

SNO-STR-92-42

Investigation of Stress Associated with Cycling Acrylic in H_2O , Brine and D_2O ¹

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Abstract

Acrylic blocks which had been instrumented with encapsulated strain gauges were cycled between pure H_2O , 1% brine and pure D_2O . Comparison with a similarly instrumented acrylic block constantly immersed in pure H_2O indicates that that cycling acrylic between these different liquids does not introduce any measurable additional stress.

1 Introduction

Acrylic absorbs different liquids at different rates and in doing so it expands according to the type and amount of liquid absorbed. The acrylic vessel of

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the Sudbury Neutrino Observatory (SNO) will be surrounded by ultra pure H_2O and over its design life of 10 years will contain either pure water, D_2O or varying concentrations of "heavy brine" (D_2O plus up to 0.25% NaCl). Although these liquids are not radically different, it has been suggested that slight differences in absorption/desorption or enhanced desorption due to osmotic effects attributed to the NaCl may result in undesirable stresses occurring in the acrylic. The rate of absorption of both D_2O and H_2O and the associated expansion of acrylic have been studied by the SNO collaboration [1] and no significant differences found.

To study the possibility of enhanced desorption in heavy brine, test specimens which had previously been used to study stress associated with water absorption and desorption were used [2]. These test specimens consisted of three cast acrylic blocks with strain gauges encapsulated in the center and close to the surface of the blocks. Upon completion of these absorption/desorption tests, the specimens were loaded with water and exposed to the brine solutions in the manner described below.

2 Experimental Technique

Three, 4 inch diameter by 1.5 inch thick acrylic discs were cast with strain gauges embedded approximately 1/16 inch below each surface and one at the center of the disc. Figure 1 shows the location of the strain gauges in the acrylic blocks.

The technique of embedding strain gauges in acrylic is somewhat novel, but gave reliable results when used to measure locked-in stress in acrylic bond joints [3].

2.1 Specimen Conditioning

The samples were immersed in water at 60°C for 20 days to simulate 5 years actual exposure in the 10°C water of SNO. Then for a period of 35 days, one sample was exposed to an arid atmosphere, one to saturated vapor and one remained in water as a reference. This process is described in detail in SNO-STR-92-13 [2]. At the end of these tests the two specimens that were exposed to water and saturated vapor remained loaded with water while the specimen

