

MAINTENANCE OF INCONEL AREAS IN FRANCE

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Maintenance of Inconel areas

1st incident in France : BUGEY unit 3 - 09/23/1991

Important decision end of 1991 : replacement of all vessel heads

10 years of studies since 1991

Safety authority decision on march 2001 : program of follow up proposed by EDF is accepted.

Consequences of Bugey unit 3 VH leak in 1991

Few years to understand the phenomenon on the vessel heads (case of alloy 600)

EDF decides to replace all VH in France (repair is too high cost) at the end of 1991.

Important development of NDE techniques to inspect CRDMs

In parallel, a very important program is launched in order to better assess the effects of various parameters on the Inconel 600 degradations due to PW SCC

This program is also developed to study the alloy 182.

Material studies : alloy 600 and 182

✓ A lot of experiments has been made to show that the crack growth rate can be modelled (model of propagation)

✓ Formulas obtained for alloys 600 and 182 are :

$$\text{CGR}_{600} = a_1 \cdot (K-9)^{0.1} \cdot \exp [b_1 \cdot 1/T] \cdot \exp (c_1 \text{Re}) \cdot (d_1 \cdot \text{CW}) \text{ in } \mu\text{m/h}$$

$$\text{CGR}_{182} = a_2 \cdot (K-9)^{0.1} \cdot \exp [b_2 \cdot 1/T] \cdot (1 + \text{CW}/10) \cdot (c_2 \cdot d_2 \cdot e_2) \text{ in } \mu\text{m/h}$$

✓ Many parameters have been studied for both alloys:

- *Effect of temperature, corld work, stress reliaved effect, orientation of dendrites, etc...*

Material studies : alloy 600 and 182

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- ✓ In conclusion, CGR obtained take into account :
 - *activation energy*
 - *10% cold work increases the CGR by a factor 2*
 - *the stress relieved heat treatment reduces the CGR by a factor 2*
 - *the crack propagation perpendicularly to the dendrites is twice lower than that parallel to them,*
 - *the cyclic loading enhances the kinetics by a factor 2*
 - *carbon and silicon contents may increase the CGR*
- ✓ The models are conservative and the accuracy is within a factor 2-3.
No data available for alloy 82 (20% chromium) which is better than alloy 182.

NDE for CRDMs

NDE have been developed between 1992 and 1994.

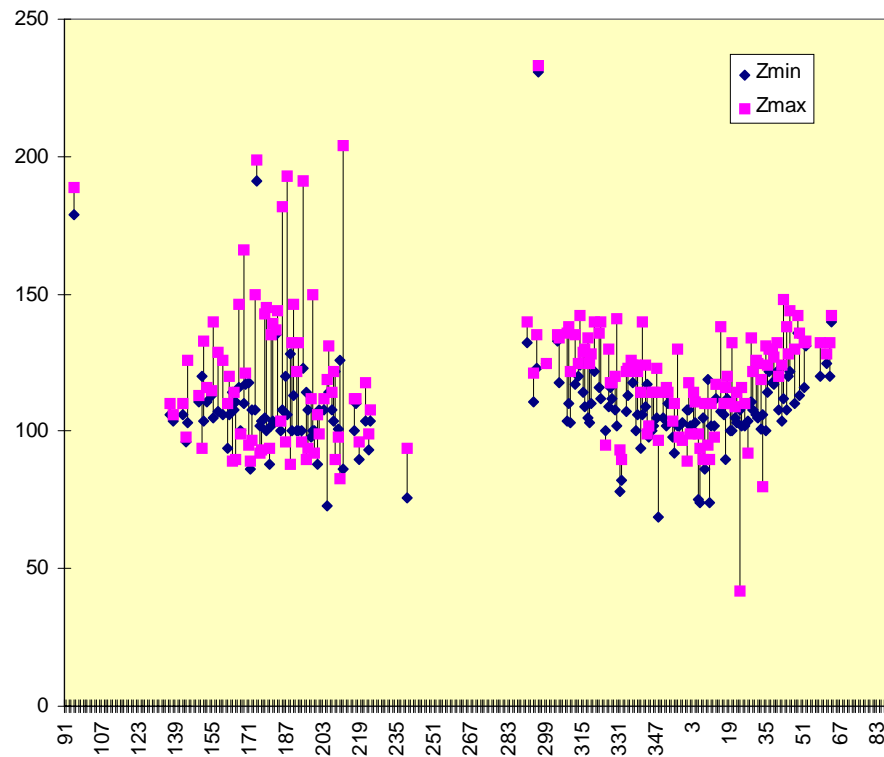
Many mock-ups were built to test various solutions.

