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LIFETIME MANAGEMENT OF EDF PWR PRESSURE VESSELS AND PIPINGS

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ABSTRACT

Lifetime management of EDF PWR vessels and pipings are one of the main technical key points of safety and competitivness.

This paper describes the EDF global approach in this field , which is applied to the nuclear fleet i.e 58 nuclear power plants , and particularly to the first 34 three loops, as far as lifetime is concerned :

- operating procedures and routine maintenance, special maintenance and ten years safety reassessment ,
- engineering analysis ,based on feed back experience , scientific knowledge, degradations mechanisms , causes and consequences management,
- operating loadings decrease,
- complementary deterministic and cost- benefit analysis ,
- fit for service justifications .
- anticipation strategy to prepare future , based on Non Destructive Testing investigations, ability to repair and/or to replace components , in situ expertises, ...

Some examples are given : lifetime management of reactor vessels heads and bottom penetrations of pressure vessels, fit for service of cast stainless steel primary pipings , primary nozzles and auxiliary pipings special maintenance.

INTRODUCTION

ELECTRICITE DE FRANCE (EDF) nuclear fleet is composed of 58 PWR plants located on 19 spots, for a 63000 MWe power. It supplies nearly 80% of total electricity generation, so 420 TWh for 2003.

That fleet has been put on the grid during a short period, from 1980: 50000 MWe during 10 years:

- 34 900 MWe plants (3 loops), with an average age of 22 years will reach 30 years of operation, from 2008 / 2009,
- 20 1300 MWe plants (4 loops), with an average age of 16 years, will reach 20 years from 2005,
- 4 1450 MWe plants (4 loops), with an average age of 8 years, will reach 10 years from 2009

Lifetime management of this fleet is essential with regards to prospects linked to electricity generation means renewal , within future energy mix.
In some respects, pressure vessels (PV) stakes are important in terms of safety and competitivness; they are technical key points to manage, with other equipments such as containment building, I&C, internal reactors equipments,...

EDF set themselves a target of 40 years at least, for all nuclear plants and consider it is reasonable to foresee a longer lifetime for the major part of the fleet.

The third decennial visit for 3 loops plants is an important issue . French Nuclear Safety Authority would give their position during 2005.

After safety reassessment process and main regulatory requirements dedicated to PV, main points concerning lifetime management of PV and pipings are presented: principles, methodology, engineering and R&D , levers used; some examples illustrate the approach.

SAFETY REEXAMINATION PROCESS – PV REGULATORY REQUIREMENTS

French Regulatory requirement is to realise a decennial safety reexamination which takes into account:

- a safety reassessment, which can lead to hard of soft modifications of the process, equipments,...
- a checking of the installations compliance to safety reference rules.

Concerning particularly main PV and pipings of primary and secondary circuits , the 10th november 1999 decree precises requirements for utility demonstration. Following points have to be emphazided, directly linked to PV and pipings integrity:

- PV are bound to a periodic requalification; particularly a whole requalification of primary circuit has to be done every 10 years: it includes: a whole visit, with thermal insulation removing, except some areas with dosimetric limiting factors, and a a hydrotest (fuel unloaded) at 1.2 design pressure, the success of which depends on respect of acceptable total leaks (for whole parts of PV) or local one (steam generators).
  A five years partial requalification is needed after each whole requalification realised on PV in operation for more than 30 years: it is limited to an in-depth visit.
- the utility has to establish reference files, including construction (design, manufacturing), completed by operating conditions and procedures, PV surveillance conditions (relief valve,...), periodical inspections and whole requalification definition (goal, Non Destructive Examination(NDE) kind and periodicity , in relation to PV and piping integrity. These files have to be updated before each whole requalification, at least.
- a particular evolution follow up during operation of materials properties likely to have consequences on PV integrity has to be implemented, technical justifications linked to the PV fit to service for the ten next years have to be explicitly provided: this deals particularly with irradiation embrittlement of reactor vessel, thermal ageing of cast stainless steels pipes or elbows, valves steels (shaft, bolts) ageing , nickel based alloys corrosion,...
- necessary means have to be implemented in order to determine kind, origin and potential evolution of defects which are put in evidence on PV; cracks have to be eliminated, except any particular justification, and maintenance actions have to be investigated. In this case, engineering analyses have to take explicit margins on loading into account, towards fast fracture analysis (crack initiation and instability)

