COMMISSARIAT A L'ENERGIE ATOMIQUE

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CEA-CONF--8651

CEA-DAS--248 R2

SMALL LIQUID SODIUM LEAKS

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Conference on science and technology of fast reactor safety
Guernesey (UK)
12-16 May 1986

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SMALL LIQUID SODIUM LEAKS

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APPRAISAL OF LEAKAGES

In order to investigate the leak behaviour of sodium loops one needs at first to analyse the initial conditions leading to a leak. For that purpose, a systematic investigation is under way in CEA to analyse the reason why a leakage has appeared. An example of this type of appraisal concerns a valve distributing the sodium between superheater and resuperheater of PHENIX reactor. A first leakage appears after 2500 hours of operation, it was located in the HAZ of the weld. 2900 hours after repair a second leakage appears at the same location. 2300 hours later a third leakage leads operator to decide a complete substitution of the butterfly valve by a diaphragm. Expertise of this phenomenon has been conducted in the following directions : examination of the rupture face-calculation of piping, calculation of the actual stresses in the weld taking into account its real geometry, measurement of the residual stresses. Up to now it is undoubted that the rupture is due to creep, the stresses induced in the cracked zone is not so high, and the residual stress approach the yield stress but in a direction perpendicular to the crack. Up to now it has not been possible to find an explanation strictly valid.

EVALUATION OF SMALL LEAKAGES

Usually, pessimistic considerations inassessing the safety of secondary sodium loops in LMFBR reactor lead to assume guillotine rupture releasing a large amount of sodium estimate the consequences of large sodium fires. In order to reduce these consequences, one has to detect the smallest leak as soon as possible and to evaluate the future of an initial small leak.

An experimental programm has been lounched to pursue the following objectives :

ANALYSIS OF THE RELATIONSHIP BETWEEN CRACK SIZE AND SODIUM OUTFLOW RATE

This involves classical formulas governing the flow of liquids with measurement of flow through a steel plate with a fatigue crack and tensile stressed under different loads. The parameter which can affect the flow and hence to be analysed are : crack length, tensile stress, upstream pressure of the sodium, temperature of the sodium, crack surface condition.

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Three open cracks : 6.11; 22.38 and 41.23 mm long respectively, were made on three specimens as shown on figure 1. These cracks were characterized by measurement of the opening under tensile stress applied to the specimens. The preliminary theoretical calculations allowed locating the sodium outflow rate range through the specimens with respect to the values of the parameters which can affect the flow. Uncertainties in the mechanical behaviour of the cracked plate can cause significant differences between the measured and calculated flow rates, especially for the 41.23 mm long crack, a previous experiment using water enabled rapid quantification of these differences. The results of the first test are shown on figure 2. When this series of measurements will have been made, the same tests will be run with sodium at 550 °C. Afterwards, the specimens will be submitted to the same cleaning, neutralization and pickling treatment as applied to a component taken from the reactor and the sodium tests will be rerun so as to simulate the life of a component whose cracking is unknown to the operator, and which is extracted from the reactor for maintenance and is reinserted in the reactor without the cracks being detected. The test apparatus will then allow observation of the transformation of the crack and its enlargement due to interaction and eventually corrosion the sodium and the cleaning product residue in the crack.

ANALYSIS OF A SODIUM PIPE WITH A SMALL OPEN CRACK

A small diameter tube (dia. 6 mm) has a crack made by drilling and then hammering. Various sensors are installed to monitor the migration of sodium in the heat insulation at different test intervals ; the tube is heat insulated according to applicable requirements. The tube is filled with sodium and the leak is monitored for the entire duration of the test. Any corrosion on the pipe is examined by X-ray without removing the heat insulation.

A test was run with a calibrated leak rate of 2 cm^3/h. The flow rate was held constant for 1950 hours, it then increased by a factor of 100 in 36 hours. The gamma examination shows a significant loss of steel thickness on the wall of the pipe. After dismounting and cleaning of the pipe, it was observed that the pipe was not damaged near the hole, but that considerable corrosion occurred at around 4 to 6 centimeters from the hole. It formed a deep continuous groove which completely pierced through the pipe in some locations. Figure 3 shows the pipe after test. Informations can be deduced from this figure on the corrosion process which occurred : when the sodium leak is high, there is a flow of sodium in the interface between pipe and insulation and the sodium goes rapidly out of the casing. When the sodium leak is small, the sodium leaving the leak channel comes in contact with air and the heat insulation, it reacts rapidly with the oxygen contained in the insulation and spreads by capillary action in the heat insulation and along the interface between the heat insulation and the pipe. The volume occupied increases steadily until it comes to the following stable condition (characterized by a roughly hemispheric border) : inside the boundary, the sodium impregnates the oxygen free heat insulation ; outside this border, the heat insulation contains air ; an interaction occurs at the interface of the sodium, heat insulation, air, humidity, plus the presence of steel at the limit of the interface between the pipe and the heat insulation. The shape and size of the boundary are the result of a state of equilibrium between the amount of sodium, hence the leak rate and the amount

