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EVALUATION OF STRESSES IN WEB-STIFFENED CYLINDRICAL SANDWICH SHELLS SUBJECTED TO UNIFORM EXTERNAL PRESSURE

by

James A. Nott and Gerald D. Ward

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September 1965 Report 2092

EVALUATION OF STRESSES IN WEB-STIFFENED CYLINDRICAL SANDWICH SHELLS SUBJECTED TO UNIFORM EXTERNAL PRESSURE

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S-F013 03 02
Task 1956

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ABSTRACT

Four cylindrical web-stiffened sandwich models were tested under external hydrostatic pressure. Experimental strains were recorded on both outside and inside shells and compared with theoretical strains computed from existing formula developed at the David Taylor Model Basin. The differences between experimental and theoretical results were within the range of experimental error.

ADMINISTRATIVE INFORMATION

This investigation was conducted under the sponsorship of the Bureau of Ships, Code 442, Project No. S-F013 03 02, Task 1956.

INTRODUCTION

In recent years, the Navy has shown great interest in the exploration of the depths of the ocean by means of deep-diving manned submarines. Since the pressure hulls of these submarines are weight critical and often involve the use of thick plates, new types of structures are being investigated to reduce fabrication difficulties and to produce hulls with improved strength-to-weight ratio characteristics. One of these structures is a cylindrical sandwich shell consisting of two concentric cylinders connected by annular webs; this type is illustrated in Figure 1.

To evaluate the structural strength of a cylindrical sandwich shell, the locations and magnitudes of maximum stresses must be determined. Analyses for stress distribution in sandwich shells loaded under external hydrostatic pressure were carried out in References 1 and 2.* The maximum stresses occur in the shells at locations next to the webs and midway between adjacent webs. The stresses in these locations are of interest for the purposes of structural design. A graphical analysis for determining

*References are listed on page 13.

these stresses is also shown in Reference 2. From the stresses obtained by use of this analysis,[2] theoretical strains can be computed and compared directly with observed data.

To evaluate the theoretical analysis, four sandwich-type models were fabricated from epoxy resin and tested under external hydrostatic pressure. Strains were recorded at locations next to the webs and midway between the two webs on both outside and inside shells. A longitudinal strain distribution along a web spacing was also measured in one model. This report presents the experimental strains and a comparison of observed and theoretical values.

DESCRIPTION OF MODELS

Four models, designated SER-1, SER-2, SER-3, and SER-4, were fabricated from epoxy resin. The composition of the epoxy resin was 50 percent Versamid 125 and 50 percent Epon 828. A sandwich-type configuration for the models was constructed by joining a series of channel-shaped rings together. These rings were individually formed by pouring liquid resin into a mold, allowing the resin to harden at room temperature for 24 hr, and then post curing the rings in an oven for 8 hr at a temperature of 130 F. Each ring was then machined to the final required dimensions. The dimensions of these rings are shown in Figure 1.

Specimens were made to determine the material properties of the epoxy resin. A Young's modulus of 328,000 psi and a Poisson's ratio of 0.4 were determined from separate tests using a compressometer, deflectometer, and a Tuckerman optical strain gage. These values were used for determining the theoretical strains presented in this report.

The design of the four models was oriented to study the effects of shell lengths on stress distributions in the sandwich shells. The basic design of the shell thicknesses and the radii was fashioned after a geometry for a proposed deep-diving oceanographic hull structure.[3] On each of the four models, the outside radius was 5.40 in., the inside radius was 4.11 in., the outside and inside shell thicknesses were 0.163 in., and the web thickness was 0.138 in. Only the web spacing in the four models varied. The spacings (dimension L_f shown in Figure 1) were 0.75 in. for Model SER-1, 1.00 in. for Model SER-2, 1.25 in. for Model SER-3, and 1.50 in. for Model SER-4.

INSTRUMENTATION AND TEST PROCEDURE

Each model was instrumented with foil-type strain gages 0.063 in. in length. These gages were located on the two shells of each model in areas of critical stress. The middle ring (Ring 5) on each model was instrumented at locations next to the web and midway between adjacent webs on the 0- and 180-deg orientation. Check points were instrumented at locations midway between the webs on an adjacent ring (Ring 6). Additional gages were also placed on the outside surfaces of the models next to the webs at the 45-, 90-, and 135-deg orientations on Ring 5. Model SER-2 was instrumented with additional longitudinal gages covering the area between midbay and the web juncture. After the models were instrumented, the rings were bonded together with the same type of epoxy resin used in the models.

Figure 2 shows the four models before testing. The models were tested hydrostatically in a pressure tank to obtain elastic strain data. Two pressure runs were made on each model to a pressure of 100 psi, and strains were read at each 10-psi increment.

TEST RESULTS

The strain recordings obtained during the second run of each test were used to compute strain sensitivities. These strains were plotted as a function of x/ℓ (where x is the distance from the web to the center of the strain gage and ℓ is the unsupported length of the bay) and are shown in Figures 3 through 10. The solid line represents theoretical strains computed by utilizing Reference 2. The dotted vertical lines in these figures represent the fillet at the intersection of the web and shell.

