EXPERIENCE WITH DIAGNOSTICS AT ANGRA I

F.R. FEINER

1. INTRODUCTION

Angra I NPP was ordered in the early seventies as a turn key contract from Westinghouse. It is a PWR, two loops, 657 MWe capacity project, and was the first Brazilian initiative on the nuclear electric field.

As a large tropical country, we benefit from a number of rivers and proper geography, such that our electric matrix rely on hydroplants as much as 95%, or more. Typically we have a hydro-electric culture in our electricity industry.

Without a nuclear culture, and being a hydro system, we had to rely on our contractors on every aspect of the project. We ordered the plant, and receive its hardware and software as they were twenty years ago, before TMI and Chernobyl. The system was typically an operation environment. Focus on ops was the major aspect, with some attention to Reactor Engineer, Health Physics and Chemistry. Training was toward ops needs, only.

In such an environment, the Maintenance needs were secondary issues, with a lack of resources, either material or human. Items such as work control system, training, types of maintenance (corrective or preventive), equipment history, procedures, maintenance operational experience (inhouse/outside), maintenance equipment and so on, were not among those considered as plant priorities. As a result, the maintenance performance was extremely low, and the overall plant performance was a great disappointment.

TMI accident, and the related results of event evaluation, brought additional impacts to our plant, since a large number of modification, either on the systems and procedures, were required. Again these changes did not addressed maintenance and its role as an important contributor for plant safety, availability and cost effectiveness. TMI improvements focused mainly on ops and safety back up systems to avoid, isolate or mitigate an event. These improvements, although very beneficial for the industry, raised the overall cost of the plant. With a single unit, inside a hydro environment, with low capacity factors, the organization struggles to improve plant performance addressing other issues, but not maintenance.

By the end of the eighties the low plant performance enhanced public and corporation disappointment with the nuclear industry in Brazil, since we were at the lower quarter among nuclear plants worldwide.

As the first quarter of the ninites has passed, the plant had accomplished most of TMI items and started to turn its attention to maintenance. Since the first core load Angra I has performed as a very safe plant. But just now, as we focus on maintenance and its role, the plant is raising its availability indicators and the early failure detection techniques emerges as one of the key factors in this recovery.

2. PREDICTIVE MAINTENANCE PROGRAM at Angra I NPP

The purpose of the Predictive Maintenance Program at Angra I NPP is to enhance plant safety and reliability though early detection and diagnosis of equipment degradation prior to equipment failure.

The accomplishment of this role rely on an organization inside the Maintenance Division. This group will perform this function through use of installed and portable diagnostic tools which will monitor selected equipment parameters to detect degradation and monitor equipment condition. It will identify which equipment is to be trended, select parameters to be monitored, establish base lines, set Alert and Action Points for each parameter, and coordinate predictive maintenance activities with other plant organizations. In addition, this group will establish and maintain the data base needed to collect and manipulate the data collected under this program and will issue periodic reports for management.

The Predictive Maintenance Program does not override the Surveillance Program, required by the Brazilian Regulatory Body in accordance with ASME Section XI requirements, but it provides detailed component evaluation and condition assessment, which adds value to the Surveillance Program.

The Maintenance Division Manager has the overall responsibility for the program. The Predictive Maintenance Group Supervisor is responsible for the development of a PREDICTIVE MAINTENANCE MASTER LIST, for its periodic review, to ensure that results of the Predictive Maintenance data collection activities are properly stored for trending purposes and future use, to ensure that data is reviewed, trended and analyzed to detect degradation of equipment condition, and for changes recommendations to the Predictive or Corrective Maintenance activities, based on the Predictive maintenance results. In addition he is responsible for providing timely notification to the Work Control System Coordinator of equipment whose condition is deemed to be deteriorating and in need of further diagnostic activities or corrective maintenance.

The Predictive Maintenance Master List plays a key role in the program. It shall be periodically reviewed (annual basis), must identify the frequency at which each component is monitored, shall contain equipment/components that are not monitored on a routine basis, and must be revised as dictated by experience, cost effectiveness and maintenance history.

The selection of equipment/component will be based on safe and reliable plant operation, equipment experiencing repeated Corrective Maintenance, ALARA requirements and equipment that justify a "run to failure" approach.
Nuclear safety-related equipment is top priority, followed by load threatening equipment without and with spare. Support equipment and high-maintenance items are the following priorities.

