AGEING MANAGEMENT PROGRAM TO REACTOR PRESSURE VESSEL INTERNALS COMPONENTS IN A BWR NUCLEAR POWER PLANT

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Abstract

Mexico has two identical units (GE) BWR 5 type reactor and nominal power is 682 MWe. Unit 1 and unit 2 have being operated since 1990 and 1995 respectively. The original licensed reactor thermal power was 1931 MWT and power was unrated to 2027 MWth in 1999. A new Extension Power Uprate (EPU) is planed for 2010 and finally the licensed expired in 2020 for U1, and in 2025 for U2, because it is for 30 years. In 2005 a Technical cooperation project was approved by the IAEA with the objective to prepare the Plant Life Management (PLiM) program for the integration of ageing and economic planning. In 2007 It was agreed to extend the on-going project focus in License extension of these BWR´s.

This paper describes the methodologies applied to the Internal Reactor Pressure Vessel components, which were designated like a pilot program within the scope of the Ageing Management Programs (AMP) and PLiM Program. Some discuss is made about the use of a conservative crack growth rate of 1 E-5 inch/hrs in Stainless steel, that produce very restricted time inspection periods. The state of the art of the AMP´s of the Internal is present.

INTRODUCTION.

Mexico has two identical units (GE) BWR 5 type reactor and nominal power is 682 MWe. Unit 1 and unit 2 have being operated since 1990 and 1995 respectively. The original licensed reactor thermal power was 1931 MWT and power was uprated to 2027 MWth in 1999 in both units. A new Extension Power Uprate (EPU) is planed for 2010 and finally the licensed expired in 2020 for U1, and in 2025 for U2, because it is for 30 years. The PRVI´s components were under surveillance program, based in ASME in the In-Vessel Visual Inspections program IVVI Code, but after the GL-94, In 1995 the IVVI was programmed based in The age-related degradation effects in special the susceptibility to IGSCC.

After that, the EPRI founded the BWR-Vessel Internal Project and the Utility obtained a membership and access to the BWR-VIP documents. In 1999, the ININ realized the first analyses of susceptibility to IGSCC of the Shroud of Unit 1, based in specific information and in BWR-VIP 76, and reprogrammed the IVVI program. Since this year the ININ had realized the analyses of susceptibility to IGSCC and the IVVI program for the principals RPVI´s components.

In 2005 a Technical cooperation project was approved by the IAEA with the objective to prepare the Plant Life Management (PLiM) program for the integration of ageing and economic planning. In 2007 It was agreed to extend the on-going project focus in License extension of these BWR´s.

One of the pilots programs chose in 2005 to applied the Ageing Management Program methodologies was the Shroud and in the end of 2006, the AMP program was extended to all the Reactor Pressure Vessel Internals (RPVI´s) components in U1 and U2.

The main RPVIs components were studied by groups: Shroud (including horizontal H1 to H7 and Verticals welds), core spray internal Piping, Core Spray Sparger, core plate, top guide, In core Housing-CRD housing-CRD Guide tube-Dry tubes, Jet Pumps, LPCI Coupling, Access Hole covers, Weld internals attachments including Surveillance Capsule Holder, Steam separator, Steam Dryer, Support Plate, Access Hole Covers and Instrumentation DP and SLC
The figure 1 show the main RPV´s components selected.

