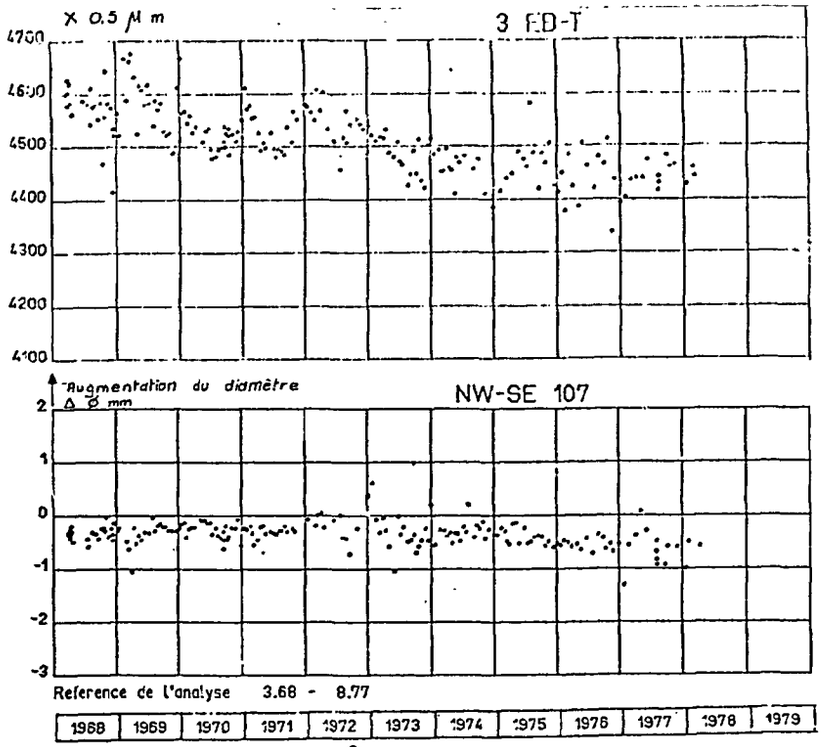

Graphique 4

CAISSON DE ST LAURENT 1

Graphiques de surveillance à conditions constantes d'état thermique et de pression interne reconstituées

- de l'extensomètre 3 EB-T (direction circonférentielle)
- de la variation du diamètre NW-SE mesurée à l'aide de deux pendules

MONITORING OF PRESTRESSED CONCRETE PRESSURE VESSELS FOR NUCLEAR REACTORS

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abstract

The paper (1) "Experience of In-Service Surveillance and Monitoring of Prestressed Concrete Pressure Vessels for Nuclear Reactors", which was presented by Irving at the York Conference in September 1975, gave details of the statutory requirements for the inspection of prestressed concrete pressure vessels in the United Kingdom, with particular emphasis on the prestressing system. Results were presented of periodic examinations under the Licensing Conditions for the vessels at the gas cooled Magnox reactors at Oldbury and Wylfa, which had been operating since 1967 and 1971 respectively, and these were discussed in relation to design expectations and future requirements. The paper also gave strain, moisture and temperature readings obtained from Oldbury PCPVs over a ten year period and compared these with predictions.

The purpose of this paper is to update the information presented in the 1975 York paper by summarising the results which have been obtained since then up to the present time (1978). The results are summarised below under six headings.

1. Tendon Load Checks

Oldbury: Tendon load checks have continued annually on the same basis as described in the York paper. Each year forty-four anchorages are checked, twelve of these being stabilised strand and thirty-two being stress relieved strand. The pattern of results for reactor 1 and reactor 2 is shown in Figures 1 and 2 respectively. The trends of loss of load established prior to 1975 have been followed in the last three years and the scatter of results is consistent with the statistical analysis presented in the York paper. The measured loss rate of the low relaxation samples continues to be, on average, 40% of the stress relieved samples.

Wylfa: As previously described fifteen tendons per vessel are checked each year, comprising three tendons from each group, which represent 1% of the total number of tendons. The results for reactors 1 and 2 are shown, for all hoop tendons in Figures 3 and 4, for top cap tendons in Figures 5 and 6 and for rib vertical tendons in Figures 7 and 8. These results fulfil the design predictions and continue to follow the trends of loss of load previously established.

2. Corrosion: Examination of tendons both at Oldbury and Wylfa for signs of corrosion continue with satisfactory results. Only minor pitting has been observed with most of the pits less than about 0.1mm deep compared with an acceptable depth of pit (for Wylfa) of 1mm deep.

3. Surface Examination: The monitoring of minor surface cracking previously observed continues with no appreciable changes in length or width. These minor cracks are considered to have no structural significance.

4. Strain Gauges: Monitoring of strain gauges continues and the results for a vertical gauge and a hoop gauge at the equator for reactor 1 at Oldbury are presented in Figures 9 and 10 respectively. The results continue to show very good agreement with design predictions.

5. Moisture Gauges: Readings of moisture gauges at Oldbury continue to be taken which show that there has been no significant change in moisture conditions from that reported in the York paper.

6. Temperatures: Temperature monitoring continues at both Oldbury and Wylfa indicating relatively small temperature cross falls through the walls of vessels. These small temperature gradients may well account for the negligible change in moisture measurements at Oldbury mentioned above.