In particular, as they are an important source of problems for safety and reliability of the plant, as identified by the industry, Check Valves and Motor Operated Valves shall receive special focus inside the Predictive Maintenance Program.

The Predictive Maintenance Group will use a variety of techniques in implementing the program, such as:

- vibration monitoring,
- lubricant analysis (viscosity, moisture, and other contaminants, ferrography, grease analysis specially for MOV),
- infrared thermography,
- motor operated valve diagnostic information,
- acoustic monitoring,
- bearing temperatures monitoring,
- in-leakage detection,
- insulation resistance monitoring,
- eddy current testing,
- temperature differential monitoring of heat exchangers,
- polarization index.

Special consideration shall be made in selecting and training the personnel responsible for obtaining and analyzing predictive maintenance data. A training program shall be implemented to support needed competency and to upgrade knowledge as technology enhances.

Equipment not in operation shall not be placed in operation for the sole purpose of predictive maintenance monitoring. Such monitoring shall be rescheduled to a time consistent with normal plant and equipment operations. In particular, standby safety-related equipment shall not be made unavailable solely to perform predictive maintenance.

Latest acquired data shall be compared with previous data to detect any degradation. If degradation is observed that indicates the integrity of equipment may be endangered, the Predictive Maintenance Group shall promptly notify the Work Control Center Coordinator as well as Ops Division, and may take the following actions: recollect the data to verify its validity, increase the frequency at which data is collected, perform any additional types of diagnostic testing to determine the extent and cause of the degradation, or schedule corrective maintenance.

Failure of equipment included in the Predictive Maintenance Program but not predicted must have detailed root cause investigation to determine why the program did not detected degradation before the failure occurred.

3. ANGRA I PREDICTIVE MAINTENANCE MASTER LIST

Angra I Predictive Maintenance Master List addresses the following equipments:

- Compressors
- Emergency Diesel's
- Rod Driver MG's
- Main Generator
- Main Exciter
- Turbines
- Transformers
- Breakers
- Electrical buses
- Batteries
- Switchgears
- Safety screen washes
- Fans
- Motors
- MOV's
- Pumps
- Oil reservoirs
- Traps
- Valves

Frequencies and types of techniques are included in the Predictive Maintenance Master List.

4. MAINTENANCE EVOLUTION AT ANGRA I NPP

The Angra I maintenance program has incorporated several different philosophies since plant startup. Initially, a Preventive Program was developed based on vendor manuals, which resulted in a very heavy list of PM tasks. That program didn't assess plant mode of operation, and was basically a list of tasks to be performed from time to time, no matter what the plant status was. Since plant training program has not assessed maintenance needs, this heavy program let to very frequent interventions on the machinery, with a high rate of malfunctions due to human performance weakness.

A different approach was introduced as maintenance personnel realized they were spending a high amount of resources with low output, and after some mistakes, which damaged major equipments. Basically we changed the plant preventive maintenance using sound engineering judgment. As a result we felt the maintenance resources were optimized. Indeed, some failures with high impact on availability were still occurring.

At this time we realized that Preventive Maintenance based on component replacement between fixed intervals was not adding value to our program due to the aleatory characteristic of the rotating machinery failure. Moreover, the replacement often resulted in equipment malfunction due to human failure.

As a result of experience exchange with foreign organizations, such as INPO, we enhanced our PM program with operational experience on maintenance area. With this evolutions we benefit from industry development in selected components and systems, like MOV's and check valves. We also learned from the benefits of new technology, what let us to introduce the Predictive Maintenance concept to our plant.

At Angra I NPP we believe the equipment in general is much more reliable than we thought before, and whenever a fail process initiates the equipment asks for help. The whole issue is to be vigilant, understand its language, and deliver the proper care at the right time. Again the COMMUNICATION PROCESS shows its importance in nuclear industry, just like it was established in INSAG-4 IAEA DOCUMENT (a questioning attitude + a rigorous and prudent approach + COMMUNICATION).