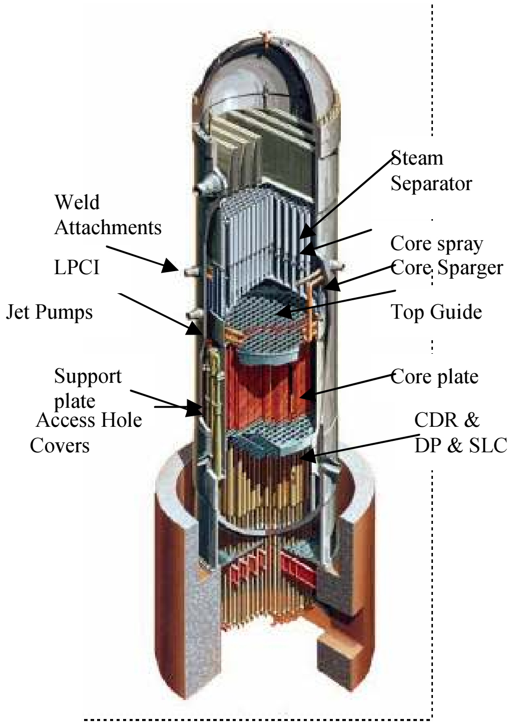

FIG.1. Main RPVI´s components in Mexican BWRs.

PROCEDURE.
The General Methodology is show in figure 2.

The first step is used the external experience of others BWR´s NPP. This information is available in the BWR-VIP, SIL´s, TECDOC´s or directed communications with other plants.

The second step is review the internal experience (For example U1 to translated to U2), Report of Inconformity RIC´s, and the results of the IVVI program. (Videos and reports).

The table 1 shows the Main RPVI´s components included in the programs for every unit.

Table 1. Main Internals components, safety function, materials and guidelines associated.

Internal Components	Safety function	Material	BWR VIP Associated document.
Shroud	Yes	304L welds 308L Support ring alloy 600	76
core spray internal Piping	Yes	304L welds 308L	18
Core Spray Sparger,	Yes	304L welds 308L	18
core plate	Yes	304 welds 308 and 308L	25
top guide	Yes	304, 3304L welds 308L	26
In core Housing-CRD housing-CRD Guide tube-Dry tubes	Yes	Several	47
Jet Pumps	Yes	304, 304L beams X-750 low ring alloy 600 alloy 182 welds	41
LPCI Coupling	Yes	304 welds 308L	42
Weld internals attachments	Some of them	A533, 82/182/600 alloys	6A, 48A, 18A
Steam Separator*+.	No	304, 316L, alloy 600	6A
Steam Dryer*+(1)	No	304, 316L, alloy 600	
Support Plate	Yes	600 alloy	38
Access Hole Covers	Yes	600 alloy	6A, 38
Penetration DP/SLC*+	Yes	Several	

*Programed in 2007
+ Only in Unit
(1) not in Unit 2

The 3rd. Step is used the Specific information, including Constructions reports, in Materials, type, chemical compositions, Intergranular attack susceptibility, Heat treatments, etc.