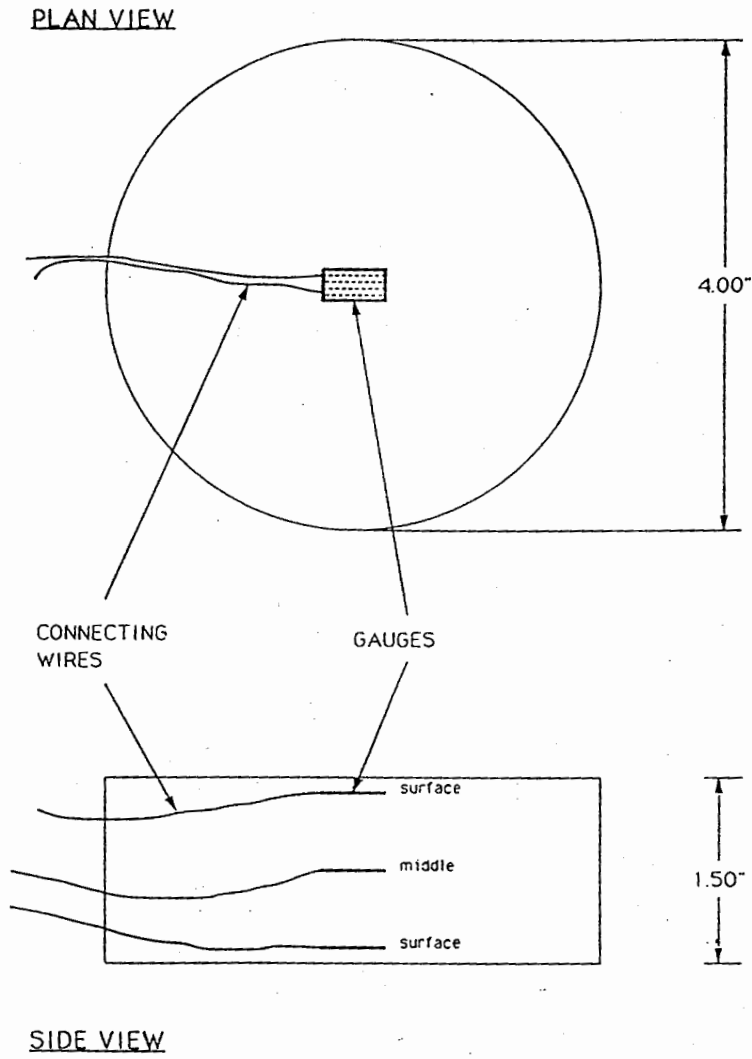


Figure 1: Location of the strain gauges in the acrylic blocks.

that was exposed to air was dehydrated. It is assumed that the specimens exposed to water and vapor were in a similar saturated condition of since their stress behavior was identical while exposed to these different environments. Further experiment then focused on these two saturated specimens

2.2 Data taking

The test specimen which had been immersed in water was left undisturbed to act as a reference. The test specimen which had been exposed to the saturated vapor was immersed in brine consisting of 1% by weight of NaCl dissolved in high purity H_2O , for a period of 31 days. The specimen was then removed from the brine and placed in high purity H_2O for a further period of 31 days. Finally the sample was transferred to pure D_2O for 31 days. Throughout these periods the resistances of the strain gauges were recorded at regular intervals to an accuracy of a part in 10^6 along with the temperature of the various baths to an accuracy of $\pm 0.1^\circ C$.

3 Results

Since the baths were not temperature stabilized they followed the variation of the ambient temperature of the laboratory as can be seen in figure 2.

Also shown in figure 2 is the resistance of the strain gauge located in the reference test specimen which was kept constantly immersed in water. It can be seen that the variation in resistance of the gauge closely follows the variation in temperature, indicating that the resistance changes are attributable to dimensional changes associated with the temperature change in the specimen.

Figure 3 shows the time history of the gauge resistance for the test specimens.

The changes in the bath types for the test specimens are indicated. It can be seen that the changes in the test specimens are essentially identical to that in the reference specimen, suggesting that these changes are also attributable to variation in the temperature of the specimens.

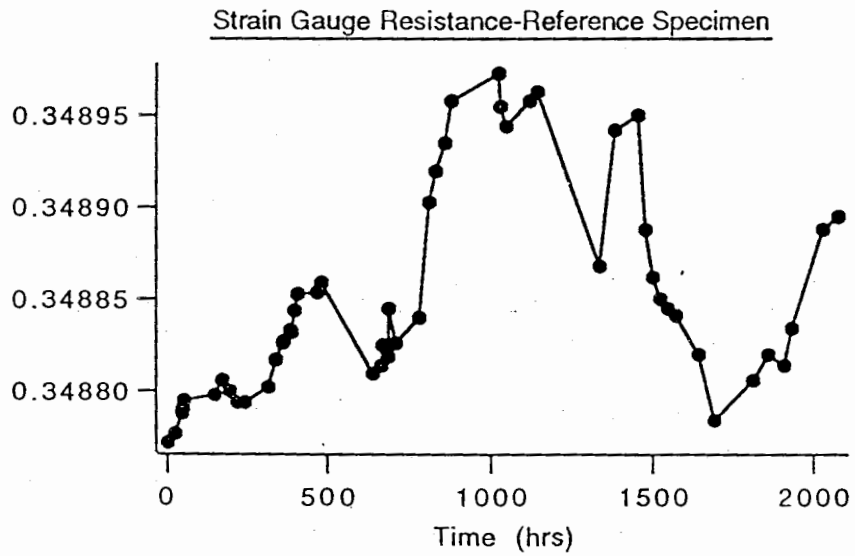
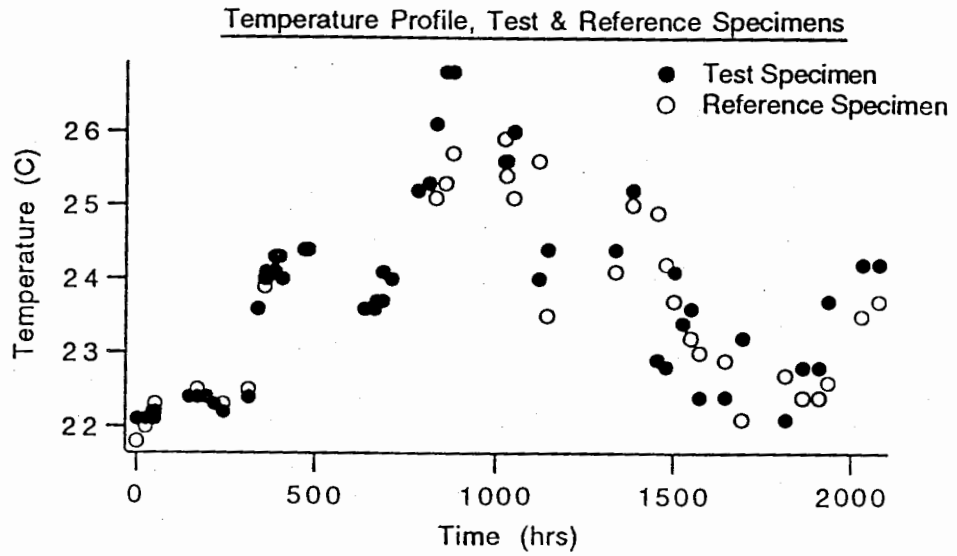