ANGRA I NUCLEAR POWER PLANT

MOVs EVALUATION PROGRAM

1. ANGRA I MOVs SUMMARY

MOST OF THE SAFETY RELATED VALVES REQUIRED FOR SAFETY SHUTDOWN AT ANGRA I ARE MOTOR OPERATED VALVES.

TOTAL OF SAFETY RELATED MOVs:
108 MOVs

SAFETY FUNCTIONS OF THESE VALVES:

- **COMPONENTS ISOLATION**
- **SYSTEMS ISOLATION**
- **CONTAINMENT ISOLATION**
- **PRESERVATION OF RCS PRESSURE BOUNDARY.**

ALL THE ANGRA I SAFETY RELATED MOVs ACTUATORS WERE MANUFACTURED BY LIMITORQUE AND INCLUDE THE FOLLOWING MODELS:

SB-0:	**04 ACTUATORS**
SB-00:	**41 ACTUATORS**
SB-1:	**11 ACTUATORS**
SMB-00:	**29 ACTUATORS**
SMB-000:	**21 ACTUATORS**
SB3:	**02 ACTUATORS**

SAFETY RELATED MOTOR OPERATED VALVES TYPES AND MANUFACTURERS:

GATE WESTINGHOUSE:	37 VALV.
GLOBE VELAN:	07 VALV.
GATE VELAN:	01 VALV.
GLOBE COPES VULCAN:	02 VALV.
GATE COPES VULCAN:	31 VALV.
BUTTERFLY COPES VULCAN:	01 VALV.
BUTTERFLY FISHER:	18 VALV.
GATE ITT GRINNEL:	02 VALV.
BUTTERFLY JAMESBURY:	06 VALV.
BUTTERFLY POSI:	02 VALV.
GLOBE GIMPEL:	01 VALV.

2. INITIAL PROGRAM

IN ORDER TO COMPLY WITH THE REQUIREMENTS SETFORTH IN THE US NUCLEAR REGULATORY COMMISSION GENERIC LETTER 89-10, FURNAS HAS DEVELOPED, BY ITS OWN INITIATIVE, A PROGRAM FOR EVALUATION AND TEST OF ALL THE SAFETY RELATED MOVs INSTALLED AT ANGRA I.

INITIALLY FURNAS CONTRACTED ITI MOVATS TO PERFORM THE EVALUATION AND TEST PROGRAM IN 20 MOVs CONSIDERED PRIORITARY.

THE ENGINEERING EVALUATION OF THIS FIRST PART OF THE PROGRAM STARTED IN JANUARY 1996 AND THE TESTS WERE PERFORMED DURING PLANT P-6 OUTAGE, IN APRIL AND MAY 1996.

THE INITIAL PROGRAM INCLUDED A COMPLETE INSPECTION AND MAINTENANCE OF ALL THE MOVs WHICH WOULD BE EVALUATED AND TESTED. THESE ACTIVITIES WERE PERFORMED CONSIDERING ALL THE RECOMMENDATIONS AND PROCEDURES OF THE MANUFACTURERS.

AS A RESULT OF THIS INITIAL EVALUATION, SEVERAL PROBLEMS WERE IDENTIFIED AS DESCRIBED BELLOW:

- 40% OF THE ACTUATORS HAD DEGRADED GREASE.

- 30% OF THE ACTUATORS HAD NON QUALIFIED TORQUE AND LIMIT SWITCHES.

- 10% OF THE ACTUATORS HAD MOTOR PINION INSTALLED IN AN INVERTED POSITION.

- 10% OF THE ACTUATORS WERE FOUND WITH THEIR MOTOR PINION KEY ALMOST SPLITTED.

- 60% OF THE ACTUATORS HAD RELAXED SPRING PACKS.

- 10% OF THE ACTUATORS SHOWN THE WORM SHAFT BEARING DAMAGED.

- 60% OF THE MOVs HAD THEIR TORQUE SWITCHES SET POINTS READJUSTED.