Loading categories	Crack initiation	instability
2nd	1.33	2
3nd	1.1	1.6
4nd	----	1.2

PV AND PIPING AGEING MANAGEMENT MAIN PRINCIPLES

The approach consists in identifying degradation modes, associated mechanisms, consequences, in relation with PV and piping integrity, in order to avoid a leak during operation, with the particular case of SG. It relies not only on degradations taken into account at the design stage, but also on feed back experience, scientific knowledge evolution ,unprospected degradation (mixing thermal fatigue for instance), or coupled with defects, undetected during manufacturing or appeared during operation.

Mechanical properties of materials
- irradiation embrittlement
- thermal ageing cast stainless steels,welds
- valves steels

Corrosion (diverse kinds)
- nickel base alloys (base metal, welds)
- work hardened stainless steel, stagnant conditions
- corrosion-erosion low carbon steel

Mechanical or thermal fatigue
- mixing areas of austenitic stainless steels primary and auxiliary pipes, nozzles
- thermal stratification
- internal parts of components (pumps, ...)

The defined maintenance strategy is based on:
- degradation mechanism (kinetics, amplitude, threshold effects,coupling effects,...), determining factors assessment,
- sensitive and critical areas determination,
- engineering analysis which allow to access potential harmfulness: defect propagation, stability,...

It results in:
- an inservice inspection program (preventive maintenance) with a systematic part and a conditionnal one :
  - ¤ sensible and critical areas,
  - ¤ forewarning areas of potential degradation,
  - ¤ PV areas or witnesses equipments where sampling inspections are done in order to check the non degradation hypotheses: this represents a complementary investigation program realised during decennial visits or routine maintenance,
- an implementation of special maintenance: this strategy deals with PV and piping (Reactor Vessel Heads, steam generator, piping, CRDM, ...) and more generally with heavy components or main system such as turbogenerator, condenser, containment building, I&C systems,...;such operations are considered as heavy ones.

They are realized because of real or potential degradations with safety / competitivness consequences (see fig. 1):
- ¤ concern a significant part of the nuclear fleet,
- ¤ are dealing with important industrial stakes

Main levers are the developpment of NDE capacity, repairs, "wisely" replacement in relation with technical end of life, safety or performances enhancement requirements: the analysis focuses on couples components/degradations with high stakes: preventive measures are taken within a large range from faisability study for equipment replacement, anticipated spare parts stock, to an operational and qualifed operational field work: feed back experience shows the joined benefit for safety and competitivness to try to anticipate some more or less caracterized threats.

OPERATIONNAL IMPLEMENTATION OF PV LIFETIME MANAGEMENT

Some following examples illustrate the approach:

- **REACTOR VESSEL**: surveillance program implemented with specific materials (base metal and weld) for each vessel; whole checking of the process: material,neutron caracterisation of vessels and surveillance capsules on feed back experience of CHOOZ A plant (first PWR reactor in France, dismantled): in site sampling, then RTNDT measures, experimental and theorical determination of steel neutron embrittlement parameter (see ref. 1).

  Inservice inspection with qualified high performances concerning undercladding area (detection and caracterisation of any defect higher than 5 millimeters- 0.24 "). Lifetime management is prepared by introducing reserve surveillance capsules in reactor with archive materials of each vessel to obtain embrittlement values for 60 years or more ;some complementary irradiations are used in research reactors (higher flux factor).

