

- With an integration of efforts from the various departments the productivity of the organization will improve.
- Modifications are complex & contractors must fit in with the other groups in the outage.

RECOMMENDATIONS

- Move away form corrective to preventative maintenance.
- Do not underestimate the contribution possible by the maintenance department from lowering total cost; while their initial requirements are often considered 'excessive' by management.

RECOMMENDATIONS

- Focus on the fact that the costs are at a maximum when the plant is down.
  - Revamp can be a result of a failed maintenance program.
  - A poor maintenance program severely limits the profitability of the business.