LAGUNA VERDE DOSE REDUCTION PROGRAM

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Summary

Due to the fact that Laguna Verde NPP collective dose has been historically higher than the average for BWRs, the Plant has given prioritary attention to the investigation of the causes of such tendency and strong support to the implementation of corrective and preventive actions. The main isotopic source of exposure resulted to be in a high proportion Co-60; this was determined trough field measurements. The sources of Cobalt were also identified and quantified. Based on these results, an Integrated Dose Reduction Program was developed; the implementation of most of the actions prescribed by the Program have already been started up in 1997 and 1998. The expected results of these actions are discussed, as well as the mid term implementation of additional measures focused to get the objective of the Dose Reduction Program.

Background

The Laguna Verde Nuclear Power Plant (LVNPP) is placed on the coast of the Gulf of Mexico, in the Mexican State of Veracruz. It consists of two Units General Electric BWR-5 of 684 Mwe each. Unit 1 started commercial operations in July 1990, and Unit 2 in April 1995.

Since the startup of LVNPP in 1990, the annual collective dose has been most times substantially higher than the average for this kind of reactors; from 1990 to 1998 the average collective dose per year and Unit was of 4.3 man.Sv.

By the end of 1996, when the Unit 1 fifth Refueling Outage finished, it became evident that LVNPP should adopt an aggressive strategy to reduce its collective dose substantially and permanently, since collective dose was not just resulting high, but also threatening to continue increasing even more.

Identification of causes

Under these circumstances, the Radiation Protection Group was asked to identify the causes of such high doses; as a result, more than fifty causes were identified and the possible solutions were proposed. However, the result of an study -included in the investigation- that combined exposure measurements with field spectrometric analysis showed the remarkable role of the isotope Co-60: Around 78% of the exposure at the plant was due to it (Figure 1). This finding coincided with similar problems that several American BWRs were facing.

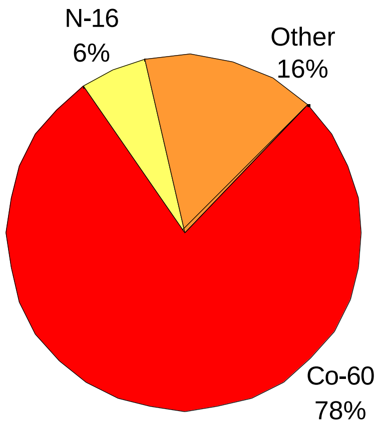

FIGURE 1. Isotopic contribution to radiation exposure in Laguna Verde NPP

Co-60 is produced by neutronic activation of the stable isotope Co-59, which in turn is in a high proportion (typically 50-60%) in the many stellite alloy components, very frequent in the primary coolant circuit.

Once knowing the enormous influence of Cobalt on the collective dose, it was decided to focus the attention on it, as the primary parameter that should be controlled towards an effective dose reduction. With this perspective in mind, the second step should be the identification and quantification of the Cobalt sources.

Using plant design documents, the stellited components in contact with the reactor primary coolant circuit were identified. The contribution of these sources (i.e. grams of Co/cycle) was determined by using in some cases EPRI methodologies, and when possible and practical, by direct measurements. Roughly, the main Cobalt contributors (so also the main contributors to the collective dose) for Laguna Verde were: low pressure turbine blades (provided with stellited edges) which contributed with about 60%; stellited valve internals contributed with 26% for Unit 1, and 29% for Unit 2. The contribution of reactor internals although significant, represented just about 9 to 13% (Figure 2).

COMPONENTS	UNIT 1		UNIT 2	
	g. Co / year	%	g. Co / year	%
1. LOW PRESSURE TURBINE BLADES	319.3	60.43	319.3	60.55
2. VALVES INTERNALS	139.62	26.43	155.59	29.51
3. JET PUMPS	23.43	4.43	23.43	4.44
4. CONTROL RODS PINS & ROLLERS	17	3.21	0	0
5. CONTROL RODS	12.72	2.41	12.72	2.41
6. CRD CHECK VALVES & RINGS	10.77	2.04	10.77	2.04
7. PIPING IMPURITIES	5.5	1.04	5.5	1.04
TOTAL	528.34		527.31	