Conclusion

The results of the monitoring of the vessels at Oldbury and Wylfa demonstrate that the vessels continue to perform in accordance with design predictions providing the required confidence that vessel integrity remains unimpaired after eleven years of operation at Oldbury and seven years operation at Wylfa. The two vessels for the gas cooled AGR reactors at Hinkley Point 'B' have now been operational for two years. Their performance has been monitored in a similar manner to Oldbury and Wylfa. The monitoring results to date compare well with design predictions.

Acknowledgement

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

Reference

(1) IRVING, J., SMITH, J.R., EADIE, D.McD., HORNBY, I.W., "Experience of In-Service Surveillance and Monitoring of Prestressed Concrete Pressure Vessels for Nuclear Reactors" Conf. Prestressed Concrete Pressure Vessels, York, England 1975.

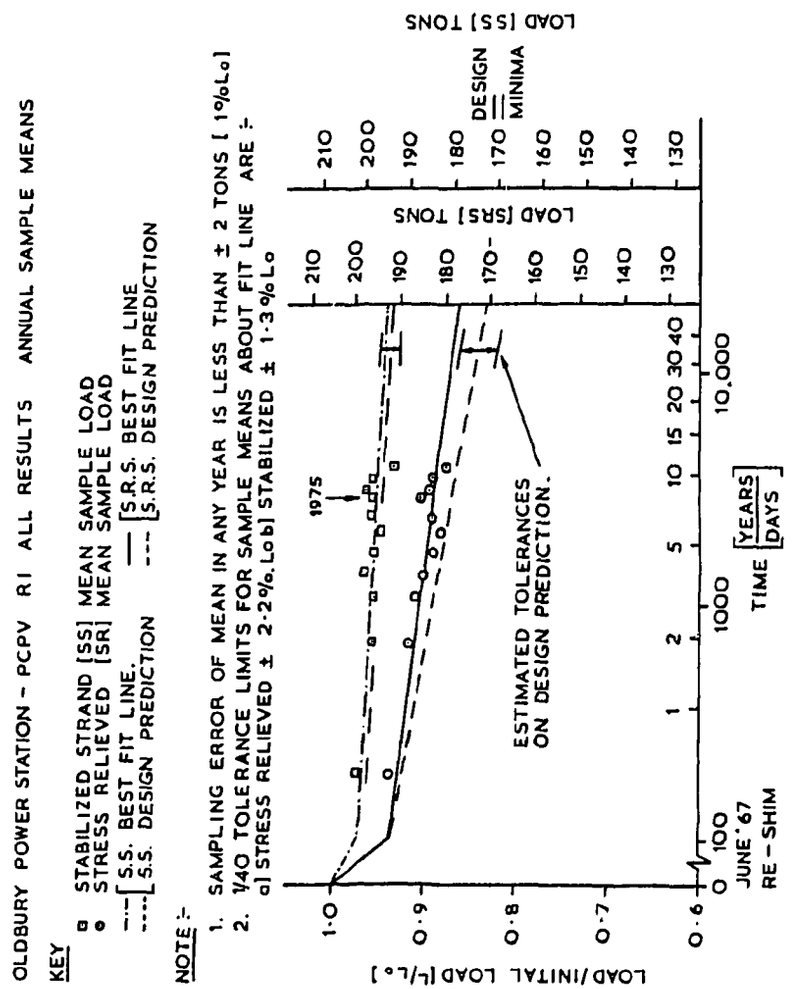
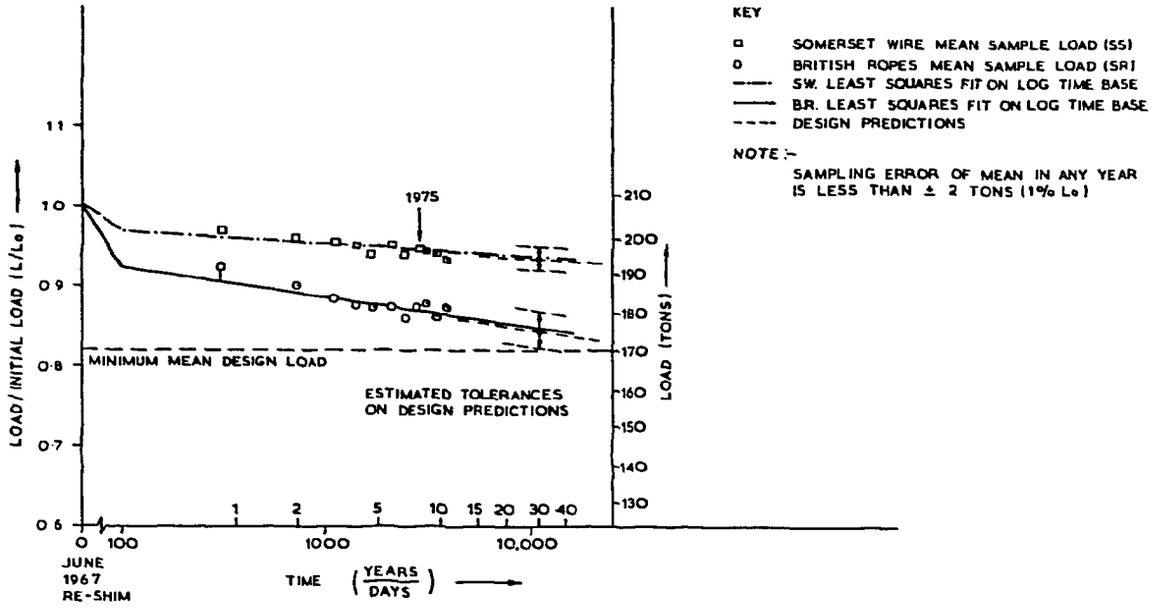


