BNL-101949-2014-TECH

AD/RHIC/37;BNL-101949-2013-IR

Mechanical Properties for the G-11CR Tubes Used in the RHIC Magnet Support Leg

D. P. Brown

April 1988

Collider Accelerator Department

Brookhaven National Laboratory

U.S. Department of Energy

USDOE Office of Science (SC)

DISCLAIMER

Accelerator Development Department
BROOKHAVEN NATIONAL LABORATORY
Associated Universities, Inc.
Upton, New York 11973

AD/RHIC-37

RHIC TECHNICAL NOTE NO. 37

Mechanical Properties for the G-11CR Tubes Used in the RHIC Magnet Support Leg

D. P. Brown
R. J. Gibbs
K. C. Wu
D. L. Horne

April 21, 1988

RHIC Technical Note

MECHANICAL PROPERTIES FOR THE G-11CR TUBES USED IN THE RHIC MAGNET SUPPORT LEG

D. P. Brown
R. J. Gibbs
K. C. Wu
D. L. Horne

ABSTRACT

The G-11CR epoxy-woven-glass laminate used in the inner and the outer tubes of the RHIC support leg is a composite material. Unlike metals, the properties of the composite material depend on its composition and the manufacturing process, and need to be verified to perfect the design. Universal tensile test machines are used to compress these tubes longitudinally and radially. The results for the elastic modulus in compression and in flexure are in good agreement with manufacturer's published data on machined G-11CR rods. The flexural strength, approximately 38,000 psi, also agrees with conservative numbers available in the literature.

G-11CR TUBES

The RHIC folded post leg consists of one inner tube and one outer tube. These tubes have a fine finish with tight tolerance and are assembled into the post leg through a series of shrink fit joints. Spaulding Fibre Company, located in Tonawanda, New York, is the supplier of these tubes. The dimensions for these G-11CR tubes are given in Table 1. The glass fiber orientation for these tubes are shown in Fig. 1.

Table 1

Dimensions for the G-11CR Tubes

	Inner Tube	Outer Tube
Radial (inch)	2.4685	3.4685
Wall thickness (inch)	0.092	0.062
Length (inch)	7.375	7.625
Cross sectional area (inch^2)	1.4269	1.3511

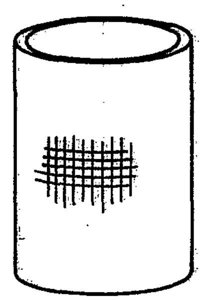

Fig. 1. The Glass Fiber Orientation of the G-11CR Tube

The mechanical properties for these tubes are anisotropic and depend on on the fiberglass orientations. Compressive properties are also different from the tensile properties. In the literature, the properties are given in compression, in tension and in flexure. The properties are usually specified in directions perpendicular and parallel to laminations. Since the tube is already manufactured, it is difficult to prepare specific test specimen from it. It is also impractical to do all the measurements in the longitudinal, the circumferential, and the radial directions.

Two selected tests are performed. As shown in Fig. 2, the tubes are compressed longitudinally for obtaining compressive properties. In Fig. 3, the tubes are compressed radially for obtaining the flexural properties. Depending on the availability, either the INSTRON 10,000 lb TT model or the INSTRON 22,000 lb 1124I model universal tensile test machine are used for the tests. Compressive loading is preferred over the tensile loading due to 1) it is difficult to hold the ends of the tube in tension and 2) the primary load for the G-11 tube in service is compression.