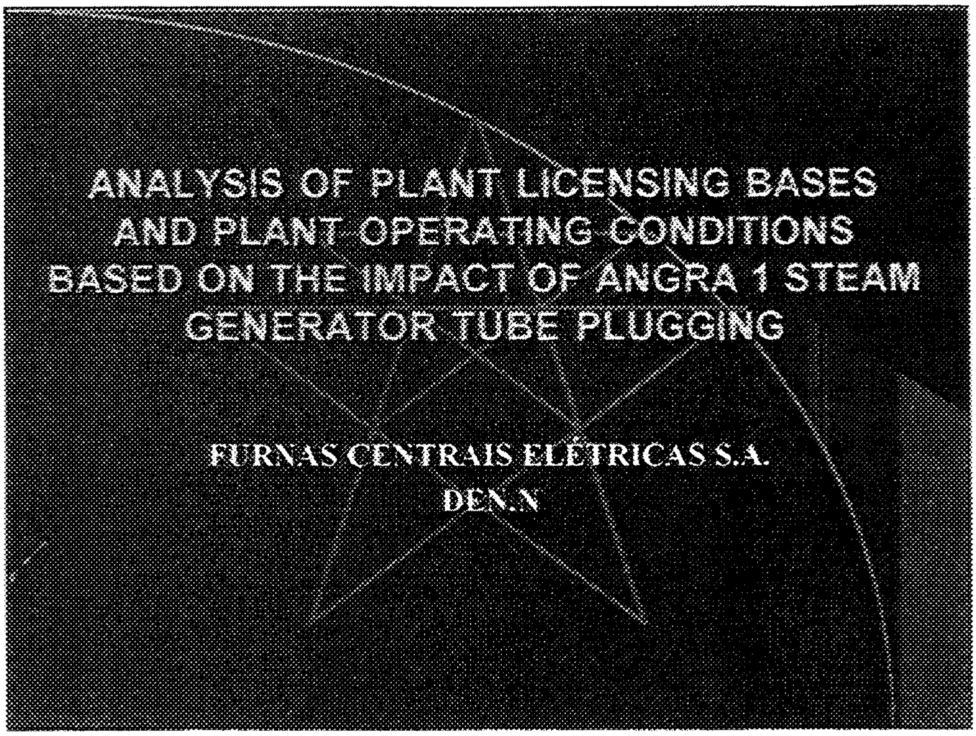
- THE AUXILIARY FEEDWATER PUMPS ISOLATION VALVES PV-1527 AND PV-1528 WERE FOUND QUITE DAMAGED.
THE ENGINEERING EVALUATION CONCLUDED THAT BOTH THE VALVES AND ACTUATORS WERE UNDERSIZED.

3. PROGRAM FOR THE P-8 AND P-9 OUTAGES

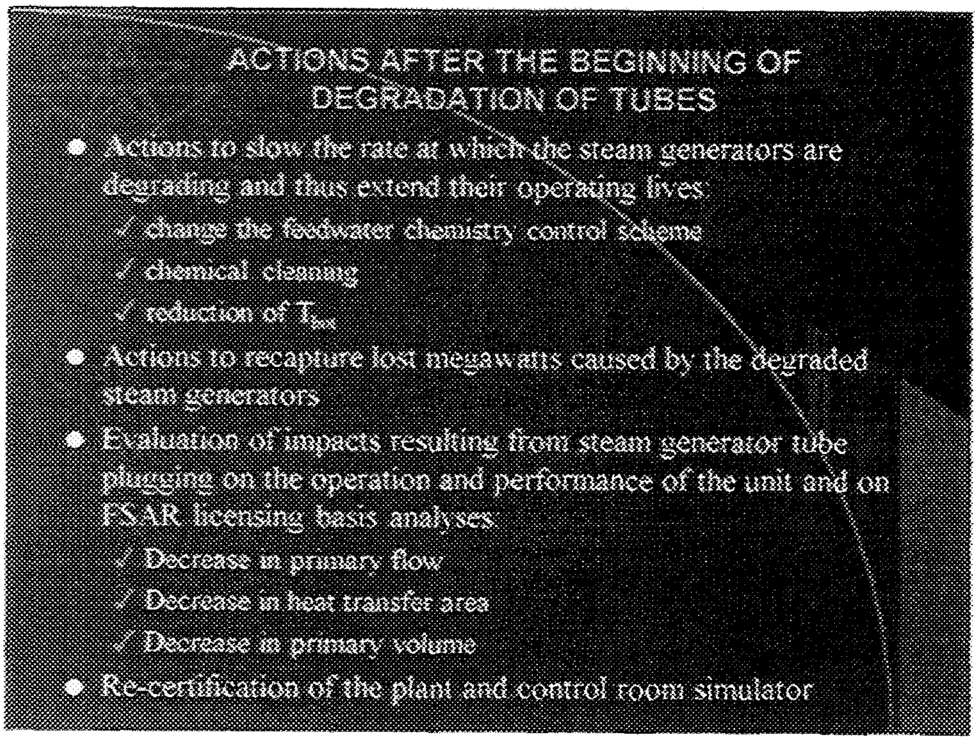
FOR THE NEXT OUTAGE (P-8) , FURNAS WILL CONTRACT SERVICES TO EXTEND THE NRC GENERIC LETTER 89-10 PROGRAM TO 50 MOVs.