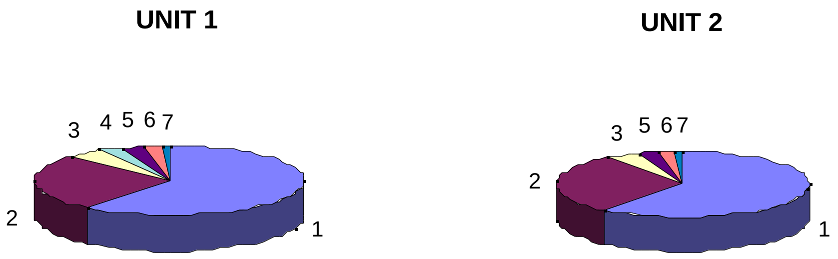

FIGURE 2. LVNPP Sources of Cobalt

<u>Dose Reduction Program</u>

The LVNPP Radiation Protection team made the initial study of alternatives for the control of Cobalt. However, soon became evident that due to the complexity and high costs of the most viable alternatives, a strong corporative support should be required, as well as the involvement of other groups of the plant. Considering these aspects, in November 1996 the General Manager gave instructions for the creation of a multidisciplinary committee: this committee (named the Dose Reduction Committee) supported by the RP team proceeded to review then the different alternatives for dose reduction, having achieved as a final result an *Integrated Dose Reduction Program* whose first phase, focused on source reduction ***(Source Reduction Program).***

<u>First Phase: Source Reduction Program</u>

Thee source reduction program includes next steps:

- Reduction of the rate of Co-59 (stable) being introduced into the Reactor Vessel.
- Reduction of the residence time of foreign cobalt in the rector vessel.
- Reduction of the release rate of Co-60 produced by in-core stellited sources.
- Reduction of iron concentration in the reactor feed water (reducing consequently the scavenging effect).
- Decontamination of systems in radiological severe conditions by accumulation of crud.

The goal of the Integrated Dose Reduction Program is, regarding collective dose, to place LVNPP in the mid term, (five to ten years) into the BWRs best quartile (best 25%).

In July 1997, the strategy proposed by the Committee in the form of a program of concrete actions was approved by the company General Director, so LVNPP proceeded to its implementation. By the end of 1998 next actions, based fundamentally on source reduction, had been achieved or started up in both units: Installation of prefilters (mechanical filters) downstream the main condenser; depleted zinc injection; and chemical decontamination of Recirculation and Reactor Water Cleanup systems as well as portions of emergency cooling systems. Table 1 shows the degree of advance on the implementation of the dose reduction program to the end of 1998.

MEASURE	UNIT	IMPL. STATUS	STARTUP DATE
ISTALL. OF MECHANICAL FILTERS DOWNSTREAM MAIN CONDENSER	U1 U2	OK OK	050597 033098
ZINC INJECTION	U1 U2	OK OK	060298 080398
CHEMICAL DECONTAMINATION	U1 U2	OK OK	052898 111598
SUBSTITUTION OF STELLITED COMPONENTS	U1 U2	COMMITED COMMITED	AS REQUIRED AS REQUIRED

TABLE 1. Implementation Status of the LVNPP Dose Reduction Program.

Mechanical Filters

The dominant contribution of low pressure turbine blades was the first target to be taken care of. In the original design, the plant was provided just with condensate demineralizers (ion exchangers) downstream the main condenser. While most of the cobalt generated by the turbine blades and coming from the main condenser was in an insoluble form, such demineralizers resulted inadequate to stop the main contribution of Cobalt. So it was decided to install mechanical filters downstream the main condenser; the system consists of a set of seven polypropylene filters per unit, with a filtration capability of 0.22 gpm/sq.ft and a crud removal efficiency >99%. Such filters act as prefilters to the ion exchangers, and other important function they have is to help to control the concentration of iron entering the reactor vessel. The control of iron is fundamental by three reasons:

- Iron itself once activated constitutes an important source of radiation.
- Iron works as a vehicle to carry and deposit cobalt on fuel and other reactor internals surfaces (scavenging effect) increasing this way the production and diffusion of Co-60.
- Iron concentration plays an important role on the stress corrosion cracking phenomena.

The still relatively short experience with this filtration system at LV has proven to be satisfactory, specially in Unit 1, where it was observed a sustained decrease of Fe concentration in the reactor feedwater: from 3ppb to around 1.5 ppb.