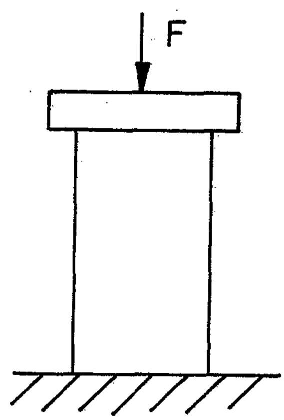

Fig. 2. Compress the Tubes Longitudinally

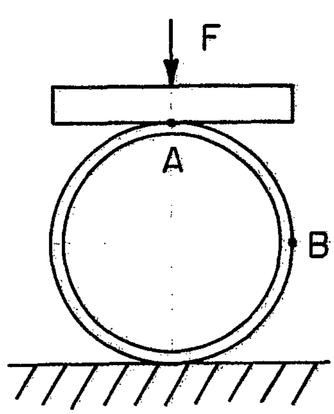

Fig. 3. Compress the Tubes Radially

COMPRESSIVE PROPERTIES

A 0.0005 inch accuracy Brown & Sharpe dial indicator (gauge 1) and a 0.001 inch accuracy GEM dial indicator (gauge 2) are used to measure the displacements of the tubes under longitudinal load as shown in Fig. 2. The displacement versus load for the inner tube and the outer tube are given in Fig. 4 and 5. The stress is obtained by dividing the load by the cross-sectional area. The strain is calculated from the displacement and length of the test specimen. The elastic modulus is defined as the ratio of stress over strain. The results for the inner tube, the outer tube, and the manufacturer's number are given in Table 2.

Table 2

Elastic Modulus in Compression

	Inner Tube	Outer Tube	Manufacturer
Elastic modulus in compression - psi	2.8×10^6	2.8×10^6	2.9×10^6

FLEXURAL PROPERTIES

As shown in Fig. 3, the tubes are compressed radially. Unlike the longitudinal load, this test measures the deformation of the tube diameters. Formulae[1] for circular rings under two opposing concentrated loads are used to calculate the flexural properties. Equation 1 is used to relate the elastic modulus to the displacement at given load. Equation 2 is used to calculate the maximum stress occurring at position B shown in Fig. 3.

$$E = 0.149 \times 12 \times F \times (r/t)^3 / (L \times D_y) \qquad (1)$$

$$S_{max} = 0.187 \times 6 \times F \times (r/L) / t^2 \qquad (2)$$

where E is the flexural modulus
F is the load
r is the radius of the tube
t is the wall thickness
L is the length of tube or test specimen
D_y is the diametric displacement of the tube
S_{max} is the maximum flexural stress

The displacement of the cross head of the INSTRONG test machine is used as the diametric displacement of the tube due to the large deflections of these tubes under small loads. The diametric displacement versus load for the inner tube, the outer tube and the 1 inch sectional specimens of these tubes are given in Fig. 6 through 9. Calculated displacements, using equation 1 and published flexural modulus, 3.6×10^6 psi, are also plotted on Fig. 6 through 9 for comparison. As one can see, the displacement for the outer tube is slightly higher than the calculated values. The displacement for the inner tube is somewhat lower than the calculated values. Discrepancies could come from the fact that the present test is not exactly a flexural test. The best estimation for the flexural modulus is given in Table 3.

Table 3

Flexural Modulus

	Inner Tube	Outer Tube	Manufacturer
Flexural modulus in 10^6 psi	3.6 - 4.0	3.0 - 3.3	3.6

The flexural strength for the 1 inch sectional specimen of the inner tube has been also obtained. At 38,000 psi, the specimen started to produce a cracking sound. At about 55,000 psi the specimen finally broke.

CONCLUSION

The current results are found to be in reasonable agreement with data available in the literature. It is not hard to be convinced that properties which have not been measured here are also valid. Some useful properties from other sources[2] are given in Table 4.

Table 4

Some Useful Properties

Direction	Longitudinal	Circumferential	Radial (Normal to Laminates)
Tensile modulus 10^6 psi	4.0	4.0	2.0
Minimum ultimate strength psi	40,000	25,000	30,000

Results reported in these tests support the mechanical properties of the G-11CR tubes used in the RHIC support leg design where 3 x 10^6 psi elastic modulus is used in the longitudinal and the circumferential directions for both tension and compression. A 2.0 x 10^6 psi modulus is used in the radial direction for shrink fit joint design. These data are important to the structural design and analysis of the leg.