DISCUSSION

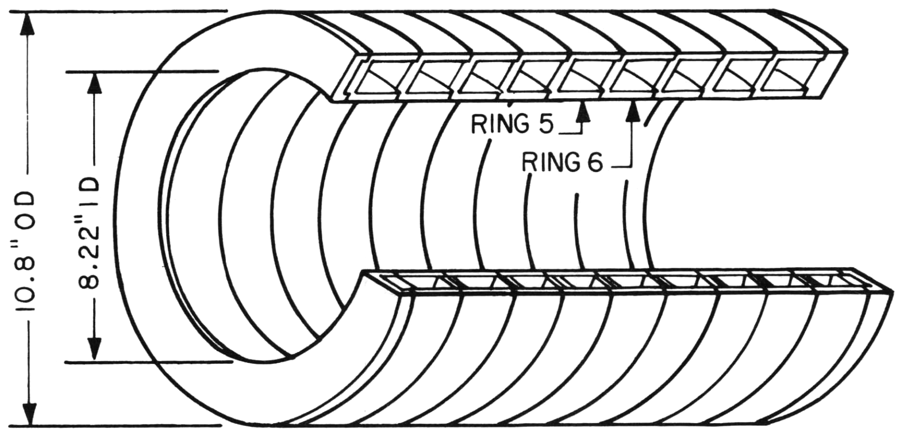
The primary purpose of this investigation was to establish experimental verification for the analysis of deformations in web-stiffened sandwich cylinders.

In general, excellent agreement was obtained as shown in Figures 3 through 10. Data on the longitudinal strain gradient between webs provided by the additional longitudinal gages on SER-2 agreed well with the theoretical values.

The largest discrepancies occurred at the intersection of the shell and web where the fillet was located. This fillet (Figure 1) was incorporated to reduce the effects of shear and possible stress concentrations due to undercutting or voids that could have developed during fabrication. Observation of the experimental strains suggested that a portion of the fillet acted as a stiffener. This effect is less noticeable or negligible on the two models with longer bay lengths.

CONCLUSION

Theoretical analysis as given in Reference 2 will adequately predict the elastic axisymmetric behavior in web-stiffened cylindrical sandwich shells subjected to hydrostatic pressure.