FIG.1



P.C.P.V. R2 ALL RESULTS ANNUAL SAMPLE MEANS

FIG. 2

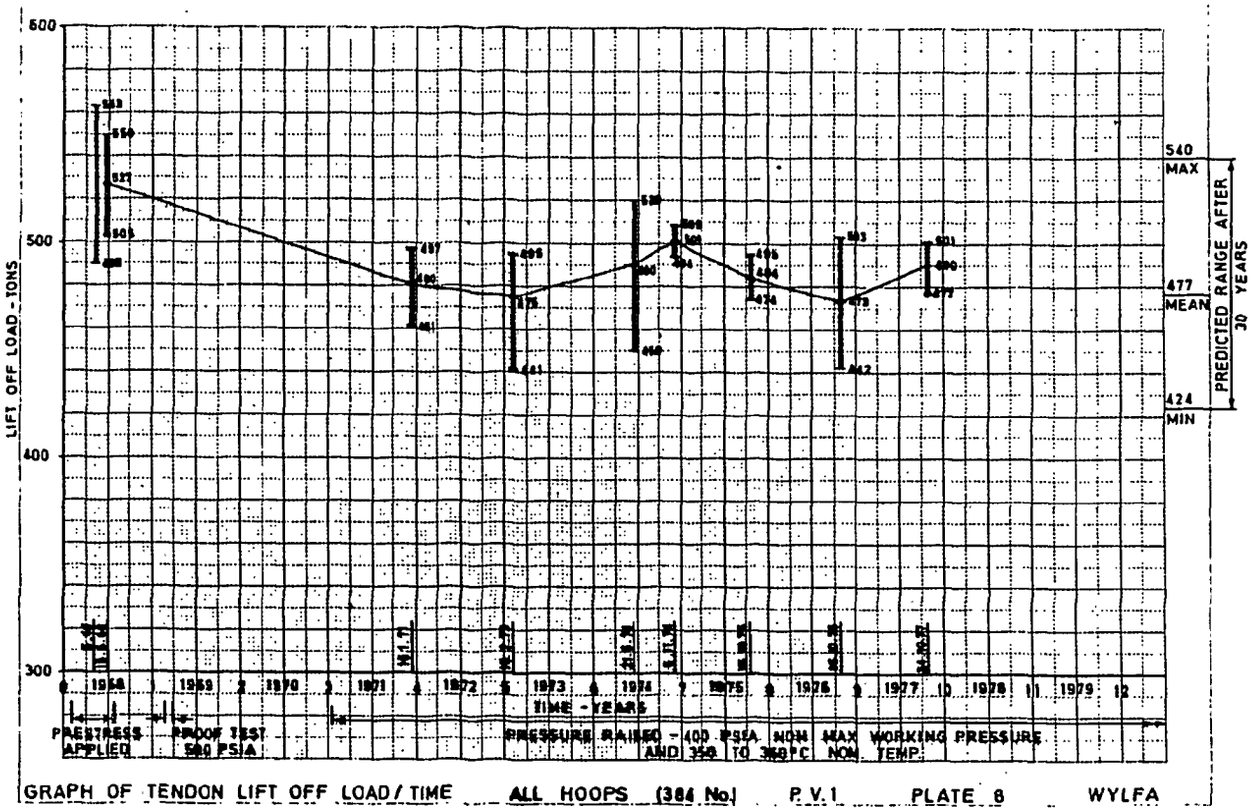