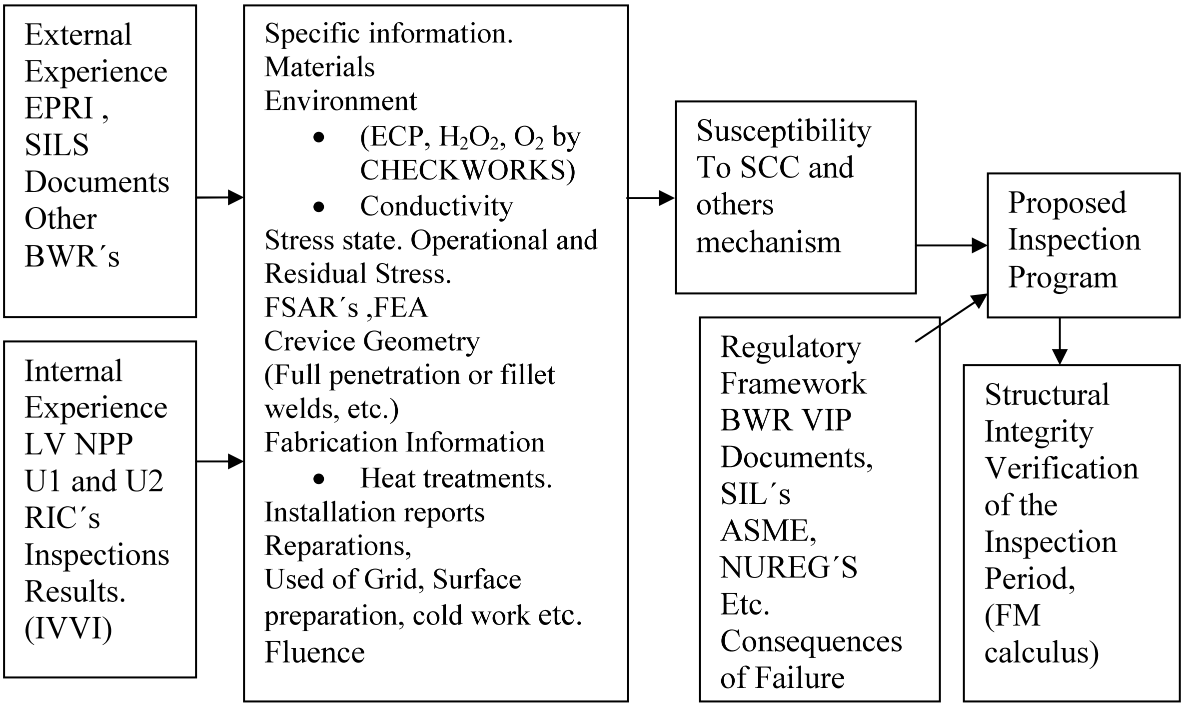

FIG.2. Methodology used to assessment of Internals components in LVNPP.

The Operational reports are very import to determinate the Environments

- (ECP, H_2O_2, O_2 by CHECWORKS)
- Conductivity of the water, Chlorides, sulfates, etc..,

Stress state. Operational and Residual Stress. (FSAR´s and sometimes it is necessary to do a Finite Element Analyses FEA)
Crevice Geometry (Full penetration or fillet welds, etc.)
Reparations,
Used of Grid, Surface preparation, cold work etc. re-machining, mistakes, surface upgrading, etc.
Fluences Maps, based in flux calculations.

Based on all data, is possible to give to the locations the relative categories of Low, Medium and High susceptibility.

We also used the Regulatory Framework, contents in BWR VIP Documents, Service Information Letters, SIL´s and normative of ASME code, NUREG´S etc.

Some important also is the consequences of Failure, because some time one locations is very susceptible to some damage mechanics, but the consequences of failure are not significative in the security because it is a redundant location.

Based in all the information, it is possible to proposed Inspection Program. In this program for example we can avoid to inspect some locations at periods on time, but it is necessary demonstrated that the component is safe in this period of time. (See figure 3)

In this case, is necessary to do a Structural Integrity Verification of the Inspection Period.