Zinc Injection

The most effective method to reduce the residence time of foreign Cobalt in the reactor vessel as well as the release of the Co-60 generated by the in-core stellited sources, aiming to reduce the generation of Co-60, seems to be the injection of Zinc to the reactor. So LVNPP adopted this method starting the injection of depleted Zinc in June 1998 for Unit 1, and in August of the same year for Unit 2. Although the maximum results of depleted zinc injection are expected to be obtained in four to five years, there have already been observed some good symptoms, prominently an still small but clear decrease of Co-60 concentration in the reactor water, and what seems to be the stabilization of a former continuous growing dose rate trend in the drywell of both Units.
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Chemical Decontamination

Chemical decontamination was achieved for both Units in 1998: in May for Unit 1 during its 6th refueling outage, and in November for Unit 2 during its 3rd refueling outage. In both cases, the recirculation loops as well as selected portions of the Reactor Water Cleanup System and Residual Heat Removal System were decontaminated. The decontaminated systems were initially so contaminated, that the collective dose saved was in the order of 4 to 5 man-Sv per Unit. In fact, this chemical decon was an obligated step in order to proceed to the replacement of the Recirculation System discharge valves in both Units, the most important work to be achieved during these outages.

Additional future chemical decontaminations might be achieved if required in case of contingencies or unexpected factors that could lead to a significant deviation from the expected results of the dose reduction program.

Stellited Components Replacement

The alternative of replacing stellited by no stellited parts of the main Cobalt contributors was also studied. In this case the conclusion was that such substitution should be made, but not in an ad-hoc basis. That replacement shall be done any time it be necessary to replace the component by maintenance reasons or whenever it be required by design modifications.

Noble Metal Injection

Hydrogen injection into the reactor vessels of both Units is planned be started in the short term (year 2001). This is a measure to prevent the vessel and vessel internal components from intergranular stress corrosion cracking (IGSSC) effects. However, it has proven to have significant side effects on dose fields, increasing them in a remarkable manner by inducing changes in the reactor water chemistry, that in turn leads to an increase of N-16 production in normal operations, and to a release of Co-60 from the vessel internals oxide films, increasing this way the dose rates in the drywell during outage works.

For these reasons, concurrent with the hydrogen injection startup, a noble metal injection (Rh, Pt) has been planned as a method to neutralize most of the negative effects of hydrogen injection on radiation exposure. It has been assumed that noble metal injection could neutralize up to 90% of these negative effects.

Complementary Strategies: Second Phase of the LV Dose Reduction Program.

In addition to the actions that have been described, LVNPP has considered additional mechanisms for collective dose reduction to be implemented as the ***second phase of the LV dose reduction program, based on design improvements, management and performance, and yet complementary source reduction measures*** :

- Installation of semipermanent shielding on pipes that historically increase radiation levels on the general areas of the plant (in progress).

- Installation of hydrolyzing ports on the piping of the Fuel Pool Cooling and Cleanup System.

- Installation of an stainless steel liner in the Unit 2 Main Steam Reheaters as primary strategy to reduce Fe concentration in feedwater . This measure is in turn required to obtain the expected results from Zn injection in Unit 2.

- Turning LVNPP hot spot removal program more aggressive (in progress).

- Optimization of the collective time (man-hours) of the radiation workers inside the Radiation Controlled Areas.

  Since the only two factors that ultimately determine the obtained collective dose are the **dose rate** and, on the other hand, the **exposure time**, it stands to reason the importance of optimizing the last one too. LVNPP has aimed to a reduction of the collective exposure time of 30 to 50% in the mid and long times. This requires strong corporative and management actions, which in turn imply:

    - Planning improvements.
    - Field supervision improvements.
    - Reduction of oversized field working groups.
    - Identification and avoiding of unnecessary jobs.
    - Increase of the use of remote control devices.
    - Increase of safety culture / performance of occupational radiation personnel.

Cost-benefit Considerations

Considering a plant remaining average lifetime of 25 years, an admitted cost of $5,300 USD per man-rem saved ($530 USD per man-mSv) for LVNPP, and a required average yearly collective dose saving of 2 man-Sv/year-Unit to reach the Plant goals, it was concluded through a linear approach that, an investment of about 26.5 millions of USD/Unit might be justified for dose reduction during the next 25 years.

Source Reduction Program: Trends and Expectancy

Since about 2/3 of the LVNPP collective dose is got in the works made in the drywell during the outages, the Plant expectancy on the results of the Integrated Dose Reduction Program is strongly based on the reduction of the exposure rate in that location. Using primarily the dose rate on contact of a given vertical portion of the recirculation pipes (BRAC index)as indicator, in Figures 3 and 4 the trends of such index were analyzed for Units 1 and 2; as it can be observed, the influential parameters for that variable are: application of chemical decontamination (ChD); Zinc injection; application of Hydrogen injection for stress corrosion cracking control (which is expected to increase the exposure) concurrent with the application of noble metals (NM) to mitigate the effect of the hydrogen injection; and concentration of Fe in the reactor feed water, currently partially reduced by the presence of the mechanical filters already described installed in 1997 (Unit 1) and 1998 (Unit 2).

