The effects of localised steady and cyclic overheating in the Oldbury concrete pressure vessels

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The Effects of Localised Steady and Cyclic Over-Heating in the Oldbury Concrete Pressure Vessels

L'influence de suréchauffement localisé tant permanent que cyclique des caissons en béton précontraint de la centrale nucléaire d'Oldbury

Die Auswirkungen stetiger und periodischer örtlicher Überhitzung in den Spannbetondruckbehältern von Oldbury

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1. INTRODUCTION

The nuclear power programme in Great Britain has gathered considerable momentum since its start in the mid 50's. Nuclear stations with a total capacity of 5300 MW(e) are now complete; stations of a further 6600 MW(e) capacity are under construction. Of this 11900 MW(e), 70%, is from stations utilising prestressed concrete pressure vessels (PCPVs) to contain the primary gas circuit.

The first station in Great Britain to use a concrete vessel was at Oldbury-on-Severn, which has been operational since 1967. The two vessels at this station, in common with all subsequent British designed vessels, are lined internally with a mild steel membrane. This liner is tied to the concrete with closely pitched hook bolts or studs. The liner and concrete temperatures are controlled by a network of cooling pipes at or near the liner/concrete interface together with insulation on the liner/gas interface. These measures are designed to limit the concrete temperatures to less than 65°C with a reactor gas temperature in excess of 350°C.

During the commissioning tests of the Oldbury vessels, several localized areas of the steel liner reached temperatures higher than the design level of 65°C. In one area the thermocouples indicated a peak temperature of 180°C. The high temperature regions or 'hot-spots' were attributed to a small number of local shortcomings in the performance of the as installed thermal insulation. Consequently attempts were made to improve the insulation performance without major redesign. It was accepted that some less severe hot-spots would be likely to remain even after these improvements.

It was recognized that these hot-spots would induce high thermal stresses in the concrete and a theoretical study was made to determine the effect these stresses would have on the overall structural integrity of the vessel. This study showed that there was no cause for concern about the safety margin against failure of the vessel, but it was possible that cracking could occur in the concrete close to the liner. It was therefore considered that a practical test was necessary to demonstrate that, if cracking occurred, it would be limited in extent and the liner would remain fixed to the concrete by the retaining bolts.

Examination of the hot-spots recorded during the commissioning tests showed that the highest temperatures occurred around the upper boiler instrument penetrations. Calculations showed that the stresses and strains imposed on the liner and adjacent concrete would be more severe at these positions than at any others under the most critical loading conditions. It was therefore decided to test a full scale model of this region under conditions which were similar to those experienced in the vessel during reactor operation.

2. PRELIMINARY CALCULATIONS AND TEST PROPOSALS

The first step in designing the model was to determine the stresses occurring in the vessel. It was essential that the stress analysis should include the effects of creep of concrete since experimental evidence(1) suggested that this could have a significant effect on the behaviour of the vessel. In the method chosen(2) the effect of creep of concrete on stress in the vessel was assessed by finding the steady state stress solution(1): the stresses found by this method are the bounding values as creep strains become large.

Stresses in the vessel at the four positions shown in Fig. 1 were compared for the six loading conditions detailed below. At two of these positions there were several hot-spots whilst, for comparison, the other two positions were in areas operating under normal conditions.

The four positions considered were:-

A Mid wall

B Upper boiler instrument penetration (hot-spot of 180°C)

C Carbon shield block (hot-spot of 90°C)

D Centre of top slab

The critical loading conditions considered (see Fig. 2) were:-

1. Before initial start-up (prestress only)

2. Half pressurised, vessel cold

3. Early operating conditions (prestress plus full pressure plus temperature).

4. Long term operating conditions (allowing for stress relaxation due to creep).

5. Shut-down after a long period of operation (vessel cold and depressurized, showing reversal of thermal stress).

6. Restart from condition 5 (vessel cold plus half pressure plus prestress).

The computed radial, hoop and vertical stress histories at the four positions are shown in Fig. 2.

It is apparent from Fig. 2 that in general there are two unavoidable critical loading conditions:-

(a) At initial start-up (loading case 3), when high compressive stresses occur.

(b) During the shut-down cycle (loading cases 5 and 6), when high tensile stresses occur.

The worst tensions actually occur when repressurising after a shut-down (loading case 6). The results in Fig. 2 show that under all loading conditions the upper boiler instrument penetration (position B), sustains the highest stresses. For this reason the model was chosen to simulate this position with a hot-spot at approximately 180°C. This simulation would also show the effects of stress concentration due to the penetration. The analysis of the vessel showed that the highest stresses occur in the hoop and vertical directions, the maxima being very similar in these two directions. The choice of a model with equi-biaxial stresses approximately equal to these stresses was therefore justifiable.

The actual model chosen is illustrated diagrammatically in Fig. 3 and is described later in the paper. In order to verify further that the model was representative a separate stress analysis was undertaken. The resulting stress profiles at the simulated penetration were compared with those computed for the vessel during a typical reactor start-up/shut-down cycle. The calculations showed that a steep stress gradient behind the liner is caused by the temperature gradient between the liner and the cooling water pipes which are positioned 100 mm into the concrete. The tensile stresses predicted under loading case 6 greatly exceed the tensile strength of the concrete and cracking would be expected. The results obtained from this preliminary comparison showed that reproduction of the appropriate prestress and temperature pattern in the model would produce a similar stress and strain situation to that in the vessel.

It was proposed that the main body of the model would be heated to a temperature distribution simulating the operational thermal conditions at the upper boiler instrument penetration of the vessel and finally cooled to simulate loading case 6. The expected variation in the overall stress gradient through the vessel wall due to creep relaxation during the operational period would be simulated in the model by removing some of the prestressing as the test proceeded. It was considered unnecessary to simulate the effect of gas pressure normal to the liner since no contribution to any mechanism of failure could be envisaged from this source, the stresses exerted normal to the surface being negligible in comparison to those parallel to the liner. At the end of the test an examination of the liner and adjacent concrete would be made. Cores would be taken to obtain an indication of the condition of the concrete, and dye injected into the concrete to indicate the extent of cracking.