MODEL LENGTH	
MODEL	Lf(IN)
SER-1	0.75
SER-2	1.00
SER-3	1.25
SER-4	1.50

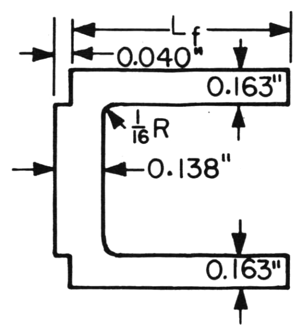


Figure 1 - Model Dimensions

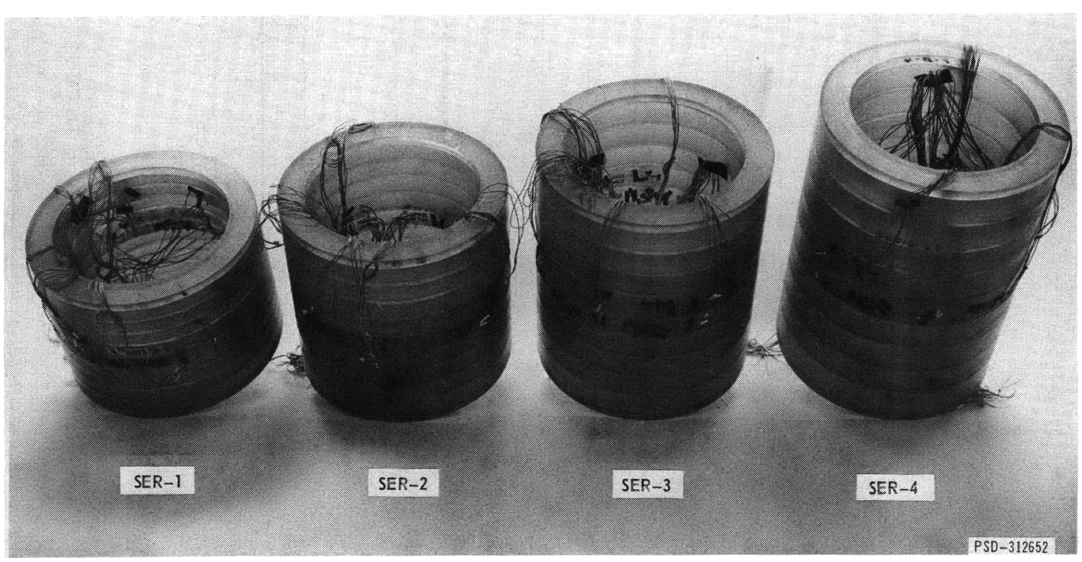


Figure 2 - SER Models after Instrumentation

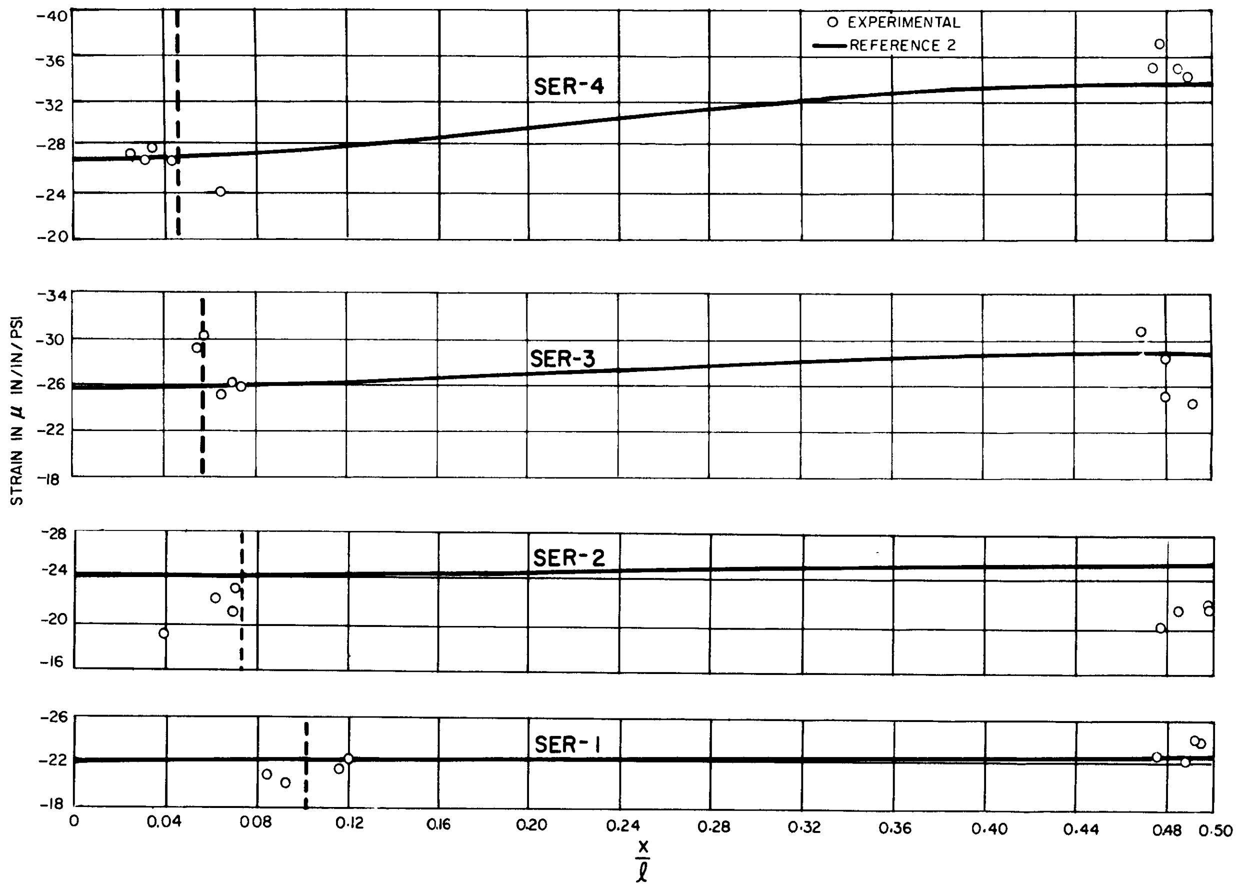


Figure 3 - Circumferential Strains on Outer Surface of Outside Shell