REFERENCE

1. R. J. Roark and W. C. Young, Formulas for Stress and Strain, McGraw Hill, NY.

2. Private Communication With T. H. Nicol of Fermilab.

Fig.4 Compression of Inner Tube Longitudinally
March 9, 1988

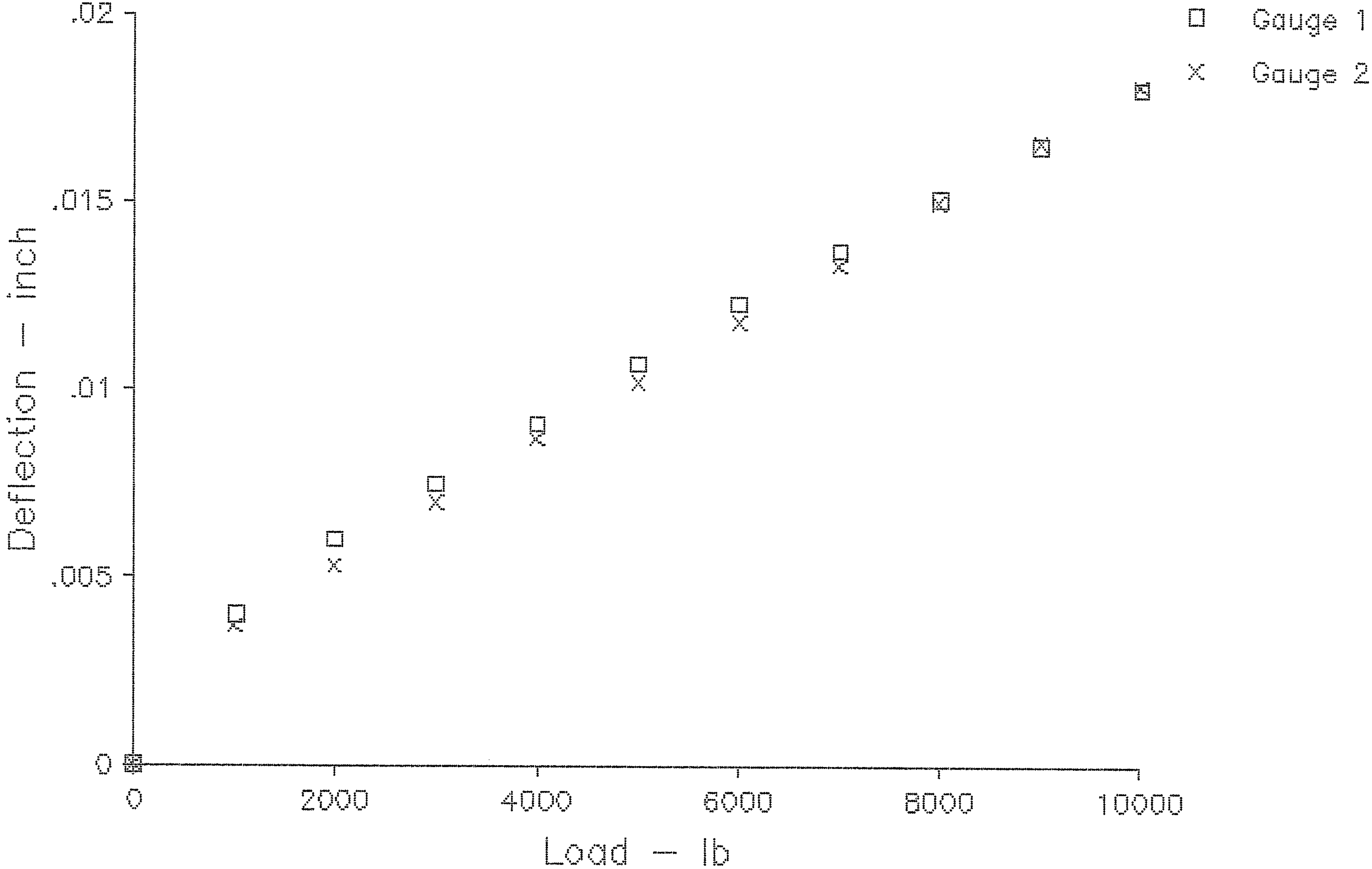

Fig.5 Compression of Outer Tube Longitudinally

March 9, 1988