The opportunity would be taken to include instruments which would measure significant phenomena such as structural strain, temperature, vapour pressure and moisture content of the concrete. The formation of cracks in the concrete would also be monitored.

3. DESCRIPTION OF MODEL

The model is shown diagrammatically in Fig. 3 and Fig. 4, shows the model before concreting. It consisted of a cylindrical disc of concrete 365.8 cm diameter and 152.4 cm thick, mounted with its central axis vertical. The bottom of the concrete was faced with a 12.7 mm thick steel liner, attached to the concrete with 38.1 cm long hook bolts at 30.5 cm equipitch. Fins 10.2 cm high were welded at right angles to the liner at 30.5 cm centres on which were mounted the pairs of cooling water pipes. These ran from north to south across the disc, except for the central pair which curved round the east side of the central penetration.

The boiler instrument penetration was 'sleeve' reinforced with 27.3 cm O.D. steel tube, 14.3 mm thick, thickened locally where it was welded to the liner. The tube was water cooled by two spirally wound pipes welded to its outer surface.

The details of the liner, cooling water system and penetration were similar to those in the Oldbury vessel, except that the large radius curve of the vessel wall was omitted.

The concrete was to the same specification as that used in the Oldbury pressure vessel, the aggregate being obtained from the same pits. Details of the mix are given in Appendix I. Casting was undertaken in two lifts on successive days. After curing, the sides and top of the model were coated with Araldite resin X83/44 to minimise moisture loss. The moisture condition of the model therefore simulated the likely moisture condition of the vessel.

The region of the model local to the hot-spot was subdivided into four quadrants by moisture barriers 10 cm high, sealed to the liner. By this means it was hoped to prevent the dye injected into one quadrant affecting another quadrant.

After curing for 28 days the model was prestressed by wire winding with 2.6 mm diameter high tensile steel wire. The total initial force in the wire over the surface was 13.0 MN, giving an average radial stress in the concrete of 4.5 N/mm^2 after allowing for losses. This value had been computed as being representative of vessel conditions. Part of the prestress over the bottom 30.5 cm was wound in three predetermined bands which could be removed when required to simulate stress redistribution due to creep strain. The first of these three bands was removed 43 hrs after the start of the first test, the remaining two bands 15 days later. This represented a total reduction of prestress over the bottom area of approximately 49%.

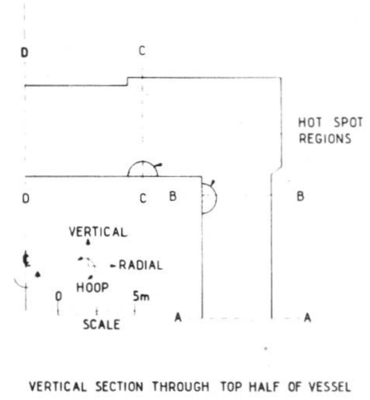

FIG. 1. OLDBURY VESSEL – SECTIONS CONSIDERED IN THE PRELIMINARY CALCULATIONS

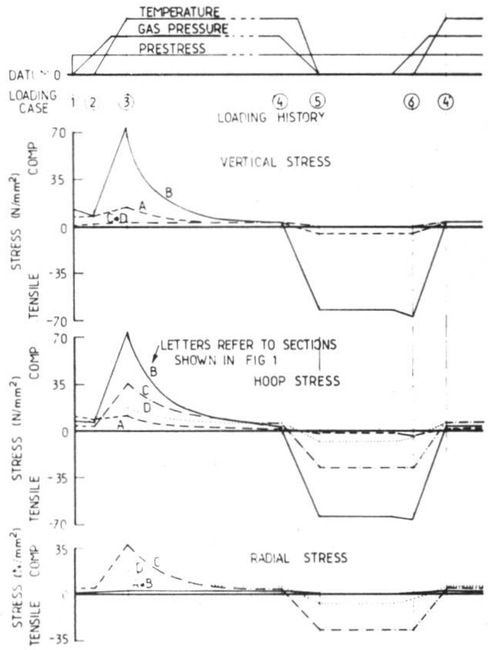

FIG 2 OLDBURY VESSEL - APPROXIMATE STRESS HISTORIES AT THE LINER FACE OF VESSEL SECTIONS A-A, B-B, C-C, AND D-D SHOWN IN FIG 1

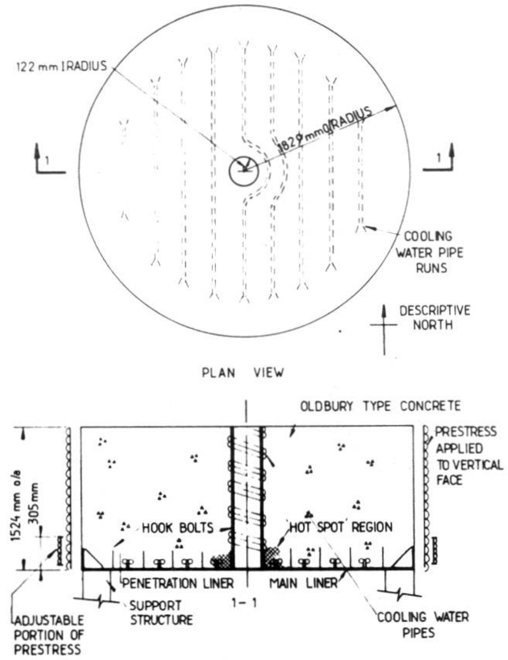

FIG. 3 MODEL – GENERAL ARRANGEMENT

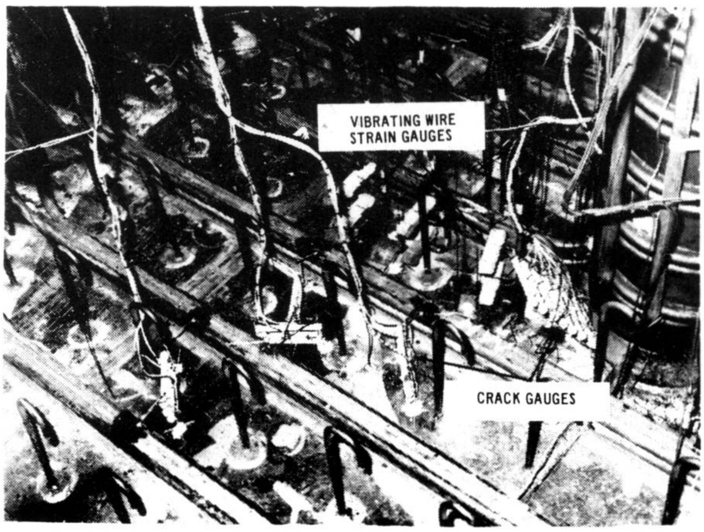

FIG. 4 VIEW OF MODEL DURING CONSTRUCTION, SHOWING INSTRUMENTATION

Heat was applied to the liner and penetration using 'Pyrotenax' electric heating cables backed with insulation. The heaters were arranged in zones for each of which temperature controls were provided.