Figure 2: Variation in temperature of the water baths and resistance of the reference strain gauge throughout the duration of the tests.

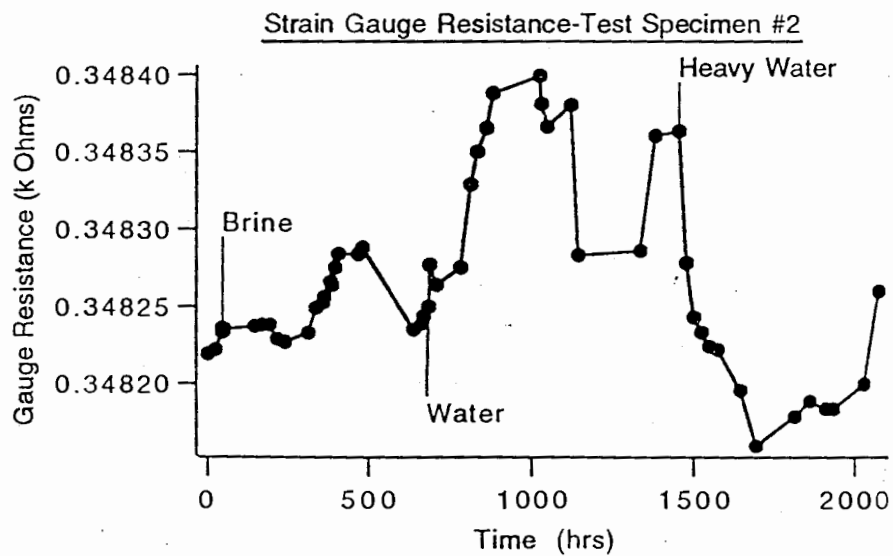
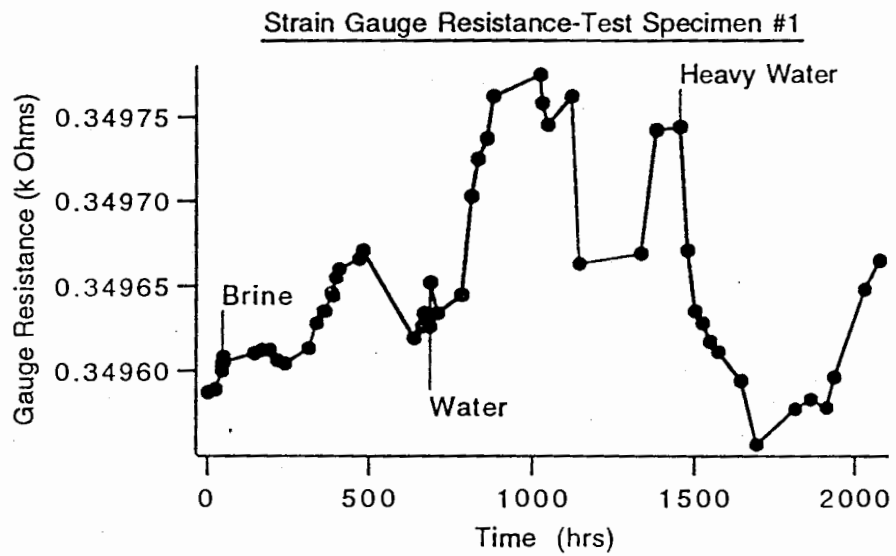