In 1995, NDE inspection procedures have been stabilized :

- ✓ Detection of longitudinal cracks PWSCC by ET with a "sword probe",
- ✓ Characterization of the cracks by TOFD techniques using a special sword probe.
- ✓ PT and VT solutions were also developed at the beginning in order to better conclude on the attendance of cracks versus manufacturing defects.

It is confirmed that up to now, only longitudinal cracks were found and they are located preferably in the azimuths 0° and 180°

NDE for CRDMs



SMiRT 16 - Washington - 08 / 12-17 / 2001 - Workshop WO

NDE for CRDMs

Location :

- ✓ Only peripheral CRDMs have cracks

Other areas :

- ✓ Vent hole (alloy 600) : no defect were found on all inspected vent holes
- ✓ Welds (alloy 182) : no defect were found using PT.

At the end of 2000, about 40 VH have been replaced. CRDMs are made with alloy 690 and welds with alloy 152.

Other areas with alloy 182

In France, the other areas where alloy 182 has been used are :

- ✓ welds of the partition plate in the SGs,
- ✓ welds of bottom head instrument penetrations,
- ✓ repairs in the RPV nozzles,
- ✓ welds of RPV clevis

NDE are performed on these areas using, PT, UT, ET and UT and VT.

No defect has been found up to now in these areas but a program of inspection has been established up to 2008 and after.