- **REACTOR VESSEL HEADS (RVH) AND NICKEL BASE ALLOY AREAS**:

  Following the feed back experience of a leak detected on the top of the reactor vessel head of BUGEY 3 in September 1991 during the first decennial hydrotest, a strategy based on inservice inspection and wisely replacement with alloy 690, has been implemented; no other leak either during hydrotest or in operation occurred. At the end of 2003, 43 RVH have been replaced and 12 will be by 2009. Such a decision has been induced, first because of the fatal feature of the degradation (SCC) for numerous alloy 600 RVH nozzles, and secondly because of lifetime behaviour uncertainty of the welds: cost / benefit analysis showed quickly the way to replace rather than to repair.Since 1992, an important scientific program and a maintenance strategy are in place to try to detect sooner enough a risk on other base nickel areas: bottom of vessel, some repaired pressure vessel nozzles, and inside SG channel head.

  Dedicated in service inspection have been realized on 15 bottom vessels, 7 PV nozzles, without indications; primary CSC defects has been put in evidence in 2 SG, on 48 inspected.

- **STEAM GENERATORS (SG):** safe operation is based on a stringent policy of operation (chemistry, surveillance by N16 chains, special technical specification "low leakage rule (less than 20 or 10 l/h")) and maintenance (NDE, plugging). SG were replaced on 11 three loops units since 1990, and the replacement for one unit a year (3 SG) is planned for the mid term.

-CAST STAINLESS STEEL PIPES AND ELBOWS PRIMARY LOOPS

A scientific and maintenance program, valid for a number of years, has been realized to demonstrate fit for service towards 40 years at least, for cast stainless steel for pipes and elbows:

¤ metallurgical and mechanical caracterisation,
¤ ageing mechanism knowledge,
¤ original casting defects caracterisation inside the products and for mechanical engineering studies,
¤ engineering calculations and test experiments on real elbows with defects,
¤ ageing surveillance program in laboratories,
¤ in situ samplings on elbows in order to determine specific base metal toughness values, on small CT specimen, made from material removed,
¤ in situ ageing measurement by dedicated device (BARKHAUSEN effect),
¤a global engineering work which answers to regulatory requirements

NOZZLES OR PIPES CONCERNED BY THERMAL FATIGUE

Feed back experience from a leak on a RHRS pipe on CIVAUX plant in 1998 led to a whole engineering and maintenance strategy to manage thermal fatigue risk on NPP's:

- in service inspections (ISI) and RHRS pipes replacement on each reactor ; the first ISI realized after 400 hours operation on CHOOZ and CIVAUX plants shows no indication of defect. Mainly ,this is due to a design modification of the circuit,
- reduction of (Δ temperature, time) couples for concerned circuits,
- RHRS operating procedures modification, after plant testing,
- transverse analysis to determine risk mixing areas on primary and nuclear auxiliary circuits:
  ¤ engineering screening criteria for sensibility to the degradation risk,
  ¤ loadings decreasing ,
  ¤ outside in service inspection development on primary nozzles for detection and caracterisation of potential defects, taking into account biaxial orientation of the surface cracks; industrial repair and replacement have been developed in the same time, in order to begin a first status of the concerned areas on plants , from July 2004.
  ¤ a CVCS nozzle has been removed for expertise in 2003 taking the opportunity of SG replacement at Fessenheim 1 plant after 20 years of operation; expertise results (dye penetrant test, UT) show no indication.

CONCLUSION

Safety and competitiveness associated with lifetime management of PV and pipings lead to develop a systematic and anticipative approach, particularly in a nuclear standardized fleet context: the ambition is not to foresee future but to prepare it with regards to some residual uncertainties : engineering and R&D studies, loading effects decreasing by operating procedures modification, wisely development of in service inspection, repair or replacement strategy, are decided , based on stakes analysis results .