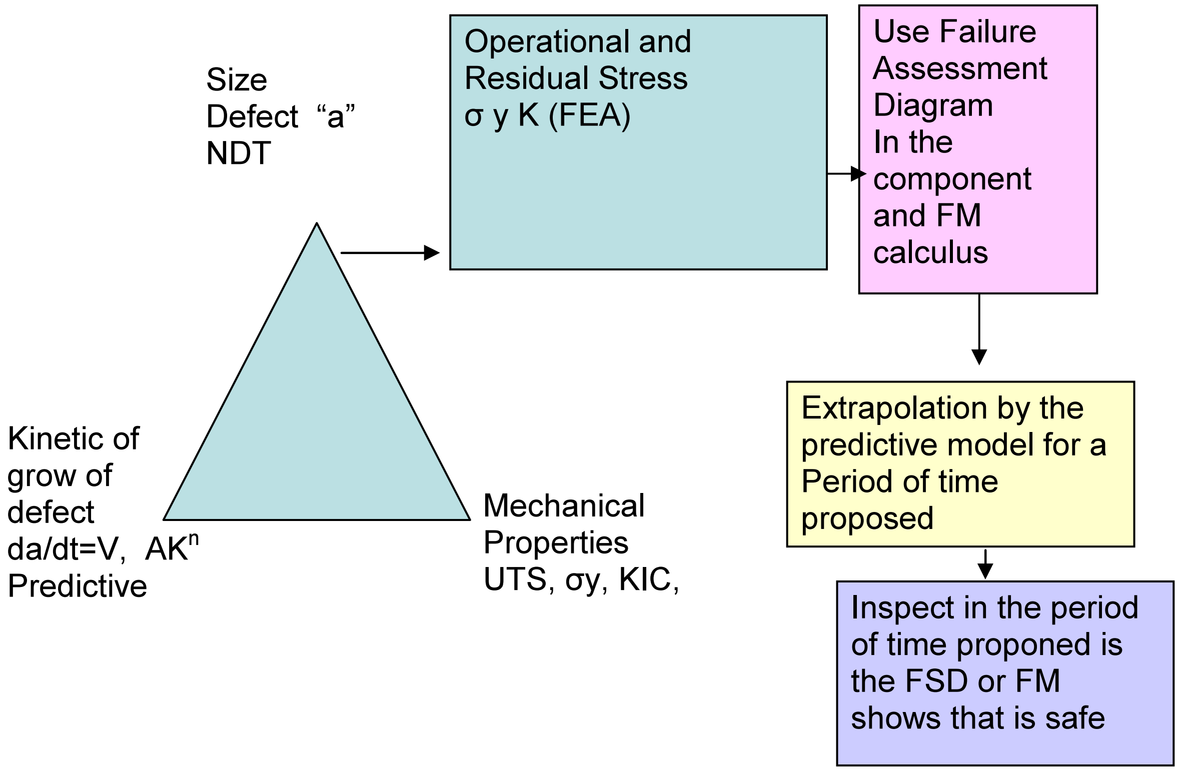

FIG.3. Methodologies for Structural Integrity used in some components.

Function.

The function of RPVIs may divided into safety and non-safety functions. The safety functions are to support the core under all loading conditions, maintain a coolable geometry, assure control rod insertion times, assure Reactivity control, direct and contain emergency cooling flows, assure availability of monitoring instruments and allow recovery to safe shutdown conditions. The added non-safety functions are to channel the incoming feedwater flow to the fuel, separate the water and steam providing dry steam to the turbine and recirculating the saturated water after mixing it with the feedwater and providing support for operational instrumentation and surveillance sample holders.

The table 1 shows the classification of the main RPVI´s based in BWR-VIP 6.

Materials

Due to the Mexican units was fabricated in the 70´s the internals materials were not subjected to very restrictive chemistry requirements as today. In some components the type 304 stainless steel was used. The fabrication was restricted to eliminate the processes that sensitized materials but no in all the cases and the records of fabrication are lost in some components. Table 1 shows the materials for the main RPVIs components.

Environment.

The water chemistry present in both units are show in tables 2. The ECP calculations were realized by CHECWORKS VIA Ver. 1, for Cycle 1 to 11 in the U1 and for the cycle 1 to 8 in the U2. In the shroud position, the value is near 300 mV. vs. SHE. The ECP values of U1 welds shroud are show in table 3. After these cycles, the NMCA-HWC were applied. The

ECP was monitoring in the 12 cycle but there where some problems with the H_2 generators. The ECP and water chemistry is shows in figure 4.

Table 2a) Chemical parameter in reactor Water U1

Cicle	Conductivity (µS/cm)	Chlorides (ppb)	Sulfates (ppb)	Oxigen* (ppb)
1	0.240	3.6	---	---
2	0.130	2.56	---	---
3	0.180	2.90	4.62	---
4	0.190	4.06	5.07	91.00
5	0.124	2.10	3.49	80.75
6	0.114	1.39	2.80	82.75
7	0.100	3.32	2.59	78.75
8	0.057	1.40	1.40	79.02
9	0.122	0.70	1.13	67.63
10	0.121	0.86	1.40	35.89
11	0.119	1.21	1.85	65.48
Average	**0.136**	**2.19**	**2.71**	**72.66**

*Feed Water

Table 2b) Chemical parameter in reactor Water U2.