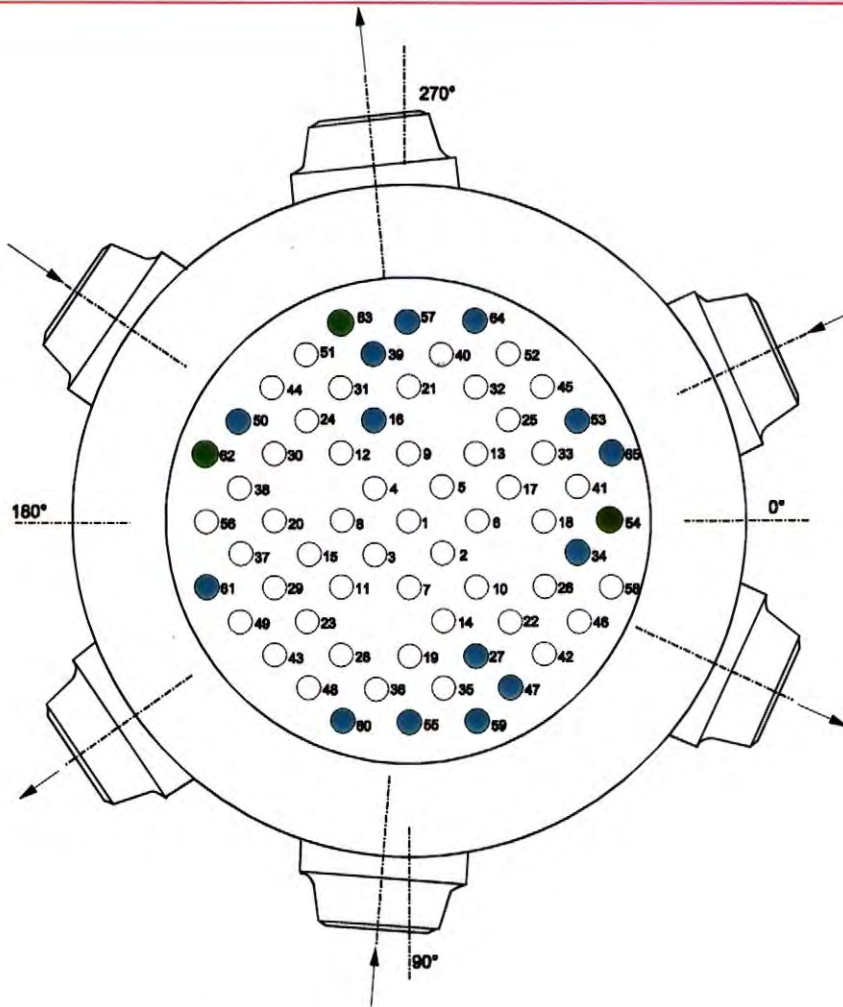
Consequences of VC Summer incident

In France, 3 RPVs have inconel dissimilar welds but welds are in alloy 82 stress relieved.

NDE : radiography and UT measurements are performed each ten years visit; performances have been assessed on a scale one mock-up.

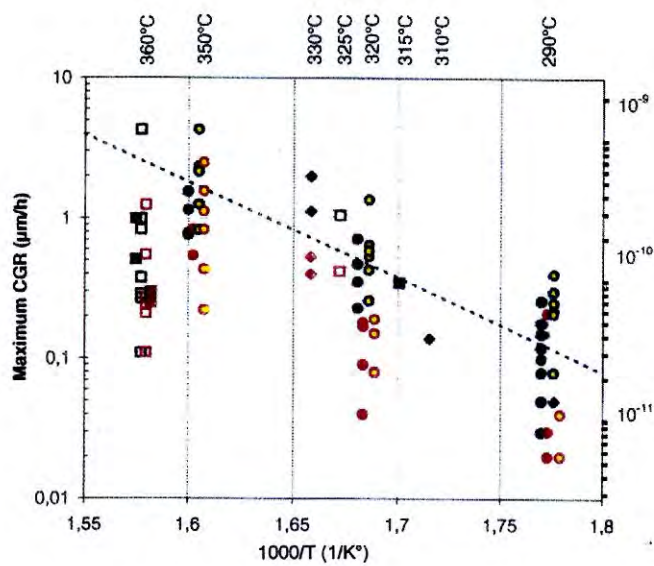
No significant consequences but attention exists.

Maintenance of Inconel areas

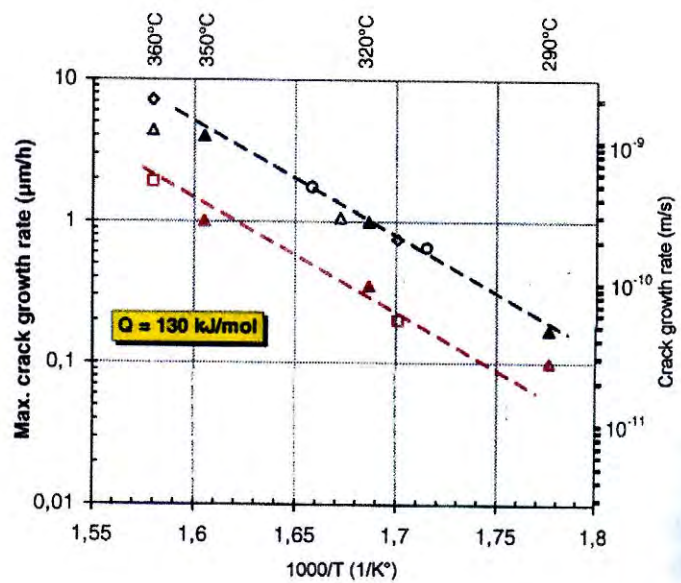


47, 49, 51 et 53 : Thermocouples

- Cracked 1 time
- Cracked 2 times
- Cracked 3 times



(a) – Alloy 182



(b) – Alloy 600

Comparison of crack growth rates measured in Alloys 182 and 600