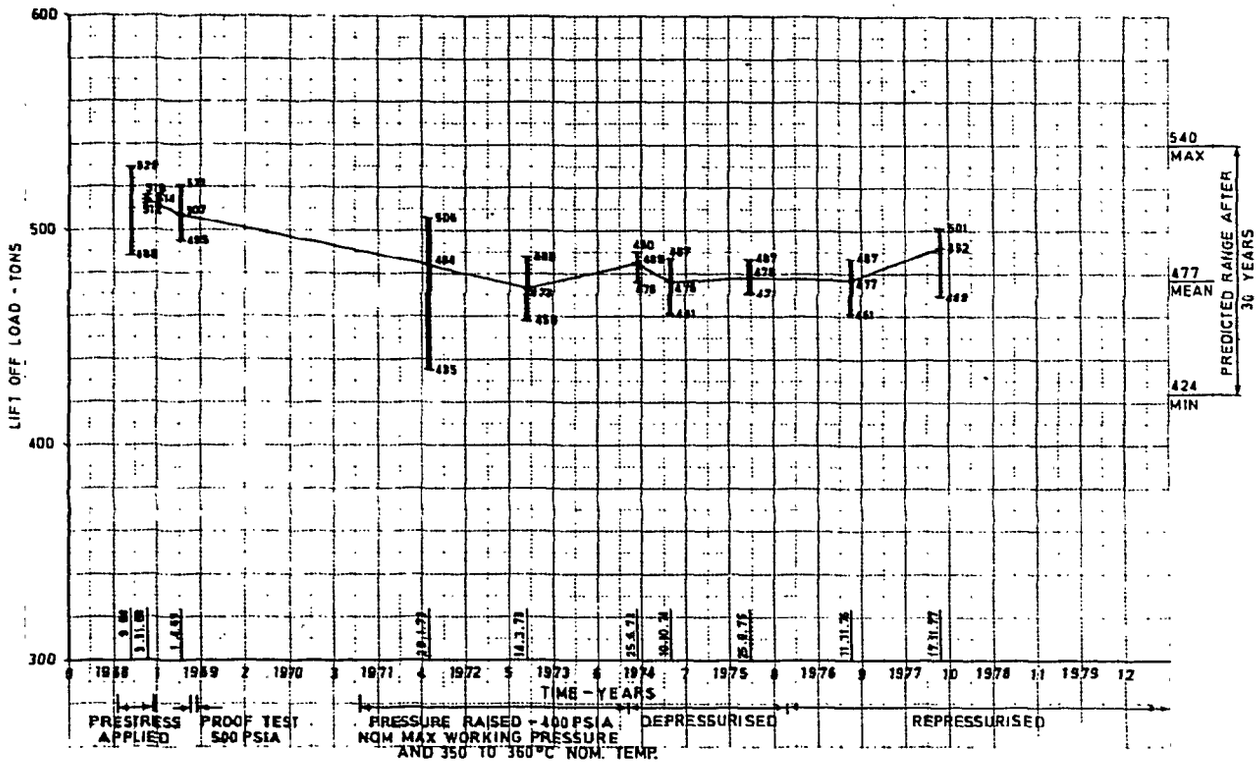
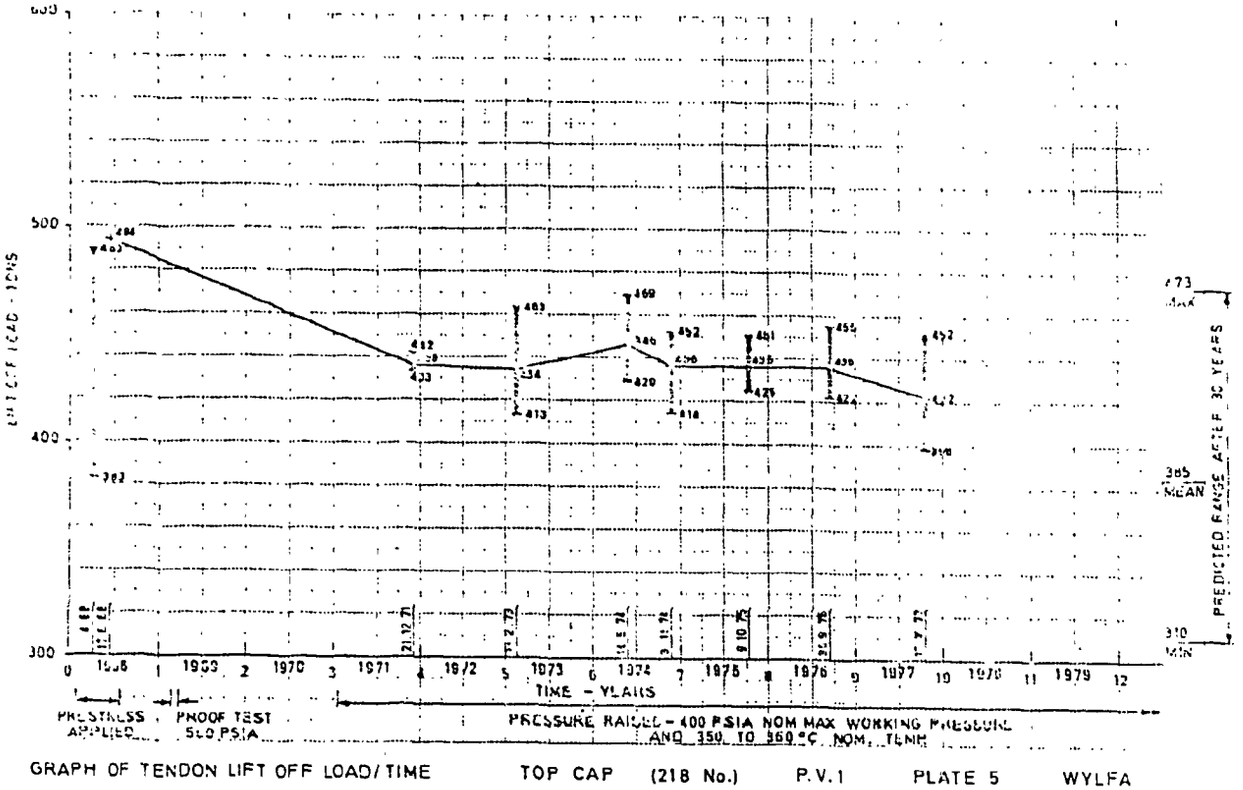