Facilities were provided to supply cooling water at 20°C ± 1°C at a velocity of 0.5 m/s through the cooling pipes.

4. INSTRUMENTATION

Eighteen 'Perivale' type 641 vibrating wire strain gauges were positioned as shown in Fig. 5. The gauges were used to measure the strains occurring in the concrete during the tests.

155 Chrome-Alumel thermocouples were fitted, 23 of which were used to control the heaters.

Seventy-eight pairs of crack gauges were fitted. These were specially developed for the experiment at C.E.R.L.,[3] and were designed to indicate the onset of cracking. The gauges respond both to the opening and closing of cracks.

Twelve C.E.R.L. moisture gauges, positioned as shown in Fig. 5 were used to determine the moisture gradients in the concrete during the tests.

Twelve pressure gauges were fitted to measure the vapour pressure during heating at the liner/concrete interface and the cooling pipe/ concrete interfaces. Three gauges were also positioned to measure the vapour pressure at the boiler penetration/concrete interface.

Injection nipples were positioned on the liner and on pipes leading to the cooling pipe level to facilitate the injection of dye after each test. This technique, developed specially for the experiment, enabled the position of cracks to be determined from cores taken after each test. The presence or absence of dye in cracks would indicate whether these had occurred before or after the coring operation.

5. TEST PROCEDURE

In the first test a thermal profile was established which was similar to that at the upper boiler instrument penetration of the Oldbury vessel R.1. This profile with a maximum temperature, at the hot-spot, of 172°C was maintained for three months. The second test consisted of fifteen thermal cycles each of 48 hours duration between 30° and 178°C. The temperature range of each cycle was controlled to correspond approximately to the range of temperatures that the hot-spot region of the liner would be subjected to, during the reactor start-up/shut-down cycle. The third test was a further over heating test but with the hot-spot maintained at a maximum temperature of 300°C for 28 days.

After each test an examination was made of the model. Blue dye was injected into one quadrant of the model at a number of points, a maximum pressure of 0.7 N/mm^2 being maintained at the pump during this injection. Some of the dye injection nipples led to the liner/concrete interface while others led through the cooling pipe fins directly to the cooling pipe/concrete interface.

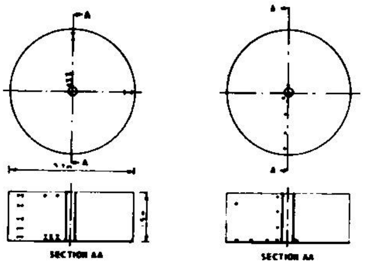
FIG. 5 VIBRATING WIRE STRAIN GAUGE (LEFT) AND MOISTURE GAUGE POSITIONS

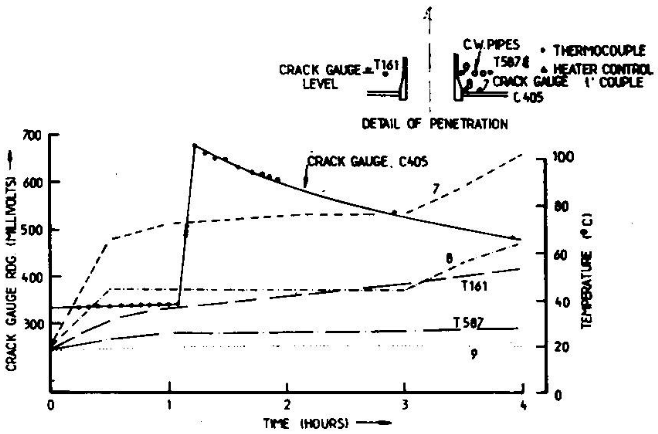

FIG 6 TEST 1 - CRACK GAUGE READINGS IN FIRST 4 HOURS OF TEST

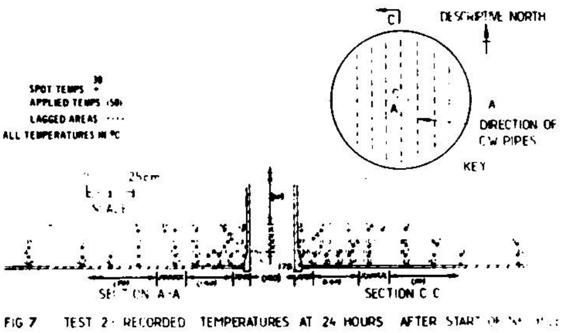

FIG 7 TEST 2 - RECORDED TEMPERATURES AT 24 HOURS AFTER START OF ...

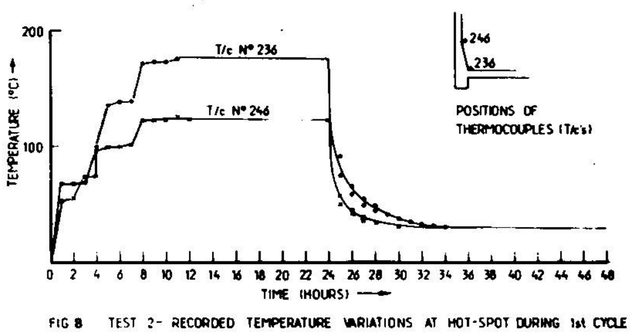

FIG 8 TEST 2 - RECORDED TEMPERATURE VARIATIONS AT HOT-SPOT DURING 1st CYCLE

Concrete coring followed, from which a study of the dyed cracked surfaces could be made. Certain cores were also used to determine the compressive and tensile strength of the concrete.