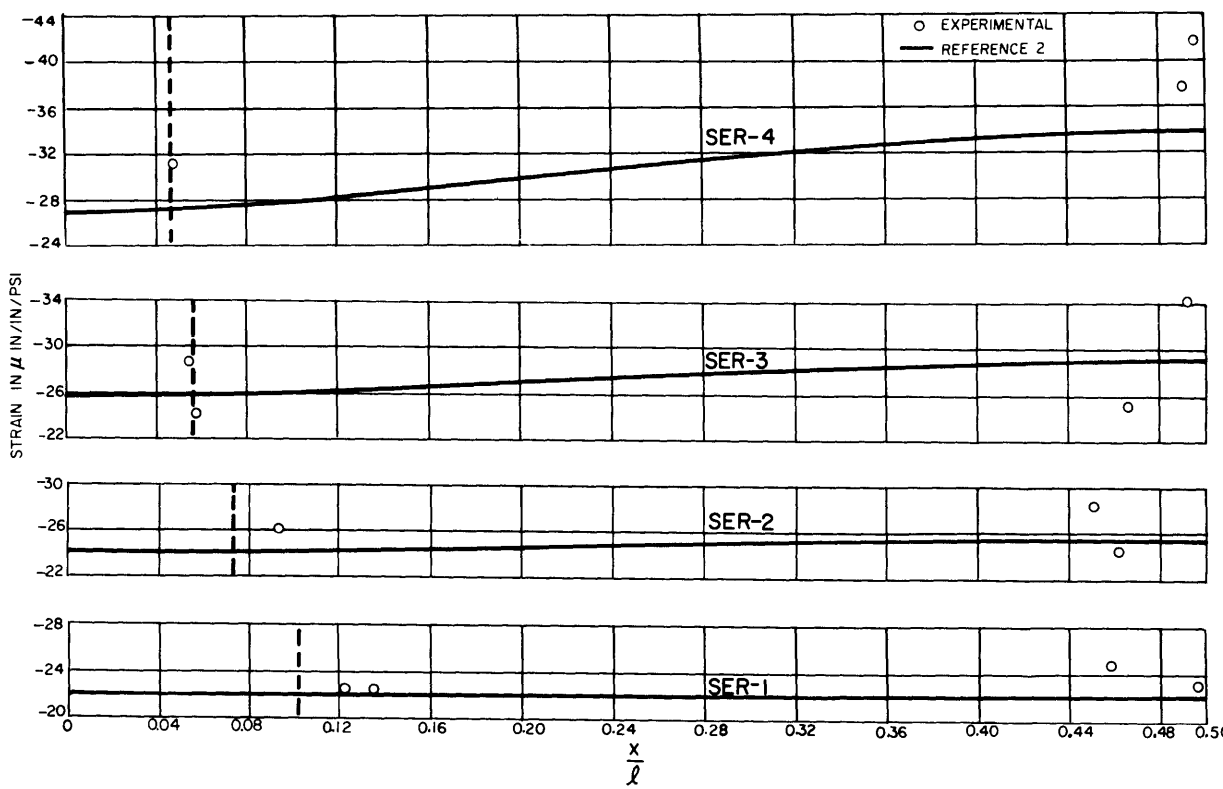


Figure 4 - Circumferential Strains on Inner Surface of Outside Shell

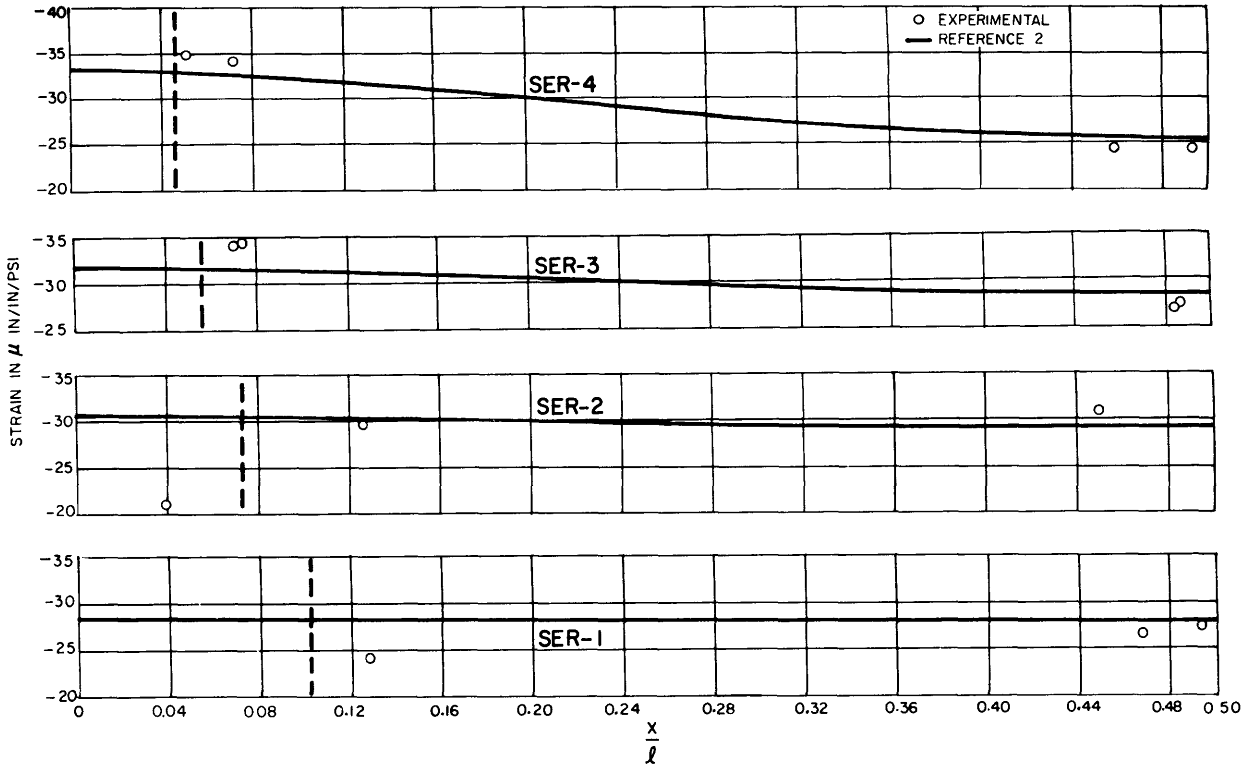


Figure 5 - Circumferential Strains on Outer Surface of Inside Shell

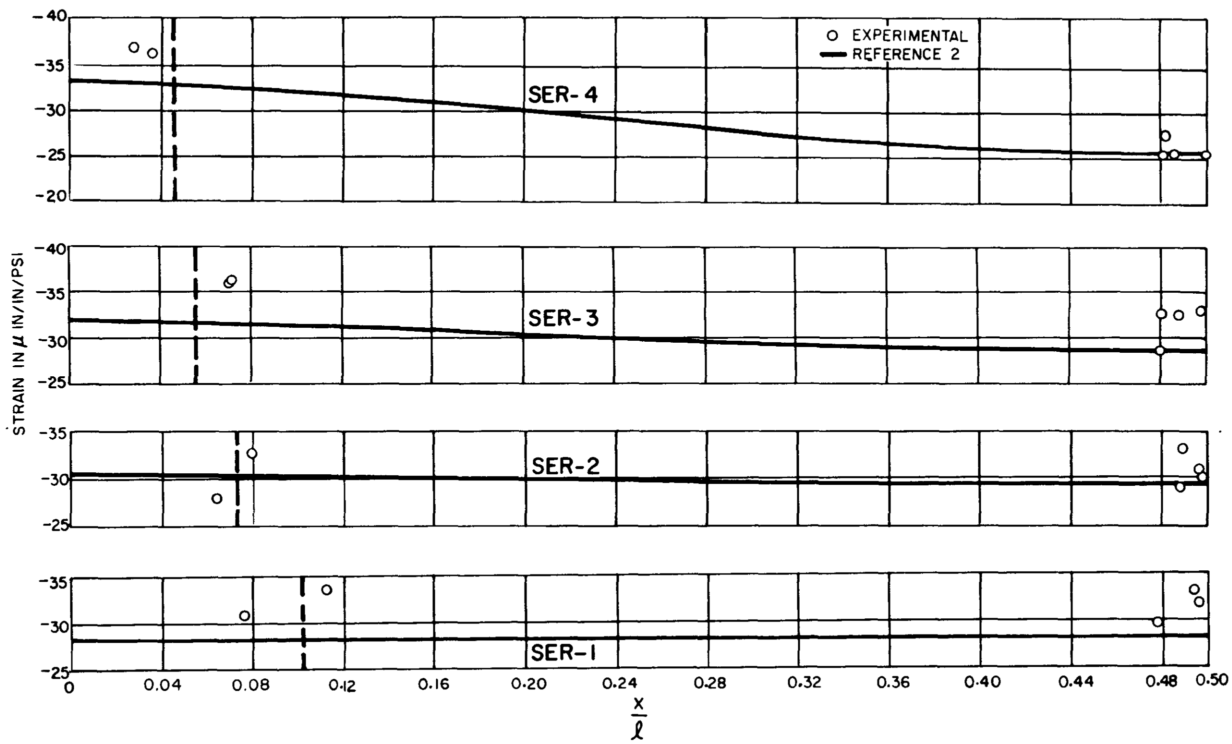


Figure 6 - Circumferential Strains on Inner Surface of Inside Shell

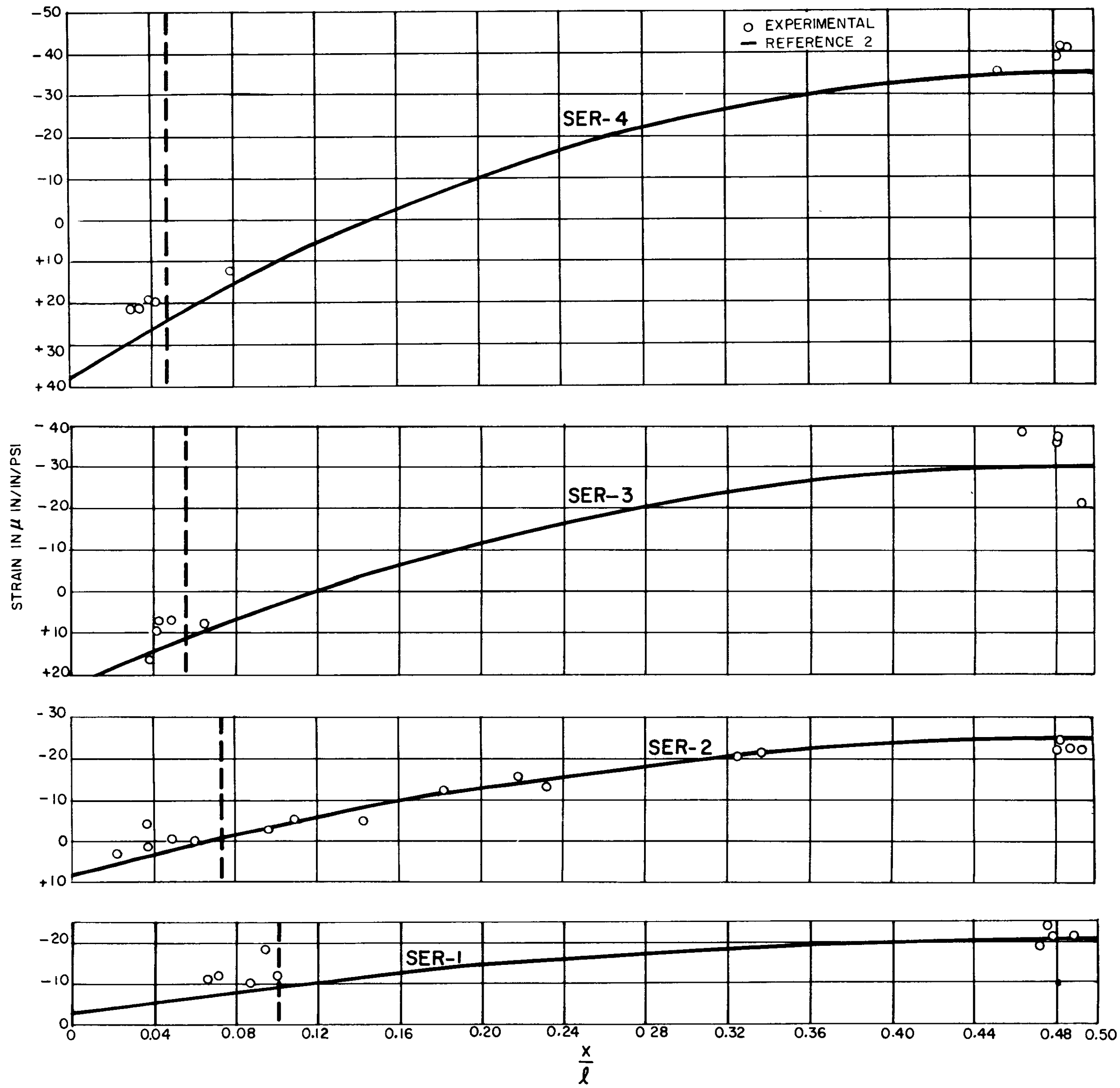