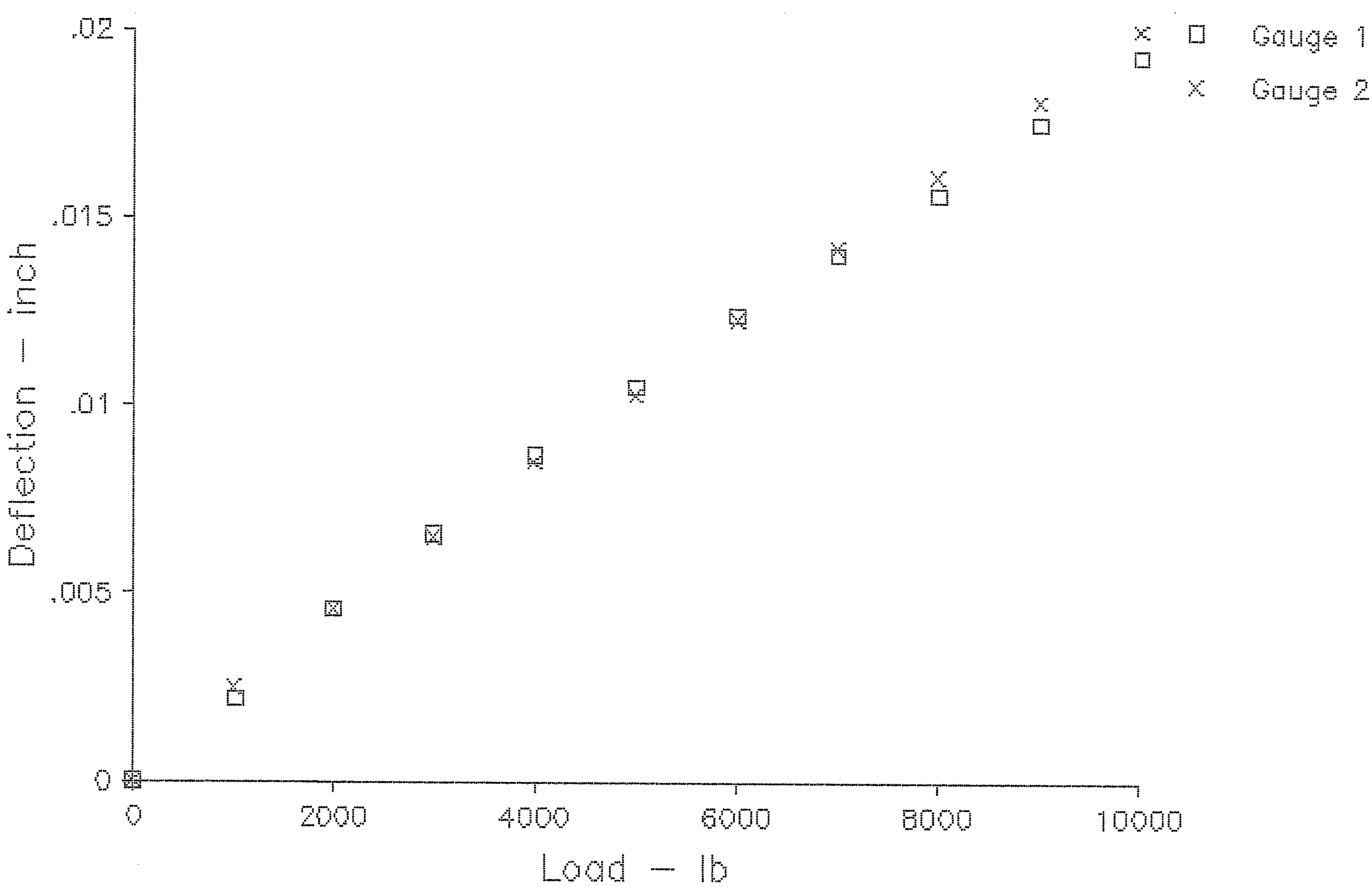

Fig.6 Compression of the Inner Tube Radially

September 30, 1987

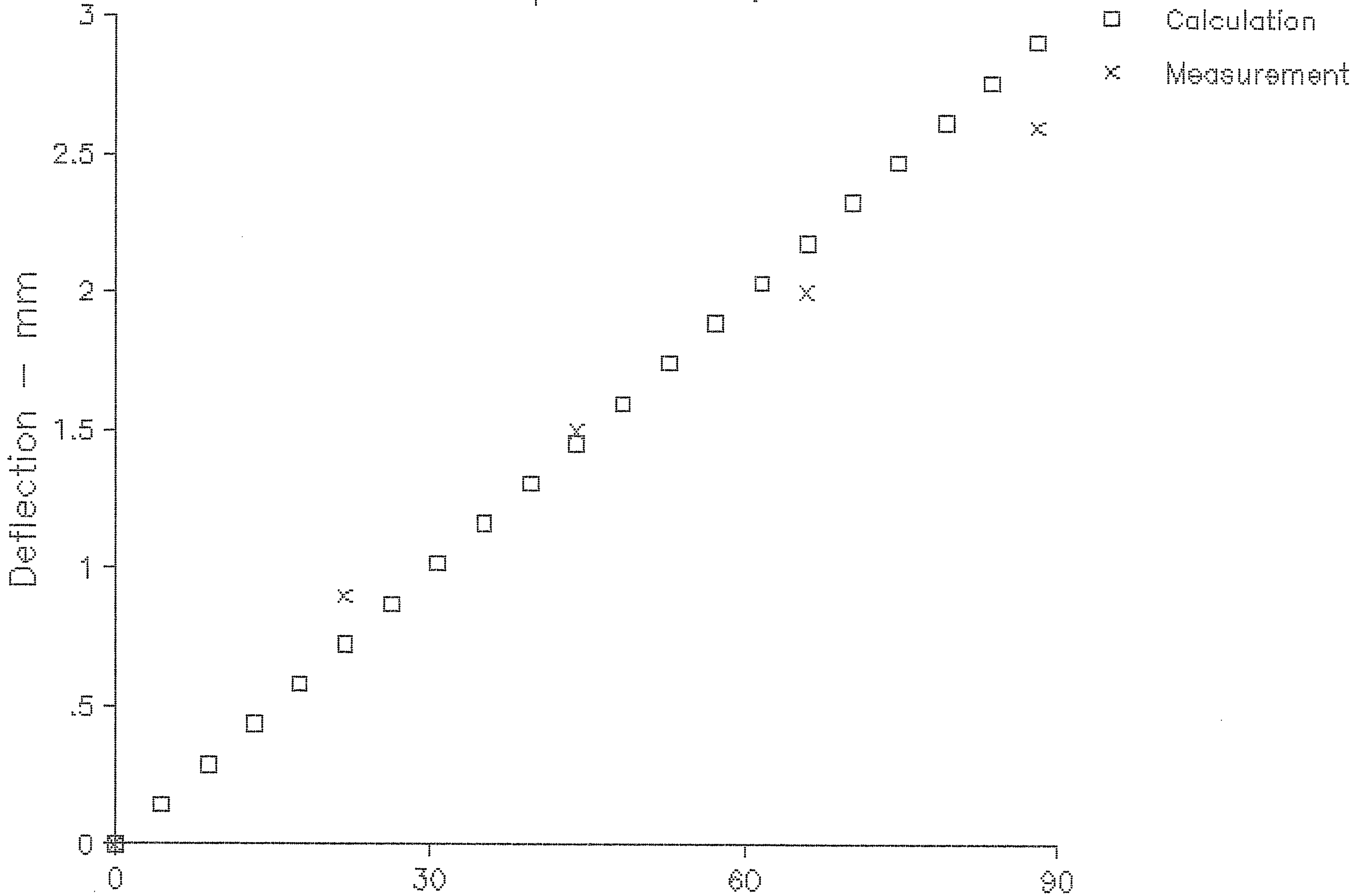