Cicle	Conductivity (µS/cm)	Chlorides (ppb)	Sulfates (ppb)	Oxigen* (ppb)
1	0.119	0.72	2.83	31.62
2	0.133	0.84	2.41	28.3
3	0.119	1.16	2.41	69.96
4	0.119	1.0	1.58	46.64
5	0.110	0.72	2.0	28.30
6	0.111	0.81	1.0	42.30
7	0.096	0.539	0.98	42.60
Average	**0.117**	**0.827**	**1.88**	**41.38**

*Feed Water

Table 3 Example of ECP values calculated by CHECKWORKS.

Cycle	Weld/Region H3 Inside Channel mV. vs. SHE	H3 Outside Down comer mV. vs. SHE	H4 Inside Channel mV. vs. SHE	H4 Outside Down comer mV. vs. SHE	H5 Inside Channel mV. vs. SHE	H5 Outside Down comer mV. vs. SHE
1	277.07	224.24	262.11	289.99	265.75	230.37
2	302.31	276.31	286.49	276.71	264.41	251.33
3	303.07	275.27	288.67	278.25	265.39	251.58
4	300.16	276.39	288.61	278.38	264.01	258.36
5	299.33	220.83	291.53	242.02	265.75	230.37
6	301.07	275.79	290.03	270.46	262.30	241.66
7	306.83	284.95	288.20	282.24	266.84	259.81
8	300.27	279.81	290.28	274.79	259.90	244.12
9	294.22	268.81	291.67	259.52	258.46	227.53
10	241.39	202.88	247.58	259.32	252.84	283.01
11	256.21	274.18	288.03	271.07	260.96	243.85
Average	**289.26**	**259.88**	**283.01**	**271.15**	**262.41**	**247.45**