Figure 7 - Longitudinal Strains on Outer Surface of Outside Shell

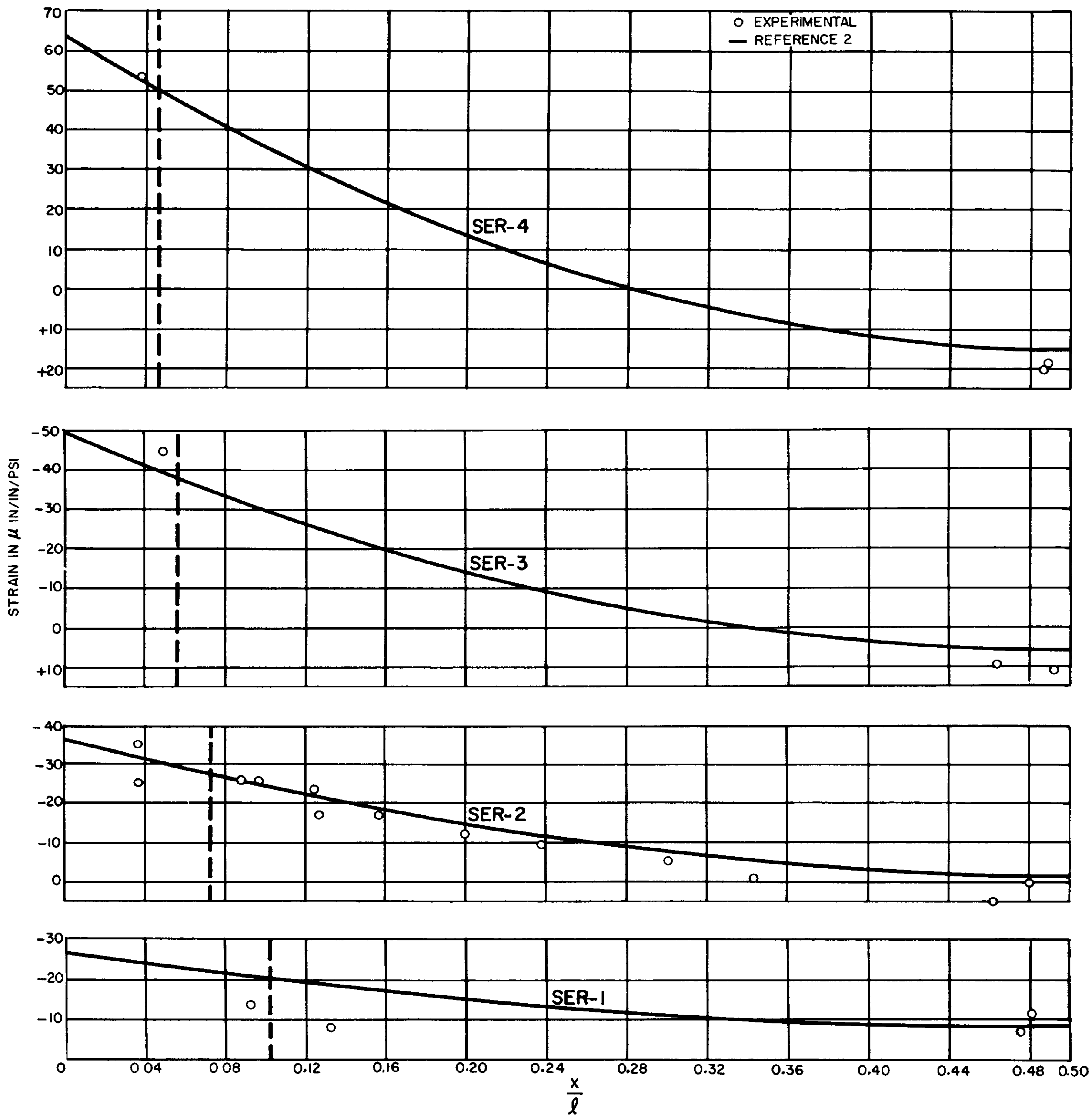


Figure 8 - Longitudinal Strains on Inner Surface of Outside Shell

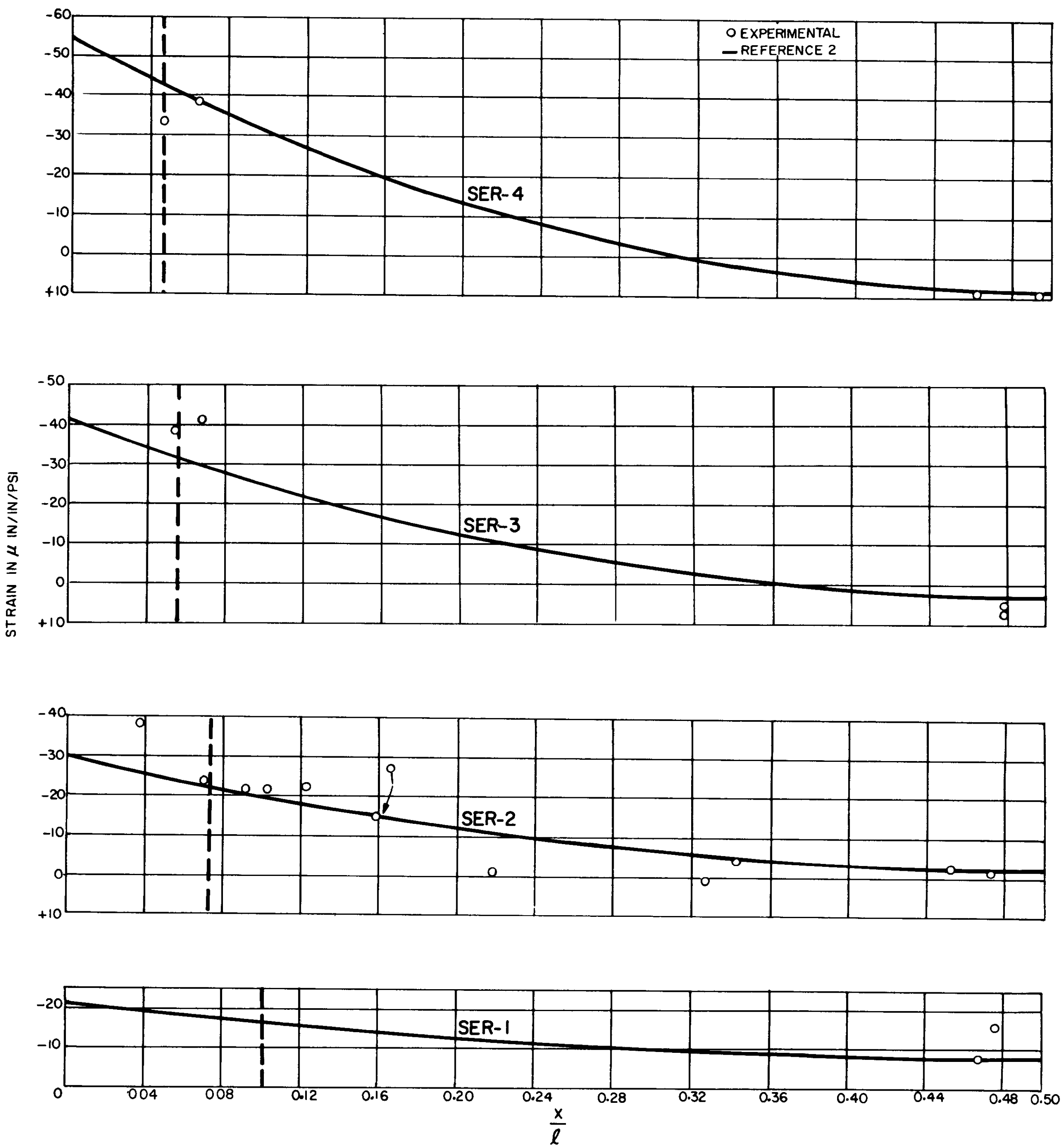


Figure 9 - Longitudinal Strains on Outer Surface of Inside Shell

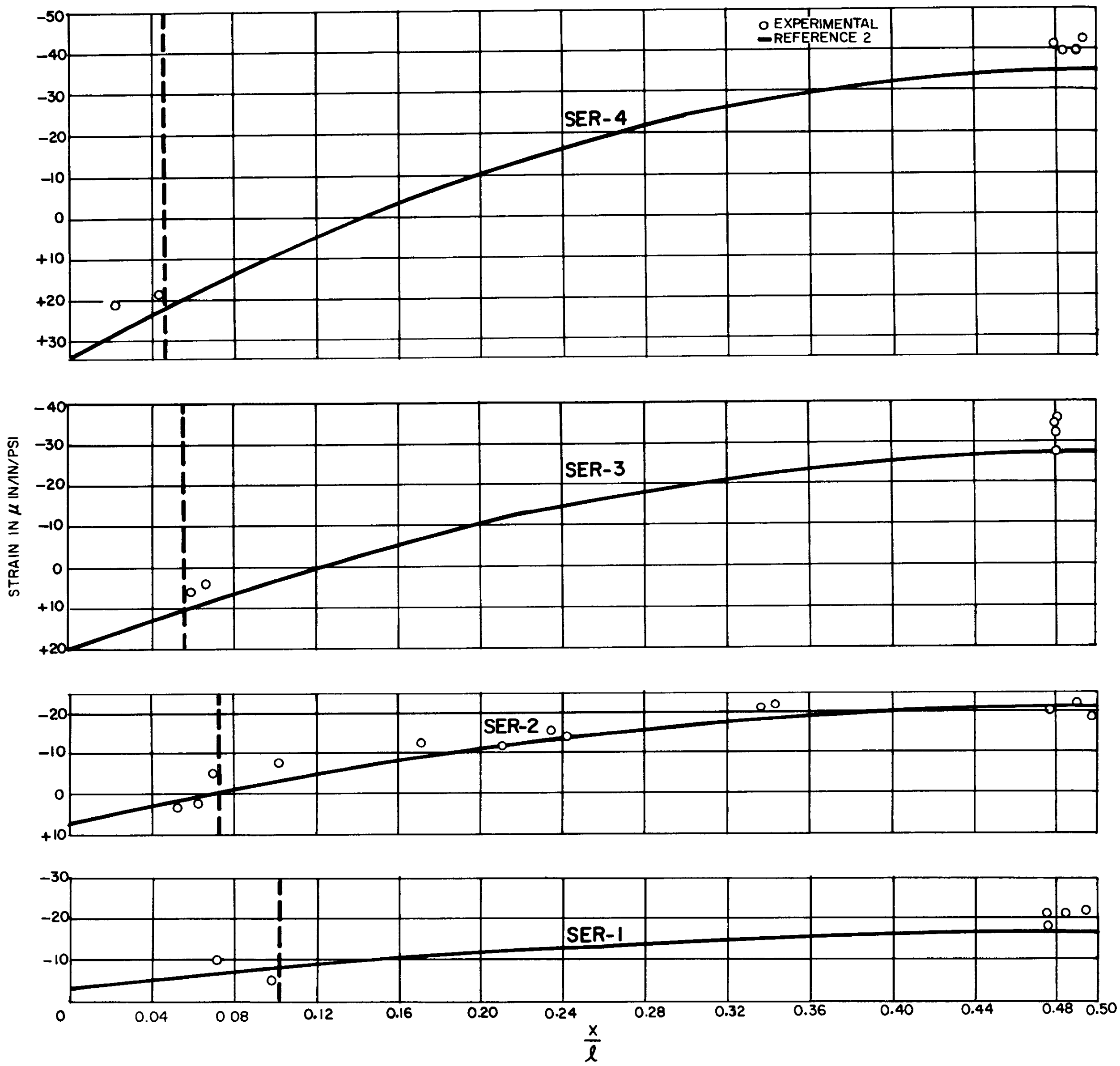


Figure 10 - Longitudinal Strains on Inner Surface of Inside Shell

REFERENCES

1. Pulos, John G., "Axisymmetric Elastic Deformation and Stresses in a Web-Stiffened Sandwich Cylinder under External Hydrostatic Pressure," David Taylor Model Basin Report 1543 (Nov 1961).

2. Nott, James A., "Graphical Analysis for Maximum Stresses in Sandwich Cylinders under External Uniform Pressure," David Taylor Model Basin Report 1817 (May 1964).

3. Hom, Kenneth and Blumenberg, William F., "Hydrostatic Tests of Structural Models for Preliminary Design of a Web-Stiffened Sandwich Pressure Hull," David Taylor Model Basin Report 1763 (Sep 1963).

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Four cylindrical web-stiffened sandwich models were tested under external hydrostatic pressure. Experimental strains were recorded on both outside and inside shells and compared with theoretical strains computed from existing formula developed at the David Taylor Model Basin. The differences between experimental and theoretical results were within the range of experimental error.

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