THE TESTS PERFORMED AT P-7 OUTAGE AND THE TESTS THAT WILL BE PERFORMED IN THE P-8 OUTAGE, DON'T CONSIDER DYNAMIC CONDITIONS.

DYNAMIC TESTS ARE SCHEDULED FOR THE P-9 OUTAGE, WHEN FURNAS INTEND TO HAVE COMPLETED THE ENGINEERING EVALUATION FOR ALL THE VALVES, AND THE GROUPING STUDY.



This project under development in Furnas Centrais Elétricas S.A. analyse impacts on licensing basis and operating conditions of the increase in Angra 1 steam generator tube plugging levels.



• Experience has shown that once steam generator tubes begin to degrade, there is no way to stop the process. Furthermore, if no action is taken, the rate of degradation will accelerate. Therefore most plant owners have undertaken some positive actions to slow the rate.

• As the tubes degrade, the amount of heat transferred to the secondary system decreases. Initially, the plant operators can compensate by opening the turbine control valves wider. Eventually these valves will be fully open and any additional loss in steam pressure will result in the plant no longer being able to generate 100% electrical power. These lost megawatts can be recaptured by making modifications to the secondary side to improve the efficiency of feedwater/steam cycle.

• The evaluation of the thermal-hydraulic impacts on plant operation, performance and licensing basis fall mainly into three areas:

• Decrease in primary flow

Primary circuit flow will decrease following any modification that increases the loop hydraulic losses.

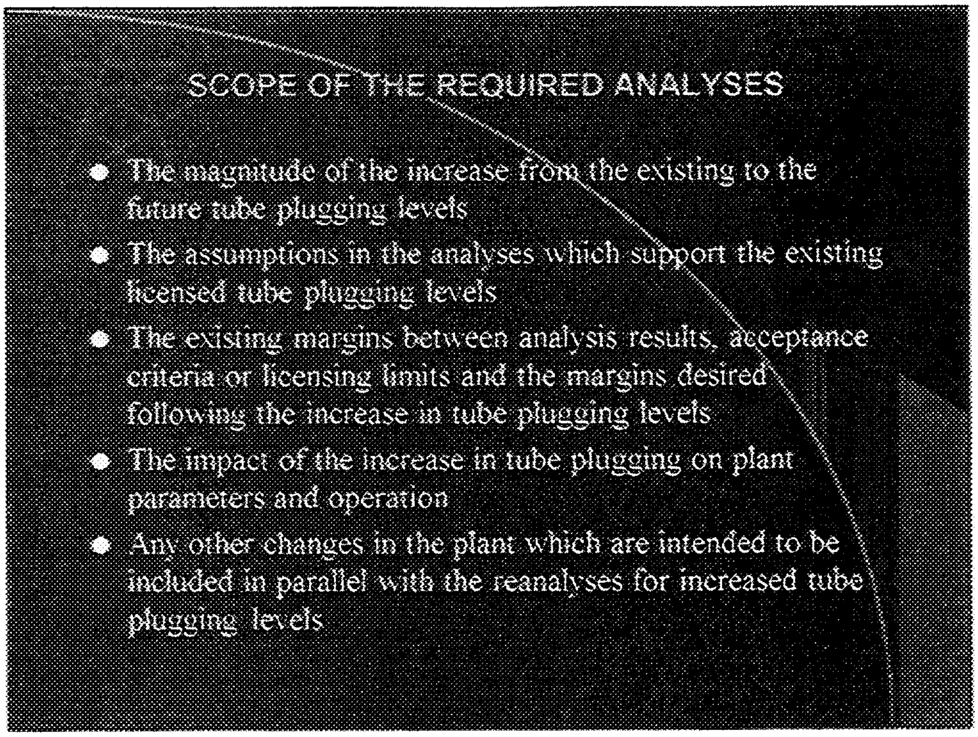
• Decrease in heat transfer area

As steam generator tubes are removed from service by plugging, there is less active heat transfer area.