Figure 3: Variation in the resistance of the test specimen strain gauges throughout the duration of the tests.

If the changes in the resistance of the gauges are truly attributable to temperature related dimensional changes, then knowing the coefficient of expansion of acrylic and the gauge factor of the strain gauges, these changes of gauge resistance can be compensated for. Any remaining change in the gauge resistance, which shows correlation with the change in the bath type could then be possibly attributed to absorption or desorption of liquid from the acrylic. The coefficient of thermal expansion (ρ) of acrylic at 23°C was taken as 6×10^{-5} per °C. The dimensional change, $\Delta L/L$, for a T degree change in temperature is therefore given by,

$$\Delta L/L = \rho T$$

and the change in resistance of the strain gauge, $\Delta R/R$ is given by,

$$\Delta R/R = GF \cdot \Delta L/L$$

where GF is the gauge factor relating change in length to change in resistance. The temperature corrected resistances for the reference and test specimens is shown in figure 4.

All plots show considerable structure, including the reference specimen, which in theory should be relatively flat if the temperature compensation was correctly applied. Therefore it is not possible to say that any change in resistance is due entirely to the dimensional changes resulting for the absorption or desorption of liquid. The resistance of the reference specimen changed by +0.058%. The resistance of test specimens 1 and 2 changed by +0.054%, -0.009% and +0.052%, -0.019%, (note that the maximum occurs at the same instant of time for all three specimens, which suggests a common cause). It is reasonable to assume that the changes observed in the reference specimen is due primarily to temperature change since the profiles of the two plots are almost identical. It would also be reasonable to assume the same for the test specimens, however, to be conservative we can claim that all the variation in the resistance of the gauge in the test specimens is due to absorption or desorption. Since the percentage change in the resistance of the test specimen and the reference specimens strain gauges are approximately the same,