Measurements to determine the ultrasonic pulse velocity between adjacent core holes and between the central penetration and core holes were made at different depths. These measurements were compared with ones obtained from control specimens.

6. RESULTS

Test 1

Results from the first test have been reported elsewhere[(4)] but, as they have a bearing on the vessel behaviour during the subsequent tests, they are briefly reiterated in this paper.

One pair of crack gauges showed a significant change in reading 65 minutes after the start of the first test. A plot of one of these gauge readings is shown in Fig. 6. The readings indicated the formation of a crack wider than 0.5 mm which decreased to zero as the test proceeded.

The coring and dye injection indicated the presence of a horizontal crack extending to approximately 500 mm radius at a level of 110 mm from the liner - i.e. cooling water pipe level. The cores also showed dye penetration on the cooling pipe-fin/concrete interface and in many cases the liner/concrete interface.

Test 2

The temperature distribution applied to the liner is shown in Fig. 7, which also shows the maximum temperatures recorded during the first cycle. The temperature variation at two positions in the model during one 48 hours cycle is shown in Fig. 8.

The strain variation at two gauge positions, at 24 hour intervals, during this test are shown in Fig. 9.

None of the crack gauges indicated cracking. Those gauges which had changed during the transient heating of test 1 showed no change in test 2.

The coring checked the limits of the original horizontal crack and found that these limits remained unchanged. Two cores had fine vertical hair cracks on their bottom face penetrating up to a depth of 50 mm. The cracks were random and not interconnected.

Test 3

Steady state temperatures recorded by the thermocouples are shown in Fig. 10.

The strain changes occurring in the hoop gauges adjacent to the central penetration are shown in Figs. 11 and 12. These figures also show the total strain history of these two gauges during the three tests.

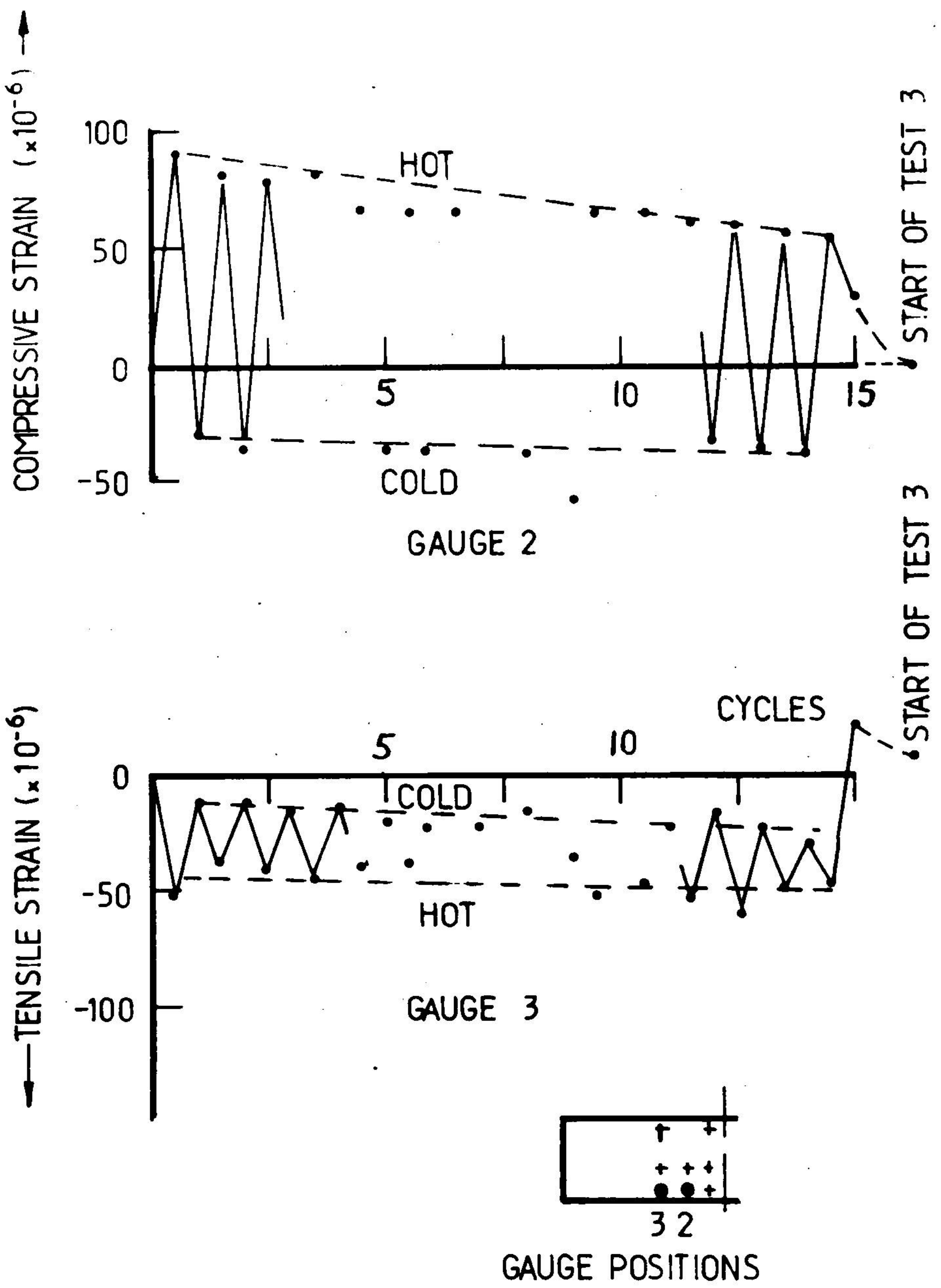

FIG.9 TEST 2 - RECORDED STRAINS AT GAUGES 2 AND 3 AT 24 HOUR INTERVALS

As in test 2, no further cracking was indicated by the crack gauges, and coring again confirmed that the extent of the original horizontal crack remained unchanged.

7. DISCUSSION

The cores taken during the first test included ones which penetrated the central pair of cooling pipes (see Fig. 13 and position of core 1/3). For the second test these pipes were isolated and consequently the concrete temperatures local to the central penetration were higher than normal. The conditions imposed on the concrete in this test were therefore more arduous than those experienced in the Oldbury vessel. (See Section AA of Fig. 7).