FIG. 3



GRAPH OF TENDON LIFT OFF LOAD / TIME ALL HOOPS (348 No.) P.V 2 PLATE 10 WYLFA

FIG. 4



GRAPH OF TENDON LIFT OFF LOAD / TIME TOP CAP (218 No.) P.V.1 PLATE 5 WYLFA

FIG. 5

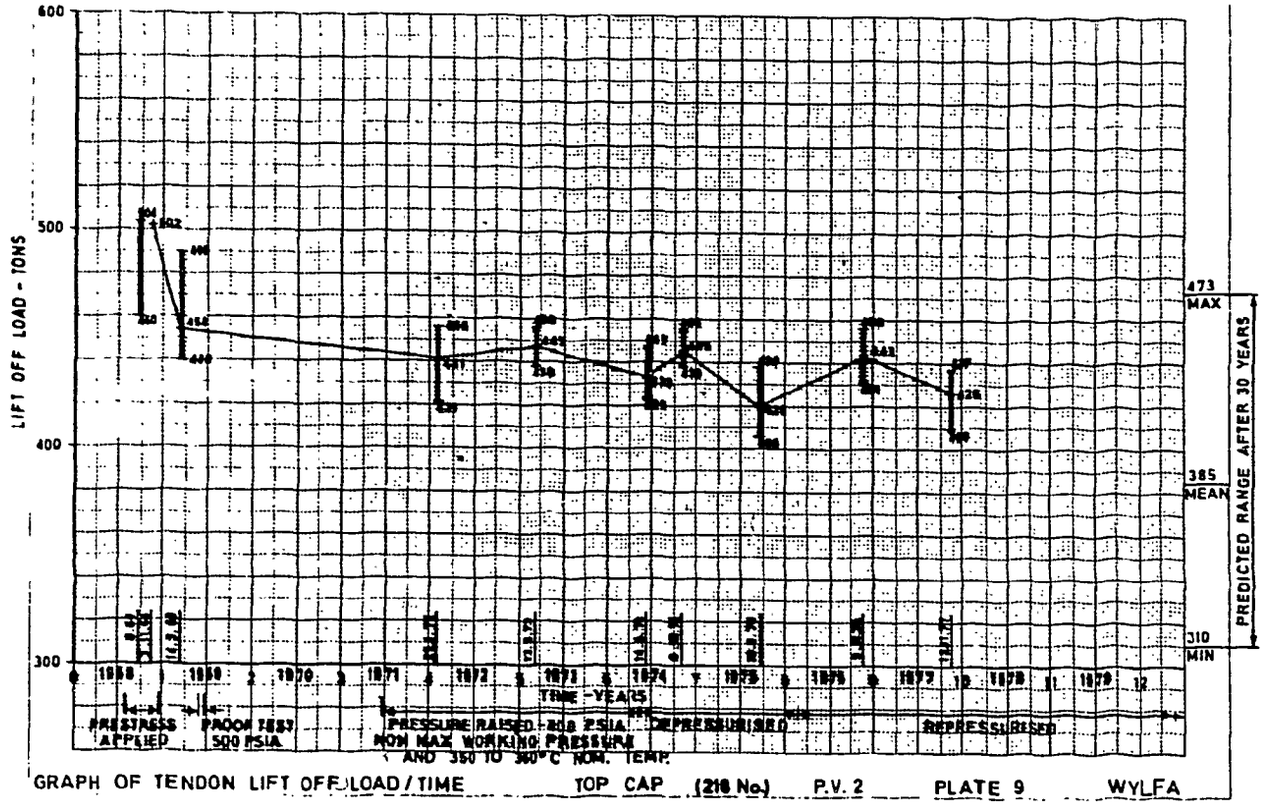

LIFT OFF LOAD - TONS
600
500
400
300
473
MAX
385
MEAN
310
MIN
PREDICTED RANGE AFTER 30 YEARS
0 1968 1969 2 1970 3 1971 4 1972 5 1973 6 1974 7 1975 8 1976 9 1977 10 1978 11 1979 12
TIME - YEARS
PRESTRESS APPLIED
PROOF TEST 500 PSIA
PRESSURE RAISED - 400 PSIA NOM MAX WORKING PRESSURE AND 350 TO 360°C NOM. TEMP.
DEPRESSURISED
REPRESSURISED
GRAPH OF TENDON LIFT OFF LOAD / TIME TOP CAP (216 No.) P.V. 2 PLATE 9 WYLFA