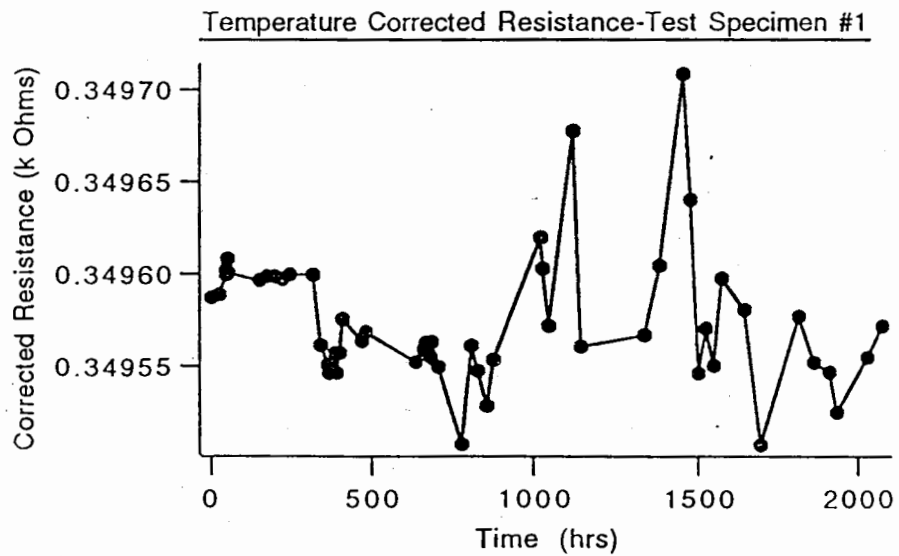
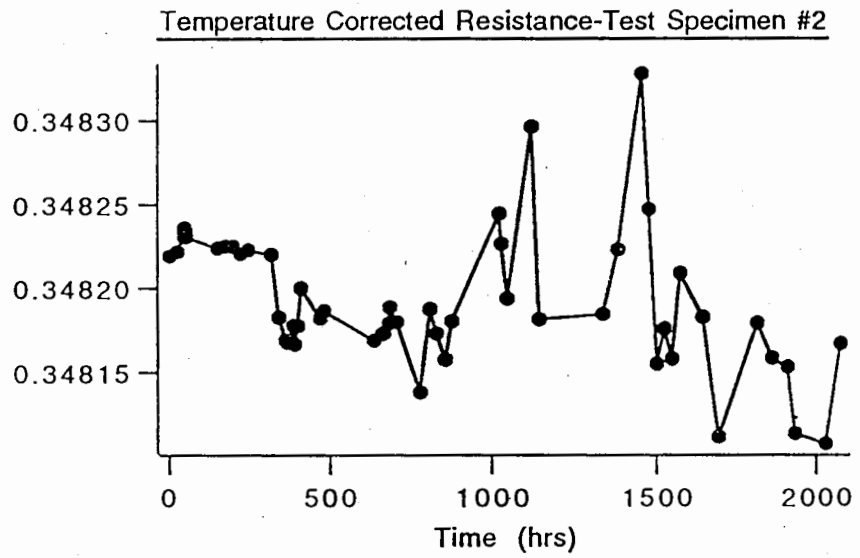
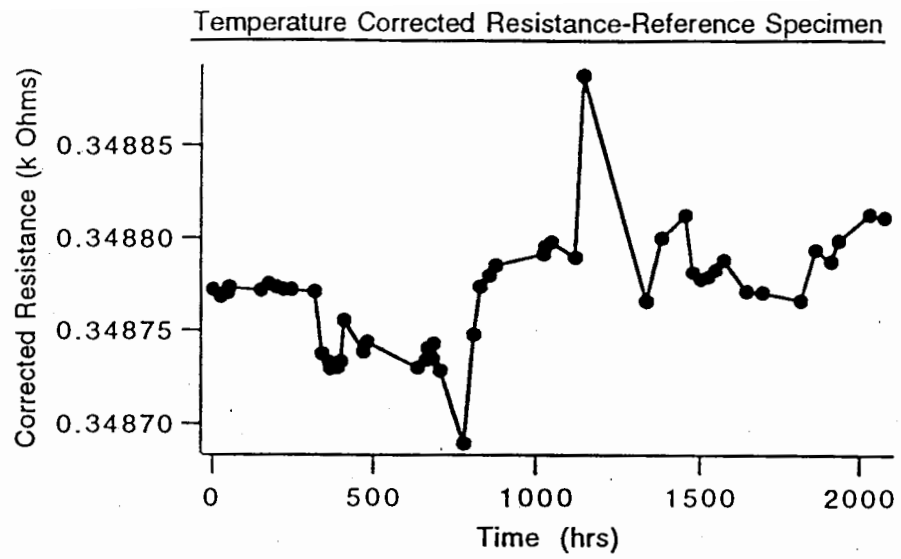


Figure 4: The temperature corrected resistance of the reference and test specimen strain gauges.

it is conservative to say that the dimensional change due to absorption or desorption of liquid is comparable to a temperature change of approximately $\pm 2^\circ\text{C}$.

4 Conclusions

Due to poor planning the experiment was unable to make a quantitative measurement of any stress that arose from absorption or desorption of liquids in acrylic. This failure is most probably due to inadequate monitoring of the temperature of the specimen baths. However it is possible to say that any dimensional change does not exceed that attributable to a small temperature change. Proper planning of any future experiment should probably include embedding a low mass thermocouple in a location similar (but not the same as) the strain gauge, thus enabling a more precise correction for thermal expansion.