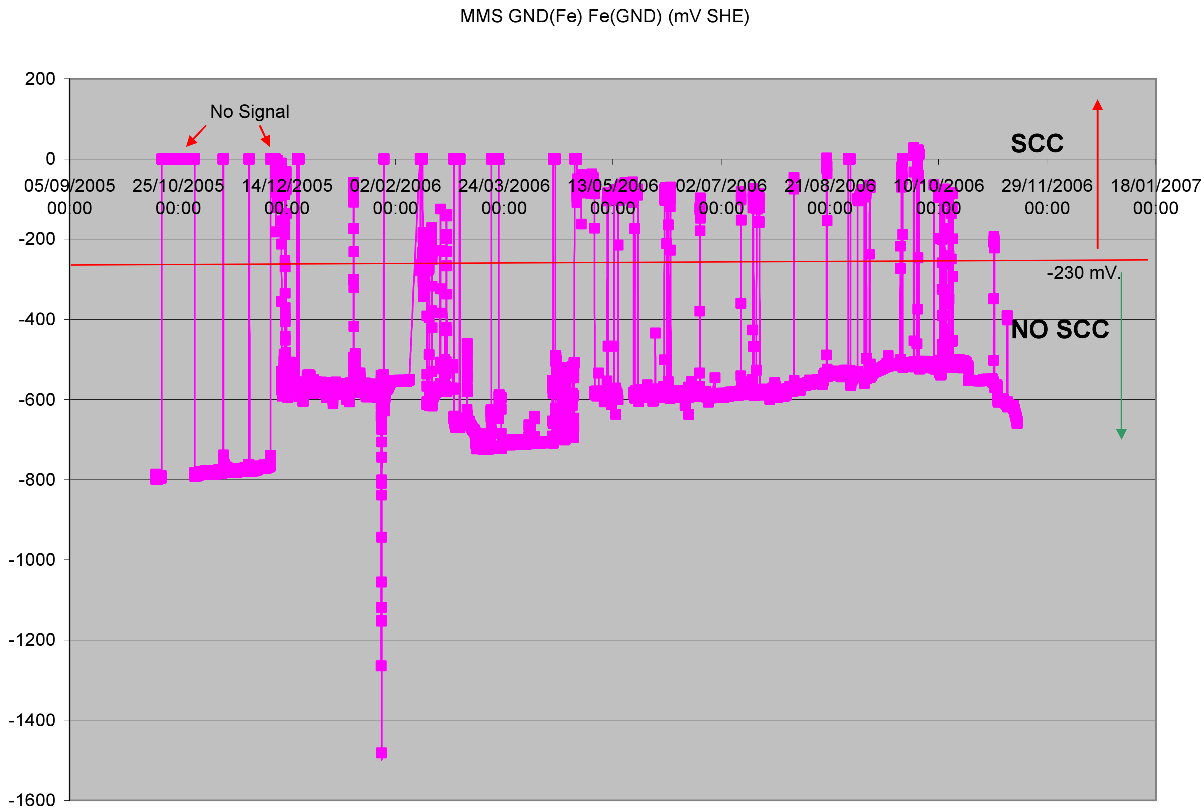

Figure 4. Performance of the ECP at the RWCU in U1. 12th° Cycle.

The results of these work, is the IVVI program that included all the internal components and how to inspected it. The table 4 present a example of the inspection program and the AMP Summary of the U1 Shroud is present below.

Summary of the AMP of U1 Shroud:

Service conditions. UP TO EOC 11 (SEPT/2005)

- Average Conductivity: 0.136 µS/cm
- Maximum Fluence at H4/H5: 4.16E+20 neutrons/cm² (calculated)
- Maximum Average ECP: approximate 300 mV vs. EEH (calculated)
- Normal water chemistry (no HWC neither NMCA)

DURING CYCLE 12 (OCT/2005-MARCH/2006)

- Average Conductivity: 0.1254 µS/cm
- HWC + NMCA

Internal Experience Operation:

- **7th RFO (August/1999) EVT-1 Inspection**
  - H3, 7% Flawed, 100% coverage
- **8th RFO (June/2001) Baseline UT Inspection**
  - **H3, 18.7 % Flawed, 65.9 % coverage**
  - H4, 4.8 % Flawed, 50.8 % coverage
  - H5, 0.9 % Flawed, 52.1 % coverage
  - H1 and H7 minor indications.
  - H2, H6A, H6B no indications
- **11th RFO (Sept/2005) UT Reinspection**
  - H3, 22.1 % Flawed, 65.2 % coverage
  - H4, 5.9 % Flawed, 50.4 % coverage
  - H5, 1.1 % Flawed, 50.7 % coverage
  - Crack growth under BWRVIP-76 (<5E-05 in/hr).

Ageing Mechanisms:

- Mainly IGSCC, TGSCC possible, in flawed welds
- Potential IASCC in H4/H5 during cycle 13 (April/2007)
  - Calculated accumulated fluence: 5.02 E+20 n/cm2
  - Utility will refined calculations during 2006, possible grater fluence.

Structural Integrity:

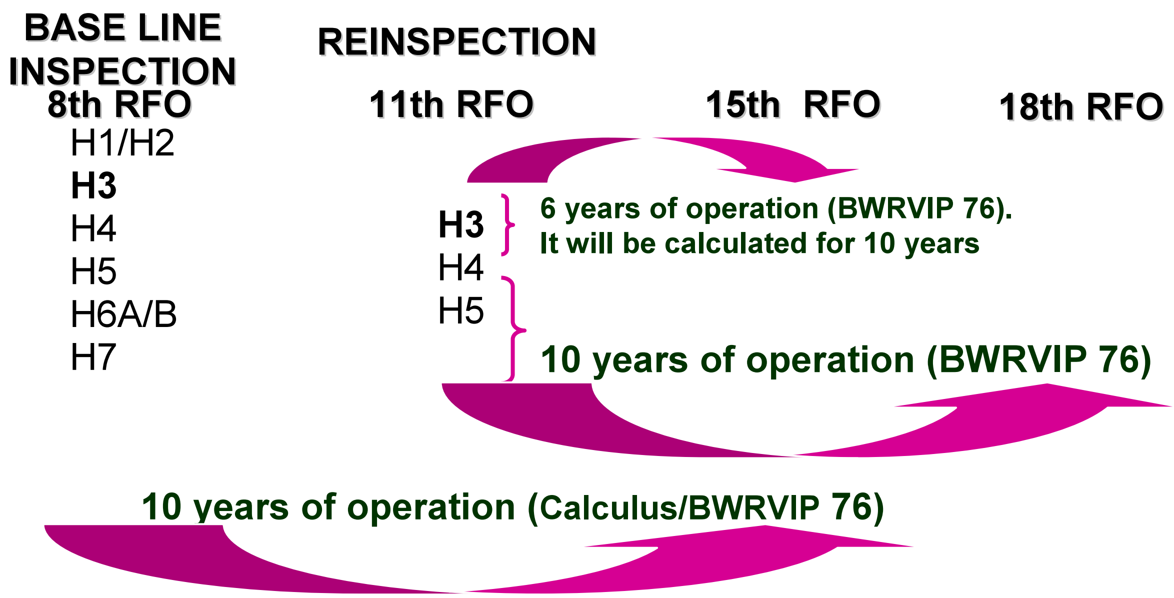

Figure 5 Structural Integrity strategies

Brief discussion

Actually the ININ is working in the AMP programs and in other lines like the use of models and inspections data to obtain more realistic crack growth rate values to obtain bigger inspections periods like the Slip-Dissolution model and BWR-VIP 14 EPRI´s model.

For example for H3 weld of shroud in U1, based in inspections data, has a longitudinal growth rate in 3 cycles of 3.997E-5 in/hr and a depth growth rate of 3.66E-6 inc/hr, and the Fracture Mechanical calculus was do with a value of 5E-5 in/hr in the longitudinal direction and the crack was consider through wall. That is a conservative assumption, and may be with the correct crack growth rate, it is possible to obtain a better period of time to inspect this weld.

Other Activities

Also, the ININ is correlated the influence of fluence peaks on cracking, and the case of the new water chemistry (NMCA) the characterization of oxides deposits with Nobel Metal Chemical Additions +Hydrogen Water Chemistry in laboratories.

Table 4. Inspection Program for the U1 Shroud

WELD	INSPECTION METHOD	RFO	REMARKS
H3, H4 & H5	UT	8 th 11th 18 th	Baseline inspection (Jun/2001). 1fst Reinspection (Sep/2005). 2nd Reinspection, Feb/2016. H3 will be reevaluated for 10 years.
H1, H2, H6A, H6B & H7	UT	8 th 15 th	Baseline inspection (Jun/2001). 1fst Reinspection (Sept/2011).
V1 through V10	EVT-1 or UT	7th, 9th	V3 through V8 inspected by EVT-1 no indications. Reinspection depends of results of horizontal welds (BWRVIP 76). V3 through V5 will be reevaluated after fluence refined calculations.

CONCLUSIONS

The methodologies applied to the Internal Reactor Pressure Vessel components, which were designated like a pilot program within the scope of the Ageing Management Programs (AMP) and PLiM Program was discuses.
The state of the art of the AMP´s of the Internal was presented.

The used of BWR-VIP Guidelines and ININ´s experience in IGSCC and other ageing mechanism obtained in IAEA research projects was very important to do the AMP for the RPVI´s in the Mexican BWR units.

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1. IAEA Technical Reports Series No. 338 *Methology for the Management of Ageing of Nuclear Power Plant Components Important to safety*, IAEA, 1992.

2. IAEA-TECDOC-1741, "*Assessment and management of ageing of major nuclear power plant components important to safety: BWR Pressure Vessel internals"*, IAEA, October 2005.