Very little strain change was recorded between the beginning and end of the test. Most gauges showed a trend in the tensile direction the maximum being 35 x 10^{-6} strain units. Results from two of the gauges in the zone of the crack (Nos 2 and 3) are shown in Fig. 9 and show no residual strain soon after the end of the test. These plots are again illustrated in Figs. 11 and 12. An interesting change occurred at the position of gauge 2. The thermal strain became compressive during the heating up part of the cycle whereas it was tensile during test 1 (Fig. 11). It is thought that this anomalous behaviour was due to the change of temperature distribution resulting from the absence of cooling water flow in the pipes mentioned above.

The cores taken after the test confirm the presence of the horizontal crack at a similar level to that found in test 1. This crack is clearly shown in Fig. 14. The extent of the crack in the NE quadrant after test 2 was similar to that in the SE quadrant in test 1. It is therefore considered that the original crack had not extended as a result of the thermal cycling. The presence of the hairline cracks in cores 2/3 and 2/5 is thought to be due to shrinkage induced by moisture movement.

The results of this test can be applied to the Oldbury vessel since temperatures will change in a similar but less severe manner during the reactor start-up and shut-down cycle. In the actual vessel, the hot periods will be of longer duration than those experienced by the model and this may lead to differences in behaviour due to creep strain. It has been observed[5], however, that the Oldbury vessel is not subject to large changes in creep strain during reactor operation. It can, therefore, be concluded that cracks which occur in the upper boiler instrument penetration of the Oldbury vessel and which are of a similar kind to those found in test 1 will not propagate further due to reactor cycling.

During test 3 the maximum temperature applied to the model was 305°C at the junction of the main liner and penetration. As in test 2, because of the isolated central cooling pipes the high temperature zone extends more deeply into the concrete than would occur with full cooling capacity. This test, therefore, simulates not only the effect of a high temperature hot-spot but also failure of the cooling water supply local to the hot-spot.

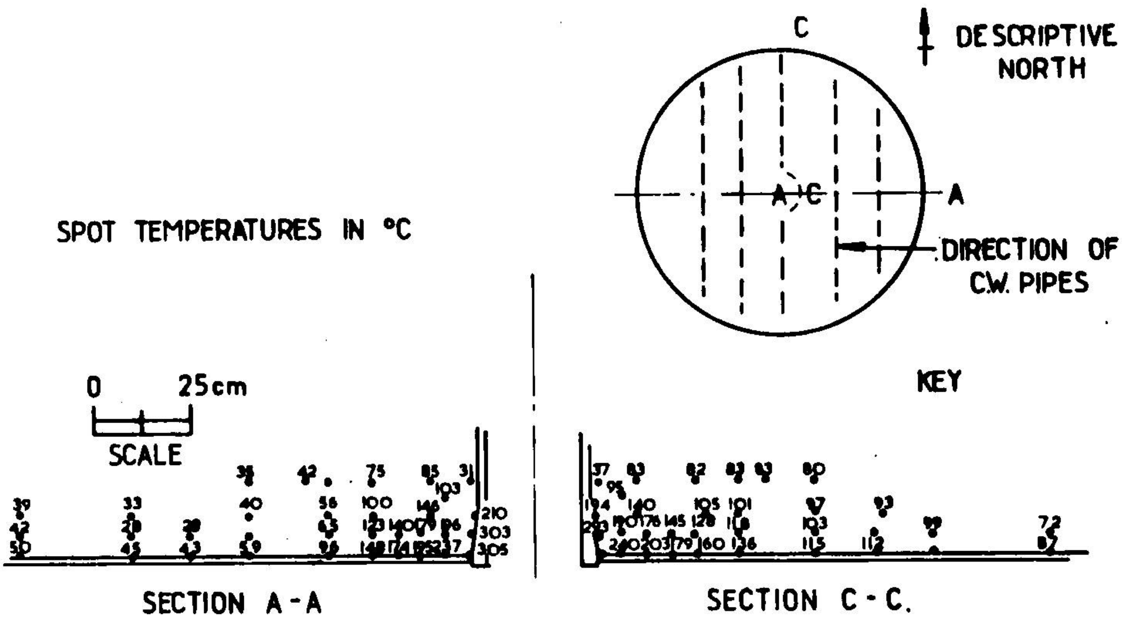

FIG. 10 TEST 3 TEMPERATURES IN THE MODEL AVERAGED FROM VALUES AT DAYS 21, 22, 24, AND 28.

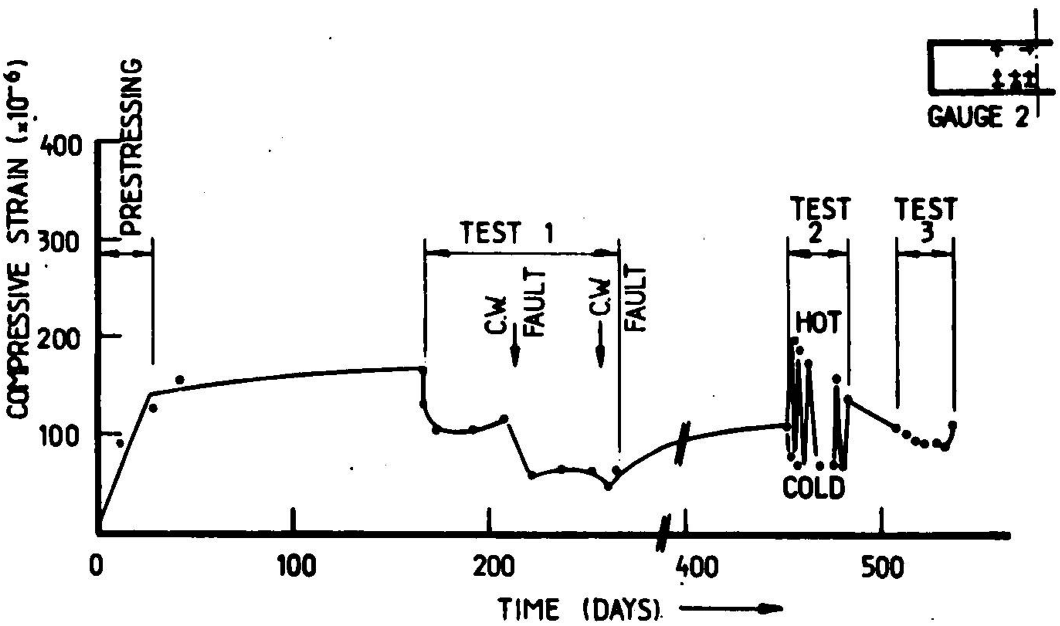

FIG.11 RECORDED STRAINS AT GAUGE 2 OVER COMPLETE HISTORY OF MODEL.