• Decrease in Primary Volume

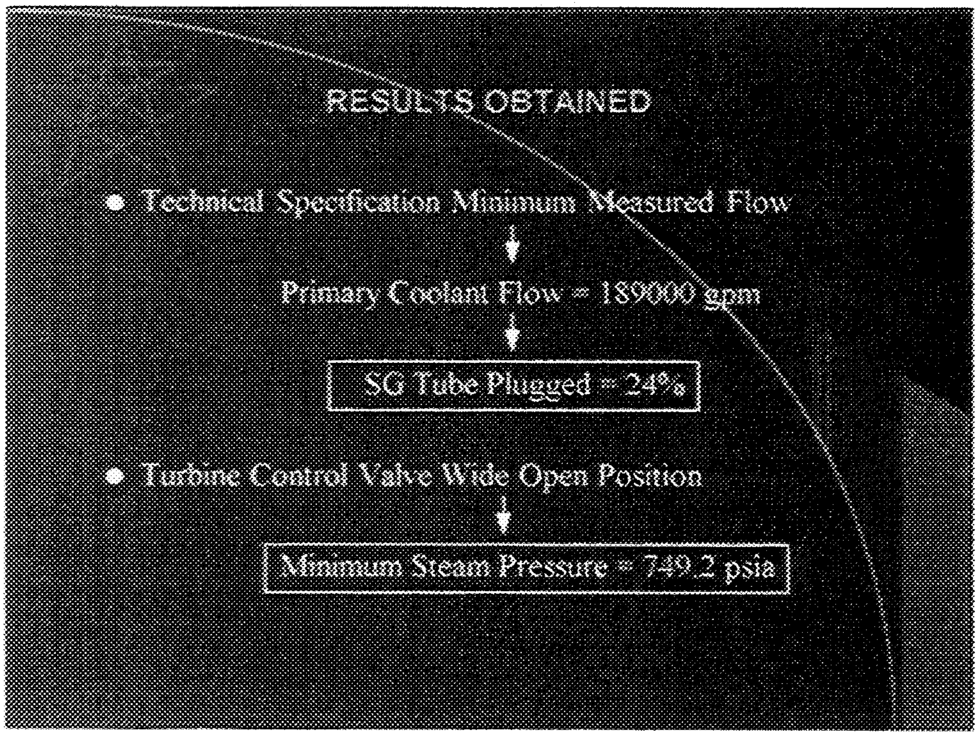
Although not as significant as the two above impacts resulting from tube plugging, there is some potencial for a smaller primary volume to contribute to a more adverse transient response.

• As the plant is modified and as new analytical models are developed, the plant simulator will need to be checked to verify that it properly represents plant performance.