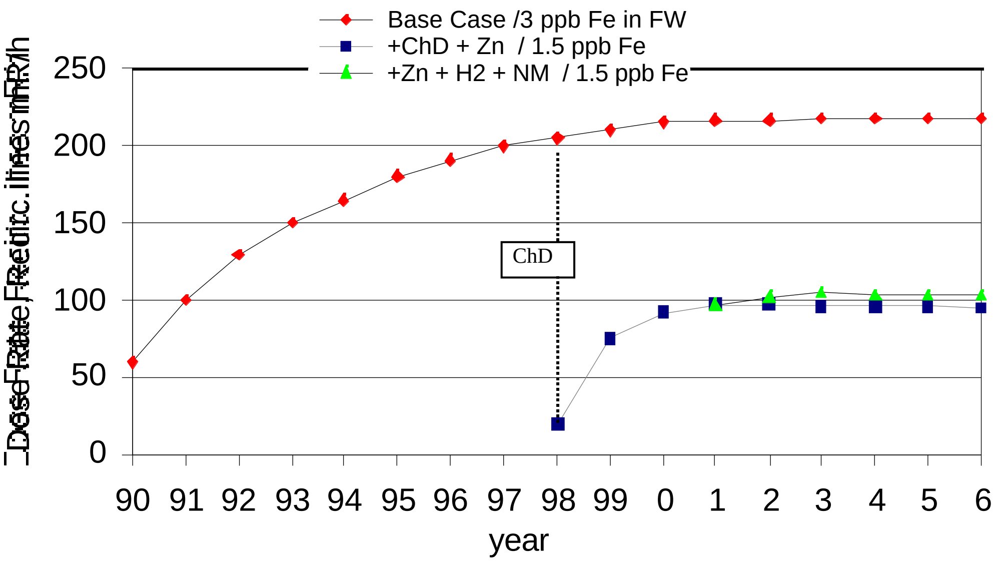

FIGURE 3. Effect of the source reduction measures on the Recirculation lines dose rate
Scenario: Unit 1, Fe concentration in feed water = 1.5 ppb
Base case: Fe concentration in feed water = 3 ppb

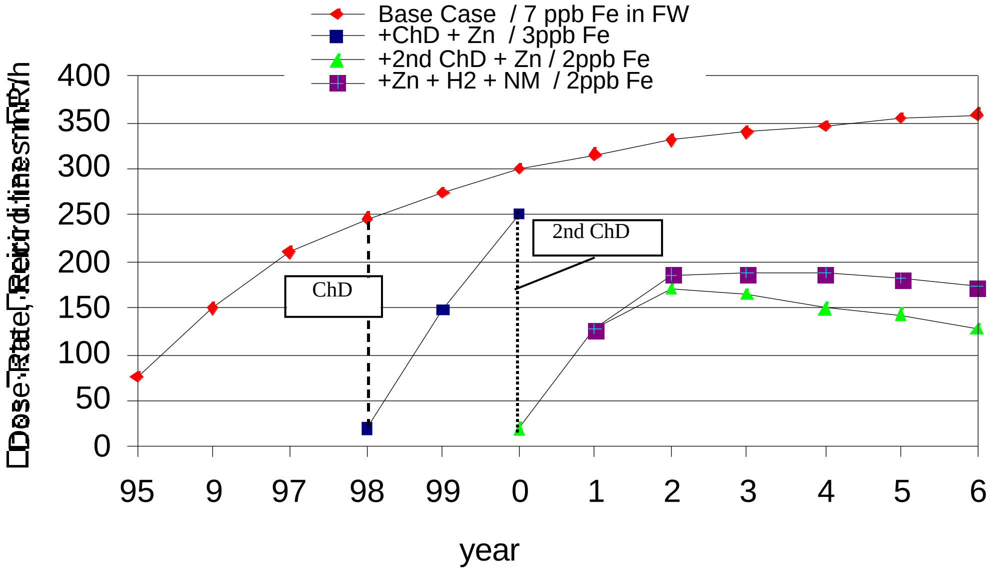

FIGURE 4. Expected effect of the source reduction measures on the Recirculation lines dose rate
Scenario: Unit 2, Fe concentration in feed water = 2 ppb
Base case: Fe concentration in feed water = 7 ppb

The "base case" scenarios for Units 1 and 2 shows how future trends for the recirculation lines dose rate would be expected to be in case no remedial measures were applied; the base case as the rest of the graphics are based in the historical BRAC indexes and in reasonably conservative expected Fe concentrations in the reactor feed water. For the Unit 2 base case, it is remarkable the dramatic reduction trend of the BRAC index.