The strains which occurred in test 3 show little change during the heated period. It can be seen from Figs. 11 and 12 that there was little change in strain between the end of test 1 and the end of test 3. There was, therefore, little additional permanent deformation in the model caused by either thermal cycling or over-heating.

The cores taken after this test confirmed the presence of the horizontal crack found in the previous tests. The extent of the crack in the NW and SW quadrants after test 3 was similar to that found in the other quadrants. It is therefore considered that the original crack had not extended as a result of the high temperature test.

It is to be expected that a similar temperature excursion in the upper boiler instrument penetration area of the Oldbury vessel, even with local cooling water failure, would not result in damage to either the liner or the concrete.

8. CONCLUSIONS

The cracks formed during the first transient heating of the model were not increased by thermal cycling between 30° and $178^{\circ}C$.

Maintaining the hot-spot at $305^{\circ}C$ for 28 days did not increase the original cracking.

It can be deduced from the model results that cracking is likely to have occurred at the upper boiler instrument penetration of the Oldbury vessel. The cracking will be limited to a depth of 100 mm from the liner which will remain fixed to the concrete by the retaining hook bolts. This cracking will be unlikely to extend during reactor start-ups and shut-downs. Hot-spot temperatures of $300^{\circ}C$ could be tolerated at the upper boiler instrument penetration, even with blockage of local cooling water pipes.

9. ACKNOWLEDGEMENT

This paper is published by permission of the Central Electricity Generating Board.

10. REFERENCES

1. Ross, A.D., England, G.L. and Suan, R.H.
   Prestressed Concrete Beams under Sustained Temperature Crossfall.
   Mag. Conc. Res., 1965, 17, Sept. 117-126.

2. Lewis, D.J. and Irving, J.
   Operational Stresses in Nuclear Prestressed Concrete Pressure Vessels.
   Civ. Eng. and Pub. Wks. Rev., 1968, 63, Part 1, 673-676, Part 2, 793-796.

3. Hornby, I.W. and Wilson, J.M.
   Instrumentation Techniques in Large Scale Concrete Models.
   Proc. Conf. on Model Techniques for PCPVs, BNES, London 1969, p3-6.

4. Irving, J., Carmichael, G.D.T. and Hornby, I.W.
   A Full-Scale Model Test of Hotspots in the PCPVs of the Oldbury Nuclear Power Station (to be published).

5. Carmichael, G.D.T. and Hornby, I.W.
   The Strain Behaviour of Concrete in PCPVs.
   Mag. Conc. Res., 1973, 25, March 5-16.