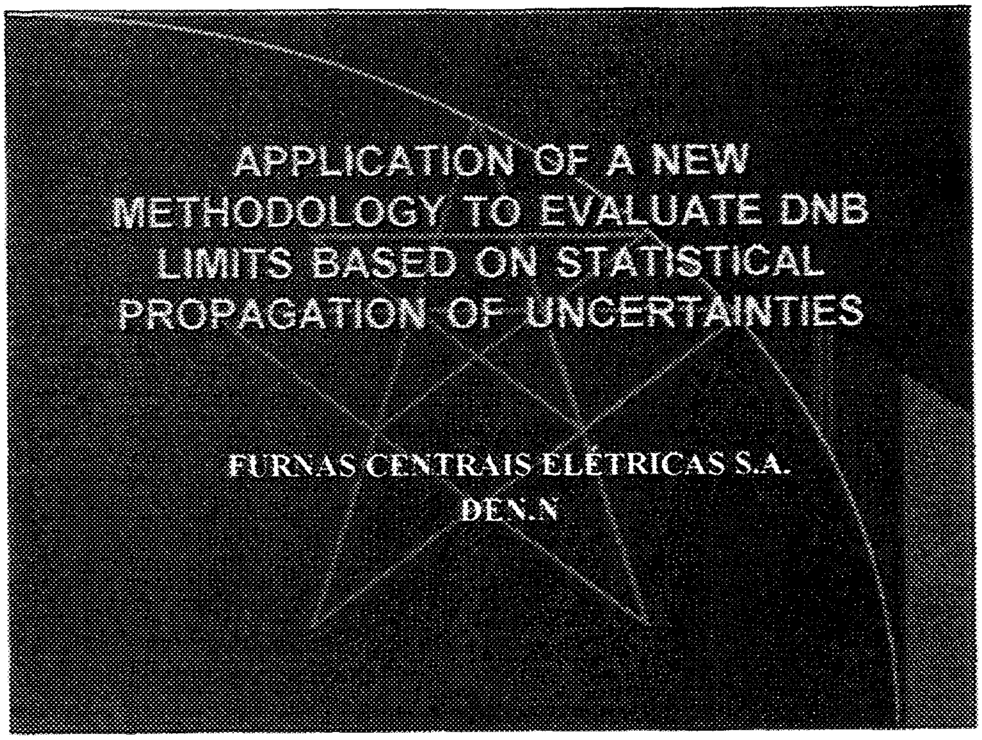
The scope of reanalysis required to justify an increase in the licensed tube plugging level depends on the following considerations:

Concerning the potencial impacts of tube plugging discussed before, only the decrease in primary flow has a Technical Specification impact.

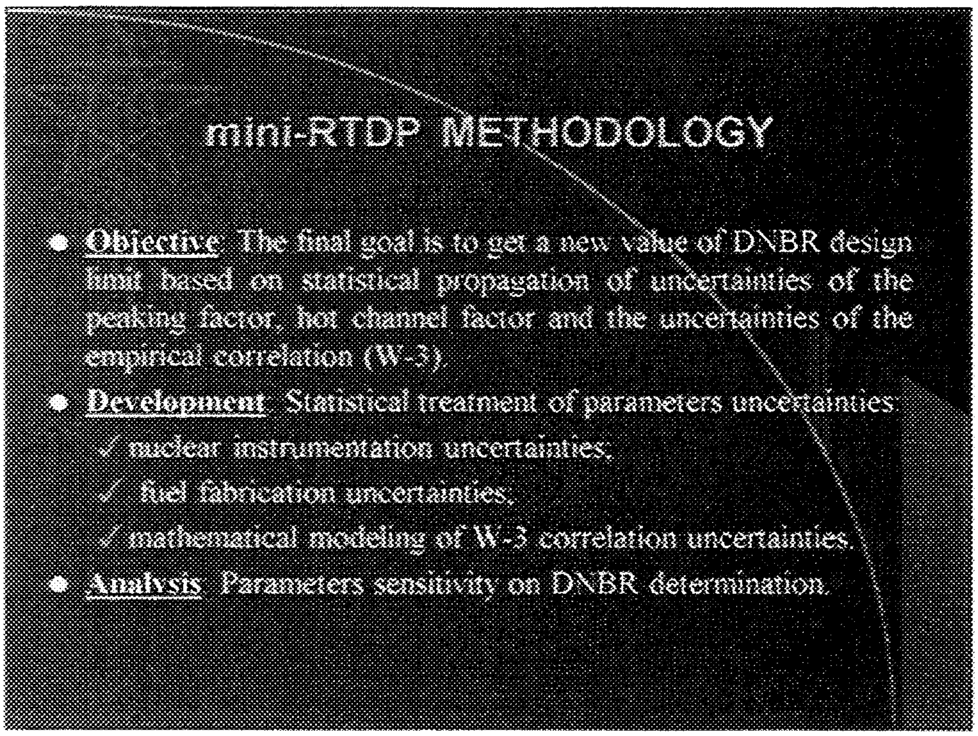


• The first step was to determine up to what level S.G. tube plugging in Angra 1 would not constitute an unreviewed safety question and that no Technical Specification changes would be required.

• Then, the minimum steam pressure required to generate full power and associated with the turbine control valves wide open position was determined.