From the analysis of figures 3 and 4 it's also remarkable the expectancy that the effect of Hydrogen injection on the exposure could be mostly neutralized by the application of noble metals.

Source Reduction Program: Updates

While in Unit 1 the BRAC index obtained in 1999 was as predicted by the end of 1998 (figure 3), in figure 4 can be observed for Unit 2 a significant deviation, after the 1998 chemical decontamination, from the prediction. This is due to the fact that for this Unit the expected concentration of Fe in the reactor feed water couldn't reach the required 2 ppb, resulting instead to be of a little more than 3ppb. For this reason, it has been programmed a new chemical decontamination for Unit 2 during its Fourth Refueling Outage by mid March 2000, as well as the lining of its Main Steam Reheaters, supposed to be the main source of the Fe in excess .

Integrated Dose Reduction Program Expectancy. Conclusion.

Figures 2and 3 were obtained from the analysis of data provided by GE. Analyzing the correlation among the BRAC index, the dose rates in the general areas inside the drywell, the collective doses obtained in works under the influence of the recirculation lines, and the expected reduction of exposure for works outside the drywell due also to the source reduction program, it can be concluded that LVNPP collective dose can be reduced to about one half the current value by year 2005.

On the other hand, the second phase of the Dose Reduction Program, starting January 2000 considers a strong ***reduction of the collective time*** radiation workers will spent in the Radiation Controlled Areas. The success of this strategy would mean also a very strong reduction on the collective dose. The target is a gradual reduction from the short to the long times of one third to one half of the man-hours spent in radiation fields. This strategy, in conjunction with the described source reduction program could lead by year 2005 to average collective doses in the order of 1/3 to 1/4 of the average current figures, with reasonably good possibilities, regarding lowest collective dose, of accomplishing Laguna Verde expectancy of reaching the first quartile among the worldwide BWRs. Figure 5 shows the Plant historical three rolling year average collective dose per year and per Unit, as well as the expected trends until year 2006 under the influence of the integrated LV Dose Reduction Program; the scenario considers a gradual reduction of 35% of the current collective exposure time starting year 2000 until 2004, and its continuity from then on.

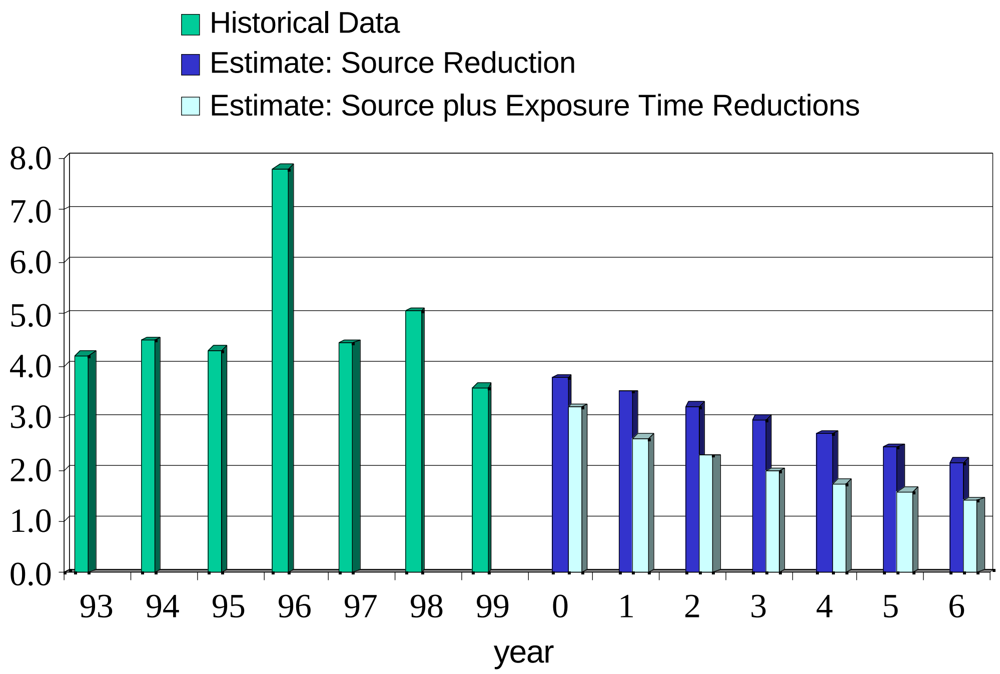

FIGURE 5. Laguna Verde Three Rolling Years Average Collective Dose per Year and per Unit (Person-Sv / Year . Unit)

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