FIG. 6

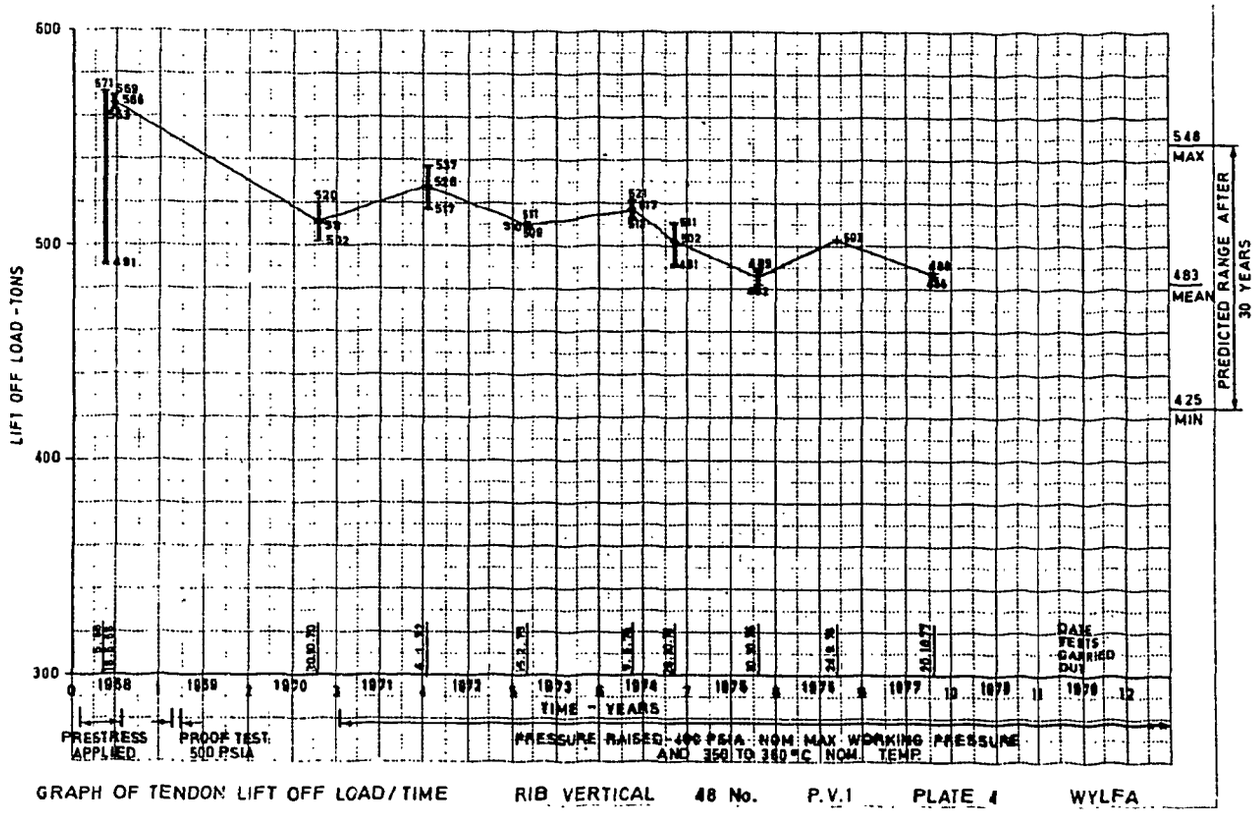

LIFT OFF LOAD - TONS
600
500
400
300
548
MAX
483
MEAN
425
MIN
PREDICTED RANGE AFTER 30 YEARS
0 1968 1969 2 1970 3 1971 4 1972 5 1973 6 1974 7 1975 8 1976 9 1977 10 1978 11 1979 12
TIME - YEARS
DATE TESTS CARRIED OUT
PRESTRESS APPLIED
PROOF TEST 500 PSIA
PRESSURE RAISED - 400 PSIA NOM MAX WORKING PRESSURE AND 350 TO 360 °C NOM TEMP.
GRAPH OF TENDON LIFT OFF LOAD / TIME RIB VERTICAL 48 No. P.V.1 PLATE 4 WYLFA