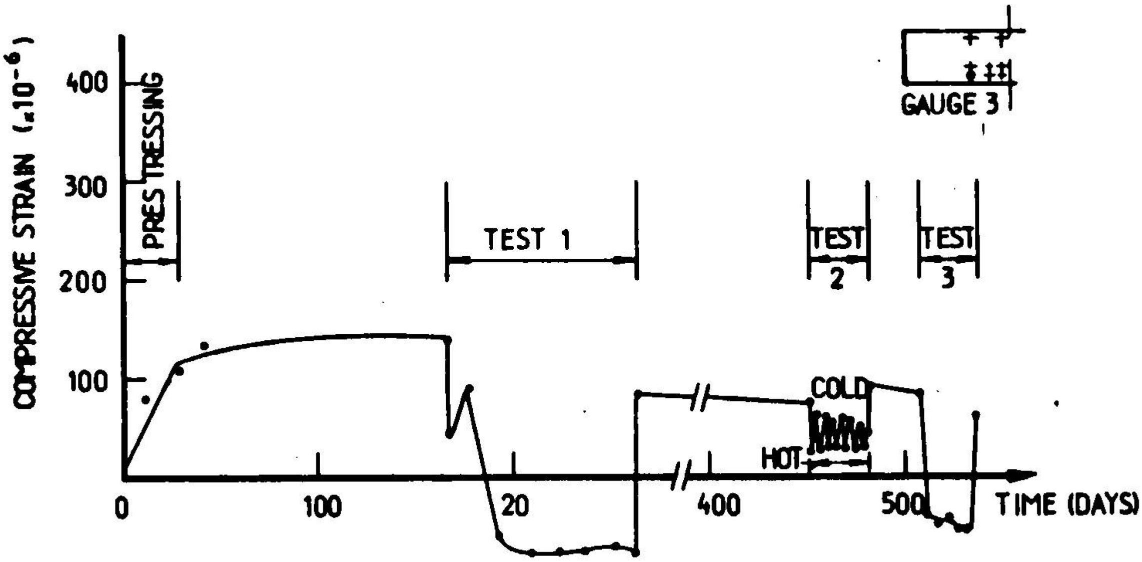

FIG 12 RECORDED STRAINS AT GAUGE 3 OVER COMPLETE HISTORY OF MODEL

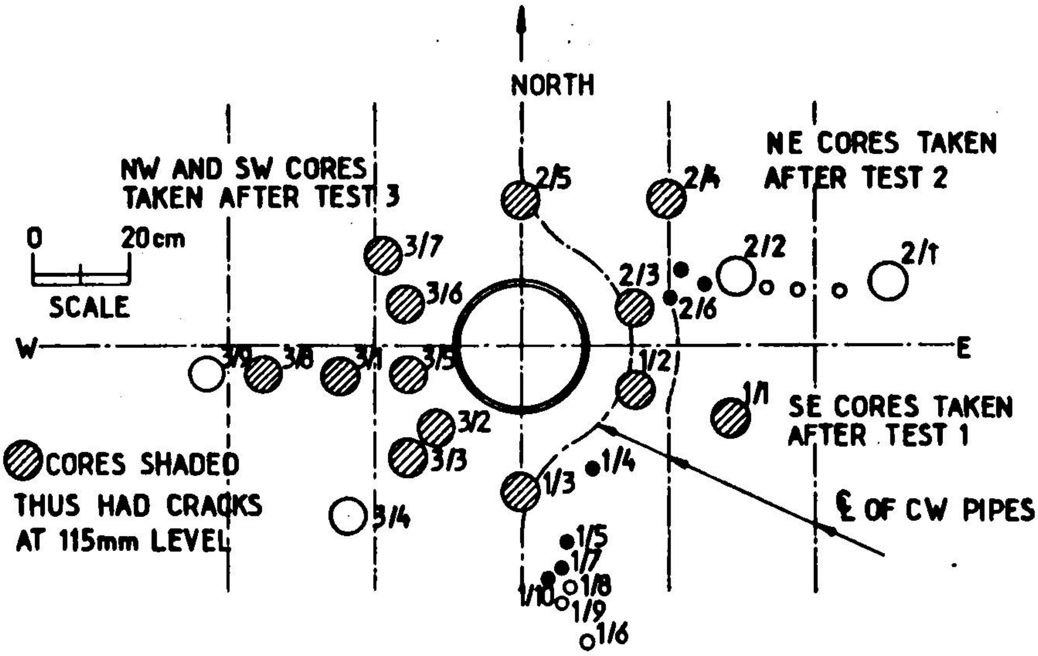

FIG.13 POSITIONS OF CORES TAKEN FROM MODEL

APPENDIX I - MATERIALS

1. DETAILS OF CONCRETE MIX

Design of mix:-

1:5.1/0.47, 19 mm maximum size aggregate

Minimum 28 day strength 41.4 N/mm^2

Target average 49.6 N/mm^2

Standard deviation 4.0 N/mm^2

Mix used:-

1:2.0:3.1/0.47 w/c

Sulfacrete cement

Ball mill put sand in zone 2 of BS 882

'Cromhall' limestone in two grades - 19 to 9.5 mm and 9.5 to 4.75 mm

½% Sika Plastocrete

2. MATERIAL PROPERTIES USED IN THEORETICAL ANALYSIS

Steel:-

Young's modulus: 207.0 kN/mm^2

Poisson's ratio: 0.3

Coefficient of linear thermal expansion: 10.0 μm/mdegC

Thermal conductivity: 41.6 W/m deg C

The steel was assumed to be perfectly elastic and not to creep or plastically deform at the prevailing stresses and temperatures.

Concrete:-

Young's modulus: 43.1 kN/mm^2

Elastic and Creep Poisson's ratio: 0.18

Coefficient of linear thermal expansion: 8.0 μm/m deg C

Thermal conductivity: 1.75 W/m deg C

SUMMARY

During commissioning tests for Oldbury Nuclear Power Station it was found that 'hot-spots' with temperatures in excess of design values occured in the concrete at a small number of positions immediately behind the concrete pressure vessel liner. An experimental investigation was conducted to ascertain the seriousness of damage, if any, to the liner and concrete which would result from these hot-spots.

The investigation consisted of testing a full-scale model of the region of the vessel local to the upper boiler instrument penetration where the highest liner temperatures had been recorded. Three tests were undertaken. In the first test a thermal profile with a hot-spot representing conditions in the vessel was established and maintened for three months. A second test consisted of fifteen thermal cycles, each of 48 hours duration. The third was an over-heating test with an applied liner temperature distribution similar to that of the first and second tests but

with the hot-spot maintened at a maximum temperature of 305°C for 28 days. After each test the model was thoroughly examined for signs of damage by cutting out sample cores and by ultrasonic probing.

This paper describes the cyclic and over-heating tests and discusses the significance of the results with respect to full scale pressure vessel behaviour.

It is concluded that limited cracking of concrete may have occured in the Oldbury vessels at modest temperatures during the first heating cycle, but that these cracks will not extend during further cycles or at hot-spot temperatures as high as 300°C. The cracks formed will not impair the integrity of the liner or vessel.

SOMMAIRE

Lors des essais de réception de la centrale nucléaire d' Oldbury, des points chauds d' une température nettement plus élevée que celles prévues ont été rélevés à plusieurs endroits dans le caisson au droit de la peau d' étanchéité. On a effectué une étude expérimentale pour évaluer toute avarie de la peau d' étanchéité et du béton résultant de ces points chauds.

On a réalisé trois essais sur maquette en vrai grandeur de la partie du caisson à proximité de la pénétration supérieure recevant les instruments des échangeurs de chaleur, à l' endroit sur la peau d' étanchéité où se trouvent les températures les plus élevées.

Pour le premier essai on a établie sur la maquette un profil de températures comportant un point chaud tel à reproduire les conditions dans le caisson qu' on a maintenu pendant trois mois.

Pendant le deuxième essai la maquette a subit 15 cycles thermiques de 48 heures chacun.

Pour le troisième essai on a procédé à un echauffement pour établir un profil de températures sur la peau d' étanchéité comparable à celui des essais précédents, le point chaud cependant étant maintenu à une température maximale de 305°C pendant 28 jours. Chaque essai a été suivi d' un examen minutieux de la maquette avec prélèvement des carotes et l' emploi de techniques à ultra sons pour en évaluer les avaries.

On décrit les essais de suréchauffement tant permanents que cycliques et on discute la signification des résultats obtenus vis-à-vis du comportement du caisson même.

On tire la conclusion que le béton des caissons à Oldbury ait pu être fissuré à des températures peu élevées dès le premier cycle thermique mais que les fissures ne se propagageraient pas pendant les cycles ultérieurs ou à des températures de point chaud allant jusqu' à 300°C. Les fissures existantes ne compromettrons pas l' intégrité structurelle ni de la peau d' étanchéité ni du caisson.