•This project developed in Furnas apply a new methodology named mini-Revised Thermal Design Procedure (mini-RTDP). This methodology is based on statistical propagation of uncertainties. This new methodology allow a gain in safety margin avoiding licensing problems for operation of the reactor on its maximum power. This new methodology reduces the level of conservatism in parameters used in the DNBR calculation, wich are in their most unfavorable values with the standard methodology, by using their best estimate values.



•Hot channel factor ($F^{E}_{\Delta H,1}$) = Engineering enthalpy rise hot channel subfactor.

This subfactor accounts for variations in those fabrication variables which affect the heat generation rate along the flow channel. These variables are pellet diameter, density and U-235 enrichment.

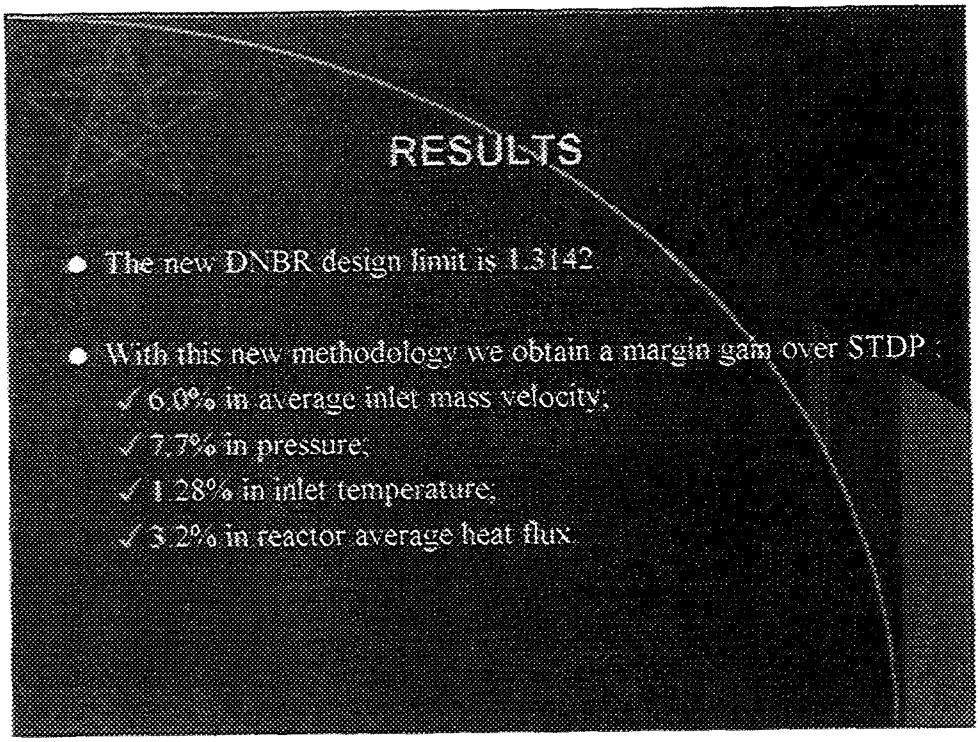
•Peaking factor ($F^{N}_{\Delta H}$) = Nuclear enthalpy rise hot channel factor.

The ratio of the linear power along the rod with the highest integrated power to the average rod power (including uncertainties).

Related with nuclear instrumentation errors.

•We must analyse the influence of these two parameters above in COBRA IIIC/MIT code. This is made by a sensitivity analysis of the code output due to isolated variations of each parameter.

•mini-RTDP Methodology = Parameters associated with plant instrumentation (temperature, pressure, power, flow) are at their worst values. Peaking factor ($F^{N}_{\Delta H}$) and hot channel factor ($F^{E}_{\Delta H,1}$) are at their nominal values.



•The new Departure from Nucleate Boiling Ratio (DNBR) design limit is based on statiscally combining the peaking factor and hot channel factor uncertainties with the DNB correlation uncertainties.

•The new value is 1.3142 that is greater than 1.3000 used in standard methodology (STDP).

•The standard method (STDP) currently in use is extremely conservative, and may result in penalties to the reactor power due to an increasing plugging level of steam generators tubes.

•With the new methodology we obtain flexibility in nuclear, thermal and hydraulic design. If average inlet mass flow is reduced in 6.0% DNB will not occur with 95 percent probability at a 95 percent confidence level.