FIG. 7

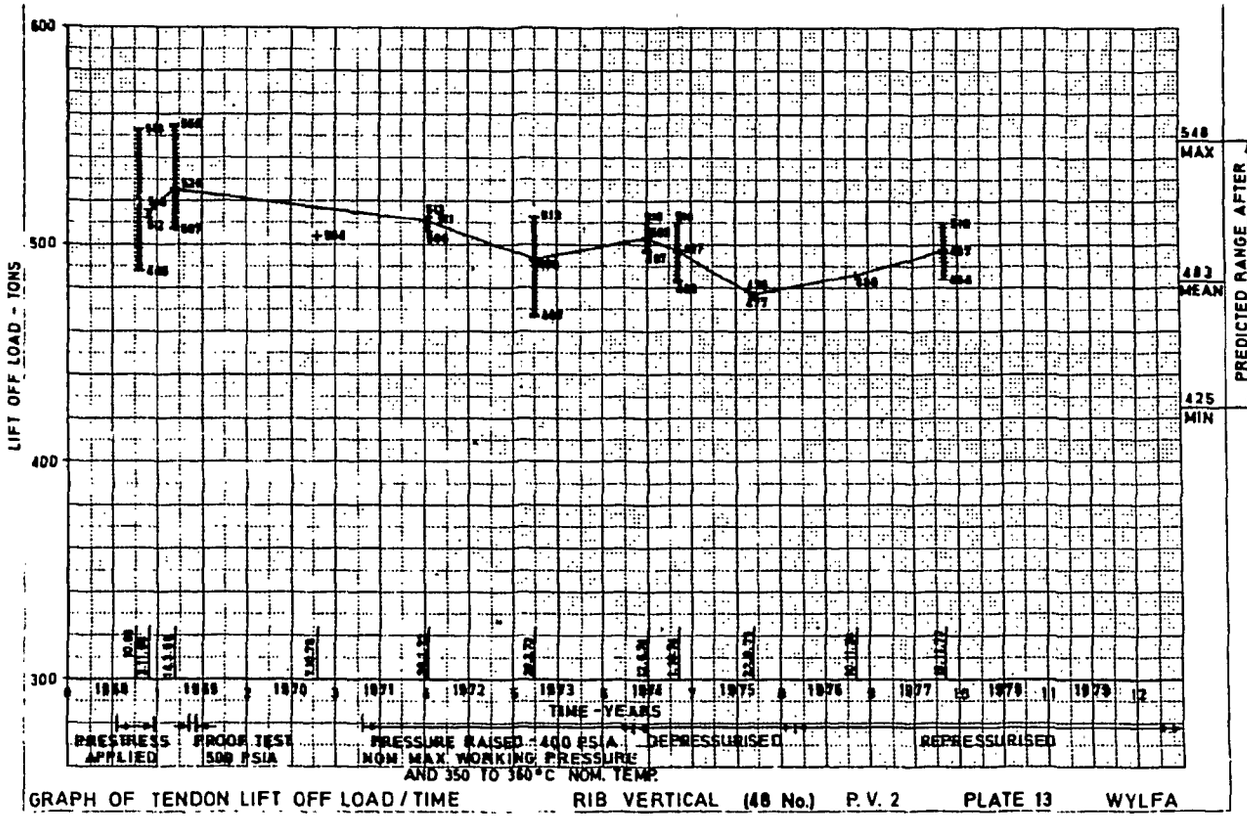

LIFT OFF LOAD - TONS
600
500
400
300
548
MAX
483
MEAN
425
MIN
PREDICTED RANGE AFTER 30 YEARS
1968
1969
1970
1971
1972
1973
1974
1975
1976
1977
1978
1979
TIME - YEARS
PRESTRESS APPLIED
PROOF TEST 500 PSIA
PRESSURE RAISED 400 PSIA NOM MAX WORKING PRESSURE AND 350 TO 360°C NOM. TEMP.
DEPRESSURISED
REPRESSURISED
GRAPH OF TENDON LIFT OFF LOAD / TIME
RIB VERTICAL (48 No.) P.V. 2
PLATE 13
WYLFA