ZUSAMMENFASSUNG

Im Laufe der Inbetriebnahmprüfungen für das Kernkraftwerk

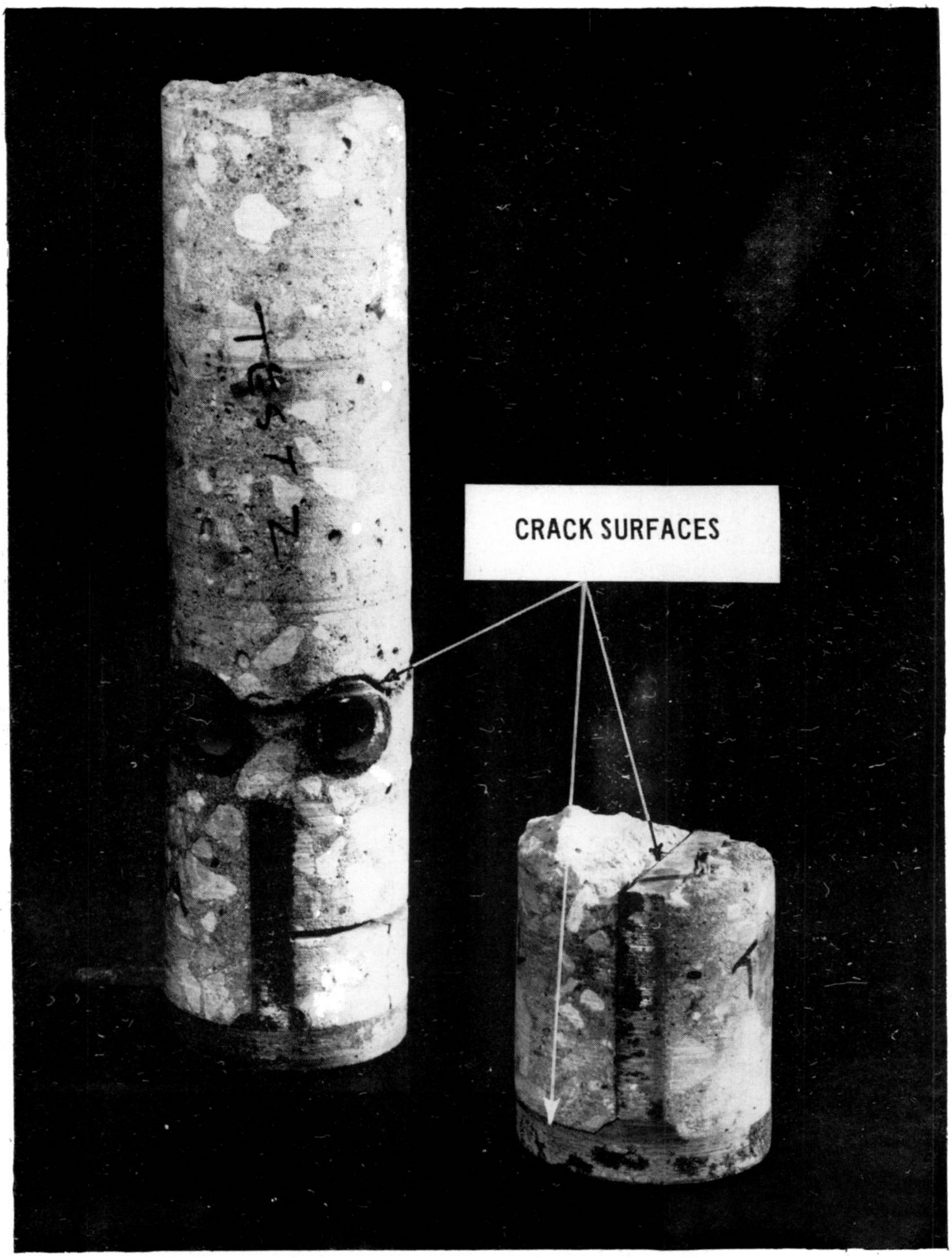

FIG. 14 CORES 1/3 (RIGHT) AND 2/5 SHOWING CRACK SURFACES

ZUSAMMENFASSUNG

Im Laufe der Inbetriebnahmeprüfungen für das Kernkraftwerk Oldbury wurden an mehreren Punkten unmittelbar hinter dem Spannbetonbehälter-Liner sogenannte Heissstellen mit die Auslegungswerte überschreitenden Temperaturen festgestellt. Es wurden Versuche durchgeführt, um das Ausmass etwaiger durch diese Heissstellen bedingter Schäden am Liner und Spannbeton zu bestimmen.

Im Rahmen der Untersuchungen wurde ein Modell natürlicher Grösse der im Bereich der oberen Durchführung für die Kesselinstrumentierung befindlichen Behälterzone geprüft, in der die höchsten Linertemperaturen verzeichnet worden waren. Es wurden drei Versuche durchgeführt. In dem erstem Versuch wurde ein Wärmeprofil aufgenommen, wobei die den Bedingungen an dem Behälter entsprechende Heissstelle drei Monate lang aufrechterhalten wurde. Der zweite Versuch umfasste 15 Wärmezyklen von je 48 Stunden Dauer. Der dritte Versuch bestand in einem Überhitzungstest. Die Verteilung der Linertemperaturen war dabei ähnlich wie in dem ersten und zweiten Versuch, doch wurde die Heissstelle 28 Tage lang auf einer Höchsttemperatur von 305° C erhalten. Nach jedem Versuch wurde das Modell durch Entnahme von Probekernen und Ultraschallsondierung gründlich auf Anzeichen von Schäden untersucht.

Dieser Bericht behandelt die Temperaturwechsel- und Überhitzungsversuche und die Bedeutung der Ergebnisse, was das Verhalten der Druckgefässe natürlicher Grösse anbelangt.

Man gelangte zu dem Schluss, dass in dem Spannbeton der Druckbehälter von Oldbury während der ersten Aufheizungsperiode bei mässigen Temperaturen in begrenztem Umfang Risse entstanden sein mögen, dass sich diese Risse aber während weiterer Zyklen bzw. bei Heissstellentemperaturen bis 300° C nicht weiter ausbreiten würden. Die gebildeten Risse werden die Verwendbarkeit des Liners bzw. des Behälters nicht beeinträchtigen.

LIST OF FIGURES

FIGURES

VERZEICHNIS DER ABBILDUNGEN

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