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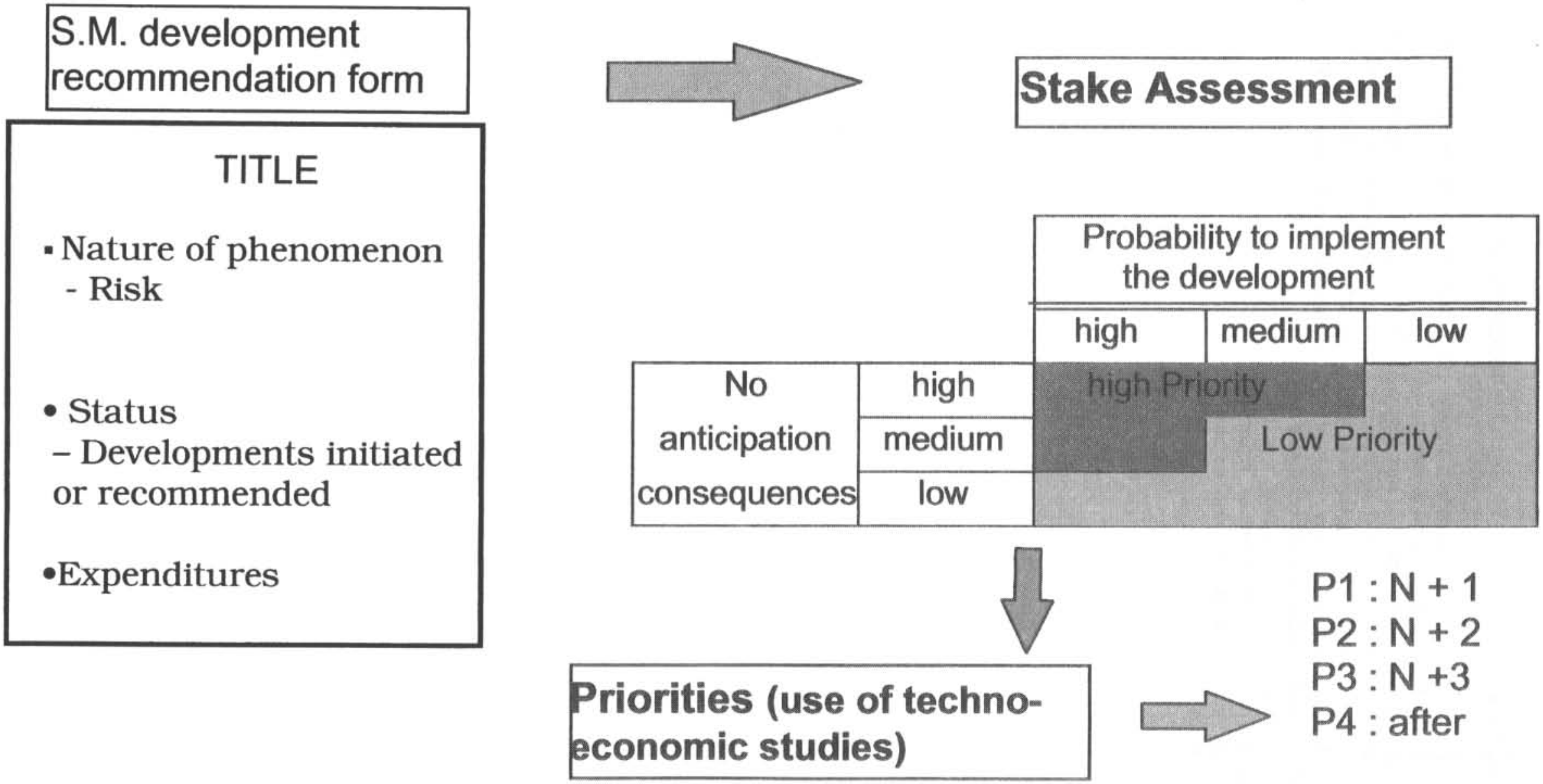

Fig 1 : Methodology for special maintenance development