FIG. 8

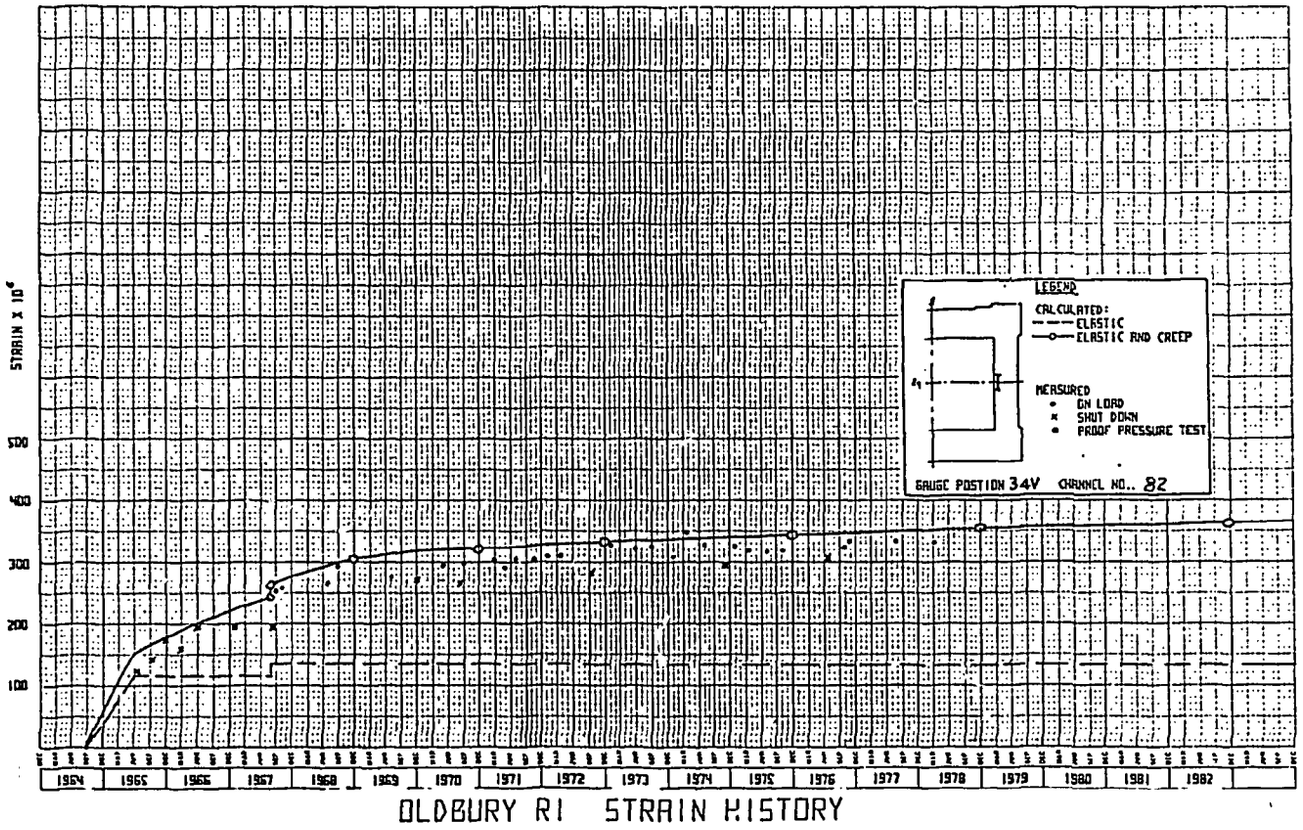

STRAIN X 10⁶
500
400
300
200
100
LEGEND
CALCULATED:
ELASTIC
ELASTIC AND CREEP
MEASURED
ON LOAD
SHUT DOWN
PROOF PRESSURE TEST
GAUGE POSTION 34V
CHANNEL NO.. 82
1964
1965
1966
1967
1968
1969
1970
1971
1972
1973
1974
1975
1976
1977
1978
1979
1980
1981
1982
OLDBURY R1 STRAIN HISTORY

FIG. 9

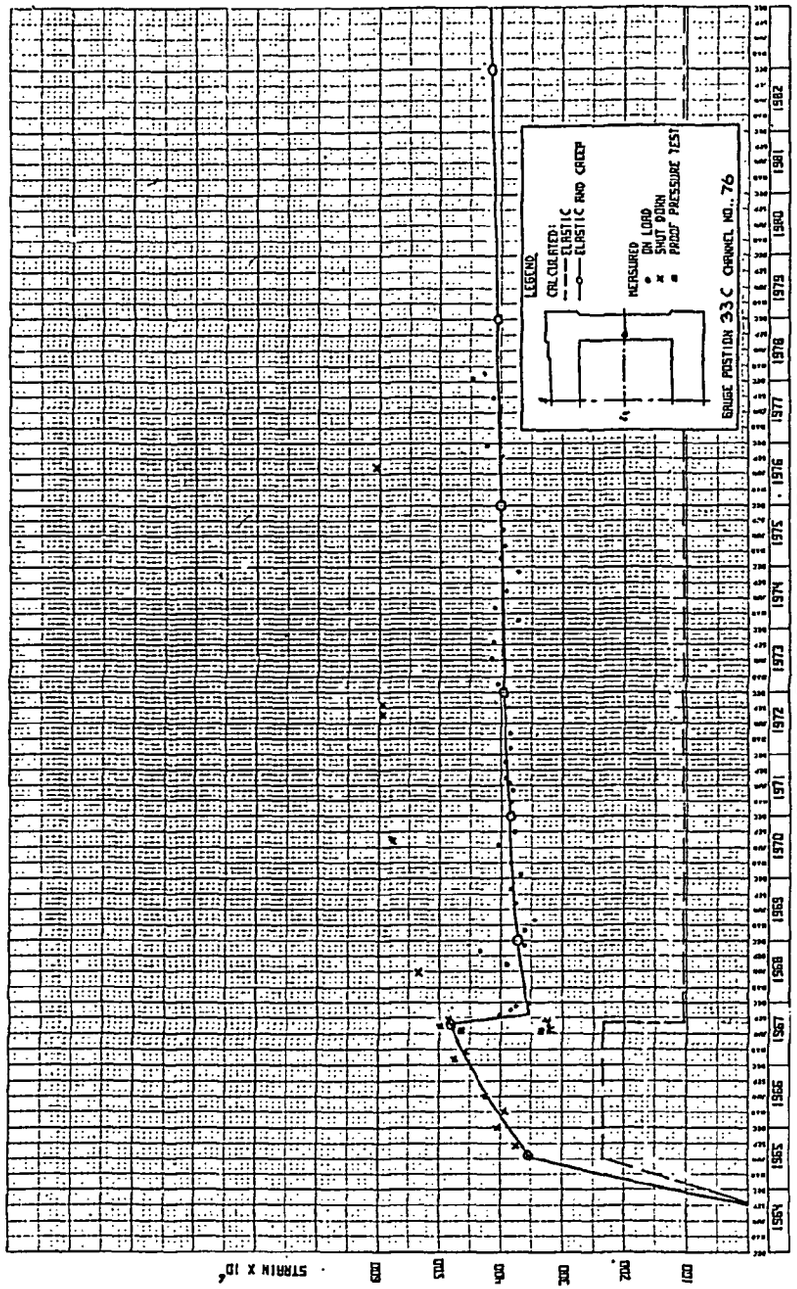


FIG. 10

PCPV INSTRUMENTATION AND MEASUREMENT TECHNIQUES AT ELEVATED TEMPERATURES

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1. INTRODUCTION

At Seibersdorf Research Center a prototype PCPV with hot liner was built [1]. It is designed for continuous operation with 100 bar inner pressure at an inner wall temperature of 300°C. Behind the liner the temperature level decreases from 300°C to 120°C within a zone of insulating concrete and stays at 100°C to 120°C within the prestressed concrete. Three periods of operation were performed till now [2]

- the period of construction and prestressing
- one year operation at elevated temperatures up to 120°C in the structural concrete
- pressure tests at 115 bar

During all periods of operation the PCPV was monitored by an extensive instrumentation both for comparison with the design calculations and for safety surveillance [3].