References

- [1] W.F. Davidson and E.D. Earle, D_2O absorption in Acrylic, July 1988, unpublished. P. Doe, Comparison of D_2O and H_2O Absorption in Acrylic, SNO-STR-92-41, May 1992, unpublished.
- [2] P. Doe, Stress in Acrylic due to Water Absorption and Desorption, SNO-STR-92-13, March 1992, unpublished.
- [3] P. Doe and K. Doughty, Stress in Acrylic Bond Joints, SNO-STR-91-59, March 1991, unpublished.

A Raw Data

Point	Time_hrs.y	Water_Ref.y	Brine_1.y	Brine_2.y	WaterTemp.y	Brine_temp.y
0	0	0.348772	0.349587	0.348219	21.8	22.1
1	24	0.348777	0.349589	0.348222	22	22.1
2	45	0.348788	0.3496	0.348233	22.2	22.1
3	46	0.348788	0.349604	0.348235	22.2	22.2
4	46.1	0.348789	0.349602	0.348236	22.2	22.1
5	49	0.348791	0.349608	0.348234	22.2	22.1
6	51	0.348795	0.349605	0.348235	22.3	22.2
7	147	0.348798	0.34961	0.348237	22.4	22.4
8	171	0.348806	0.349612	0.348238	22.5	22.4
9	195	0.3488	0.349612	0.348238	22.4	22.4
10	219	0.348794	0.349606	0.348229	22.3	22.3
11	243	0.348794	0.349604	0.348227	22.3	22.2
12	315	0.348802	0.349613	0.348233	22.5	22.4
13	339	0.348817	0.349628	0.348249	23.6	23.6
14	359	0.348826	0.349635	0.348253	23.9	24
15	363	0.348827	0.349635	0.348256	24	24.1
16	383	0.348833	0.349646	0.348266	24.1	24.1
17	387	0.348832	0.349644	0.348264	24.1	24.3
18	398	0.348844	0.349655	0.348275	24.3	24.3
19	407	0.348853	0.34966	0.348284	24	24
20	469	0.348854	0.349666	0.348284	24.4	24.4
21	479	0.348859	0.349671	0.348288	24.4	24.4
22	637	0.34881	0.349619	0.348235	23.6	23.6
23	663	0.348814	0.349626	0.348239	23.6	23.6
24	668	0.348825	0.349634	0.348244	23.7	23.7
25	685	0.348819	0.349626	0.34825	23.7	23.7
26	686	0.348845	0.349652	0.348277	24.1	24.1
27	709	0.348826	0.349634	0.348264	24	24
28	781	0.34884	0.349645	0.348275	25.2	25.2
29	810	0.348903	0.349703	0.348329	25.3	25.3
30	830	0.34892	0.349725	0.34835	25.1	26.1
31	858	0.348935	0.349737	0.348365	25.3	26.8
32	877	0.348958	0.349762	0.348388	25.7	26.8
33	1021	0.348973	0.349775	0.348399	25.9	25.6
34	1026	0.348955	0.349758	0.348381	25.4	25.6
35	1045	0.348944	0.349745	0.348366	25.1	26
36	1117	0.348958	0.349762	0.34838	25.6	24
37	1141	0.348963	0.349663	0.348283	23.5	24.4
38	1333	0.348868	0.349669	0.348286	24.1	24.4
39	1381	0.348942	0.349742	0.34836	25	25.2
40	1453	0.34895	0.349744	0.348363	24.9	22.9
41	1477	0.348888	0.349671	0.348278	24.2	22.8
42	1501	0.348862	0.349635	0.348243	23.7	24.1
43	1525	0.34885	0.349628	0.348233	23.4	23.4
44	1549	0.348845	0.349617	0.348224	23.2	23.6
45	1573	0.348841	0.349611	0.348222	23	22.4
46	1645	0.34882	0.349594	0.348196	22.9	22.4
47	1693	0.348784	0.349556	0.34816	22.1	23.2
48	1813	0.348806	0.349577	0.348179	22.7	22.1
49	1861	0.34882	0.349583	0.348189	22.4	22.8
50	1909	0.348814	0.349578	0.348184	22.4	22.8
51	1933	0.348834	0.349596	0.348184	22.6	23.7
52	2029	0.348888	0.349648	0.3482	23.5	24.2
53	2077	0.348895	0.349665	0.34826	23.7	24.2

Table 1: Table of raw data