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of oxygen which diffuses through the heat insulation and its casing. The result of this process is that the pipe is not corroded in the immediate vicinity of the leak since this region is bathed in sodium without any presence of oxygen and that it is not corroded further away because, although oxygen is present, sodium is not. In the region where oxygen from the air and humidity comes in contact with the sodium, caustic soda forms and corrodes the steel. A circular ripple is easily seen with its center in the leak on figure 3.

Tests were carried out in another parallel program on larger diameter pipes (700 mm) to analyze the development of the spot of sodium in the heat insulation and at the interface between the pipe and the heat insulation. The various leak detection systems : insulated electrical wires and thermovision, were tested during these tests.

This program will be followed by an analysis of the size of the corroded region with respect to the leak rate of liquid sodium and also when the leak is gaseous, carrying with it sodium vapor.

The same tests will be run, submitting the specimens to mechanical loading (torsion or bending) so as to study the effects of these stresses on the rate of pipe corrosion, and the evolution of the leak rate.

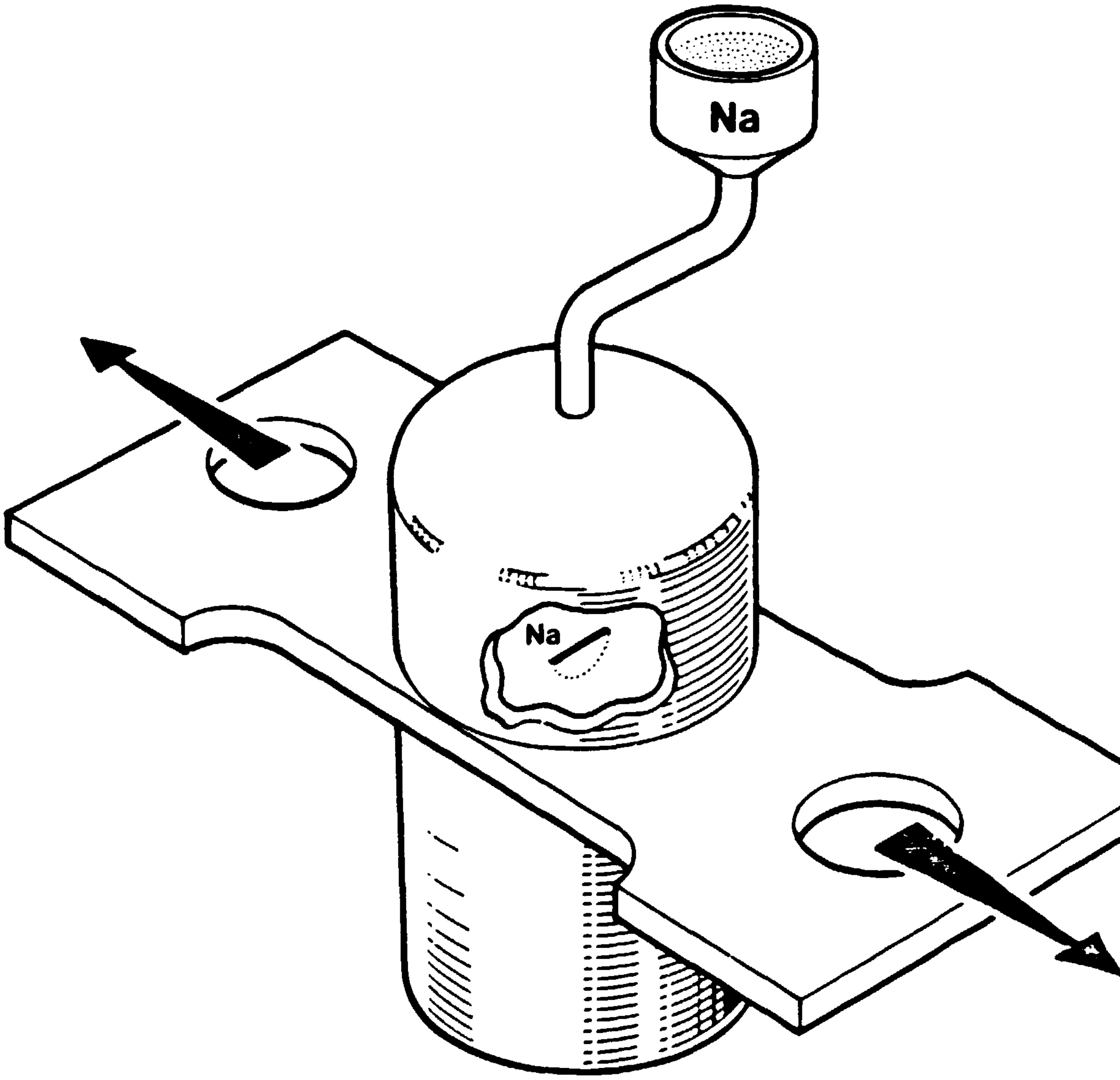

FIG. 1 - RELATIONSHIP BETWEEN CRACK SIZE AND SODIUM FLOW RATE

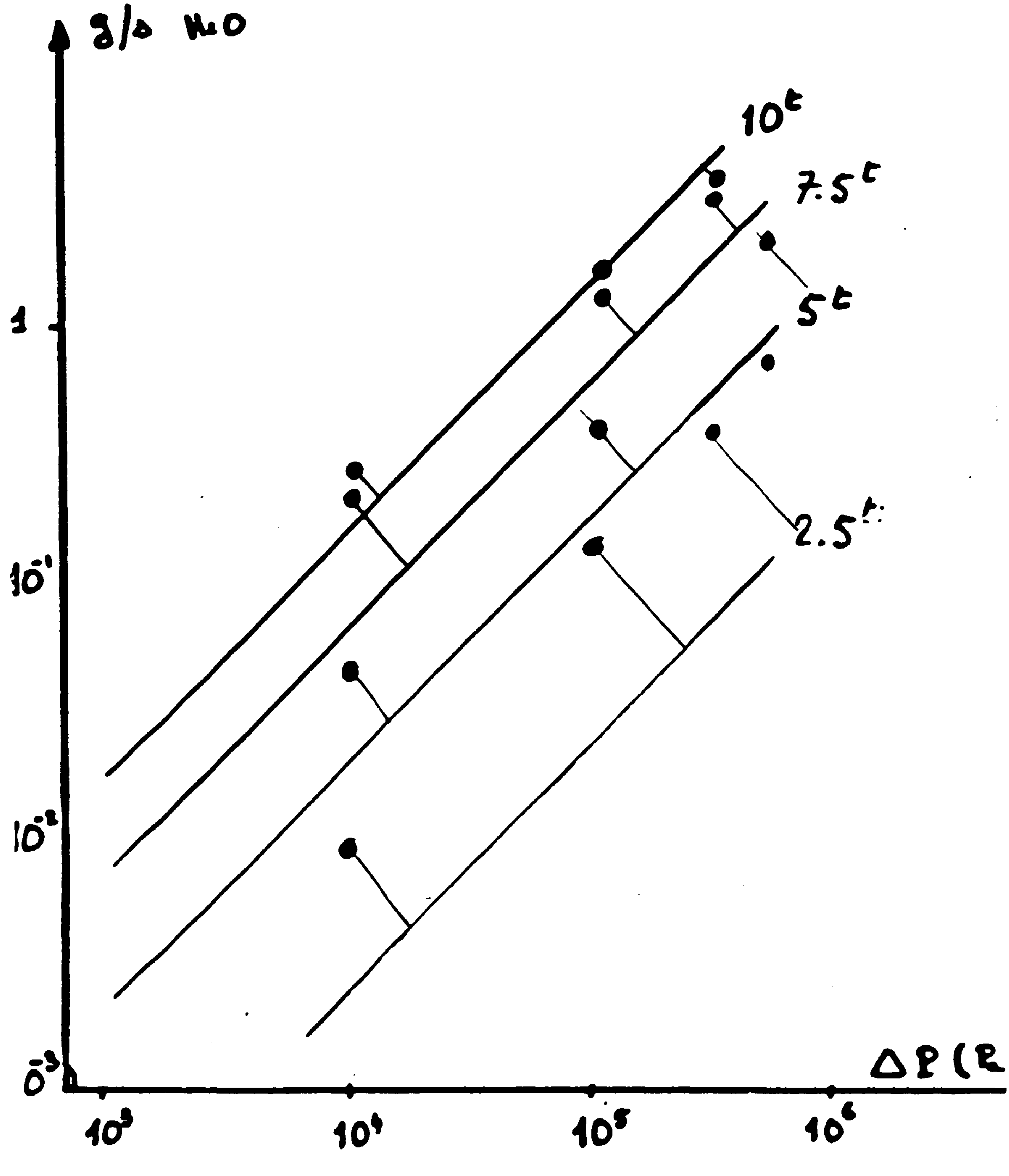

FIG. 2 - WATER LEAK RATE VS LOAD

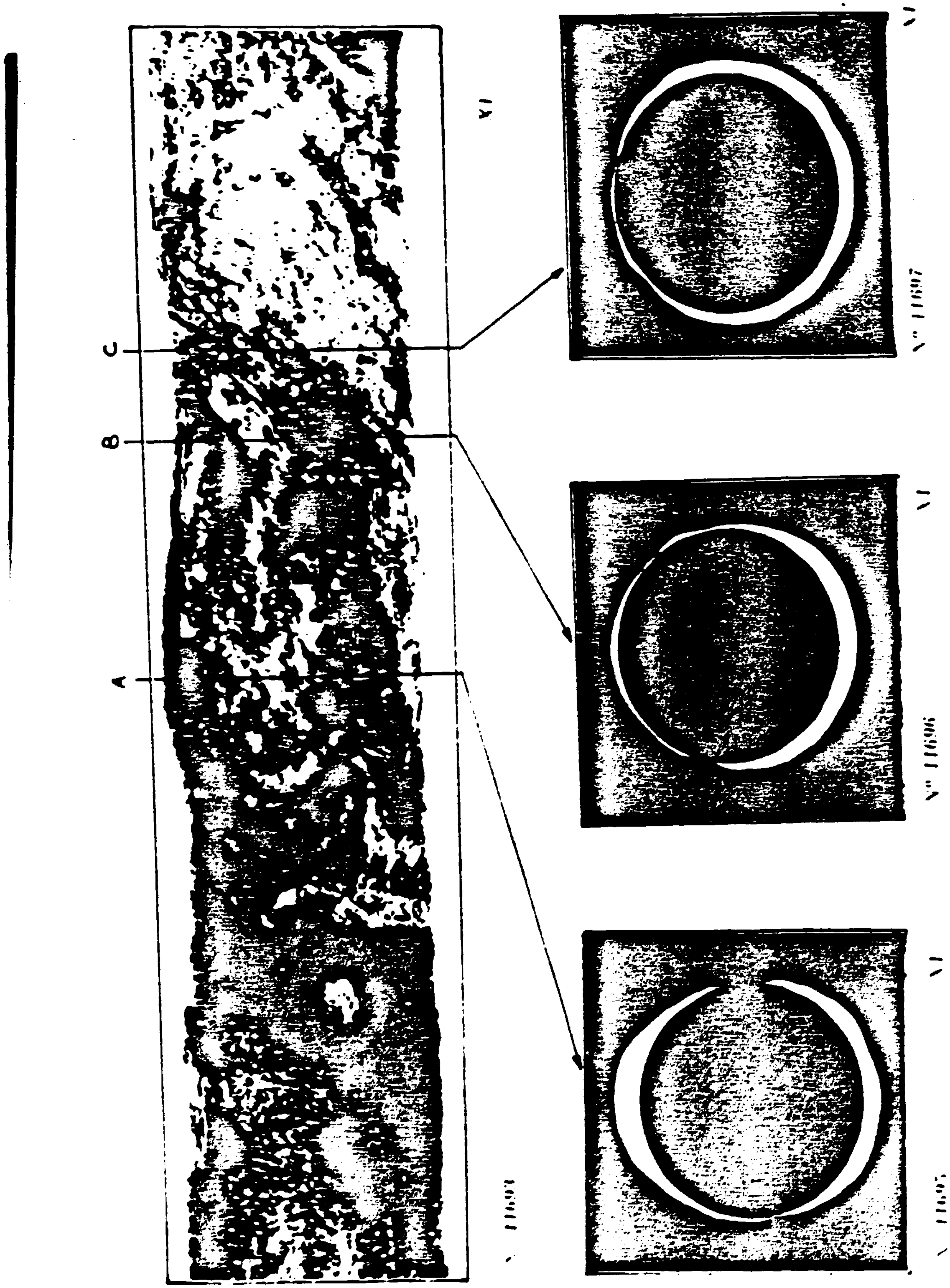

FIG.3 - SMALL SODIUM LEAK INDUCED CORROSION

Juillet 1986

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