Fig.7 Compression of the Outer Tube Radially

September 30, 1987

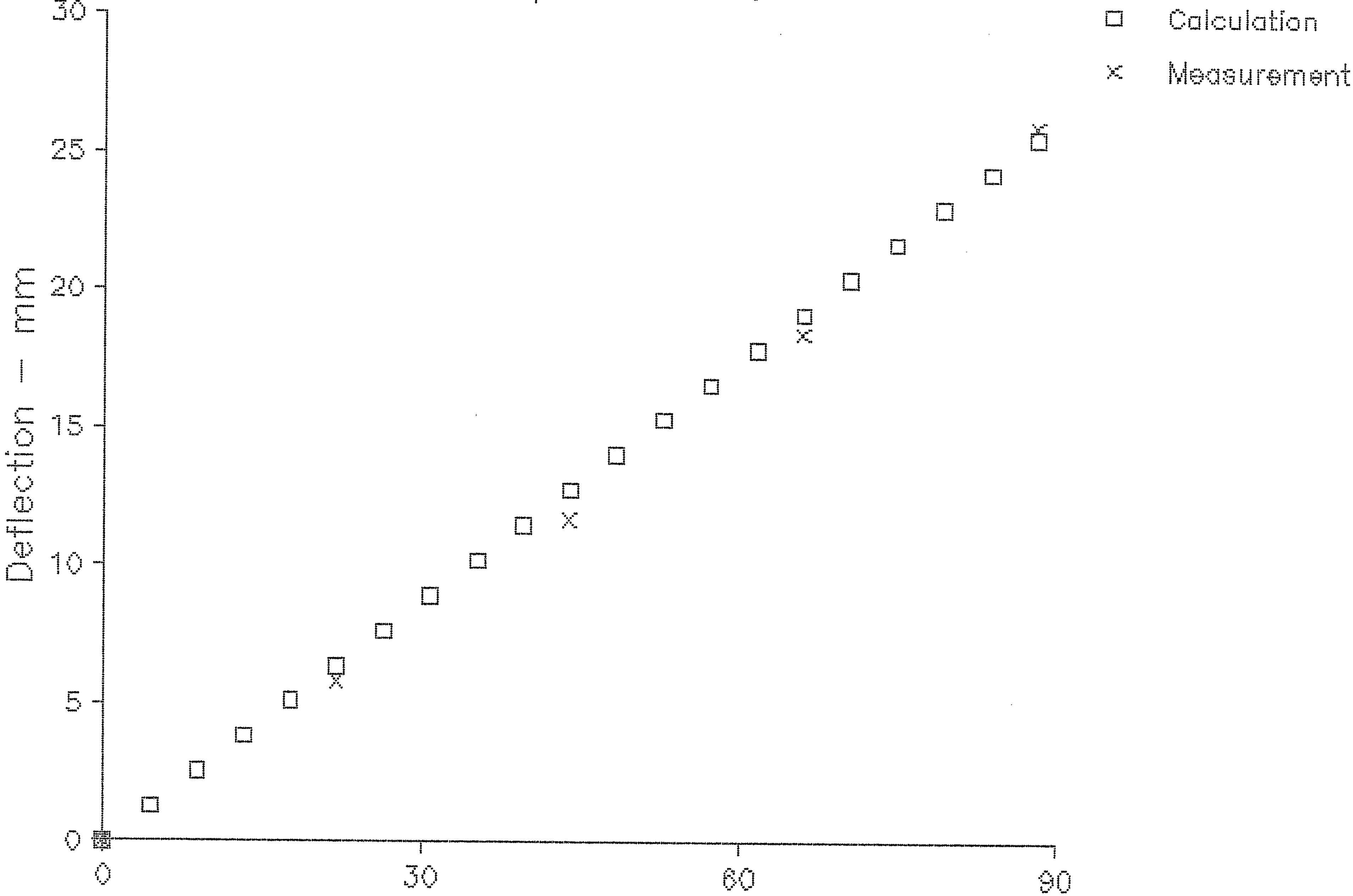

Fig.8 Radially Compress the Inner Tube

11-9-1987 (1 inch section specimen)

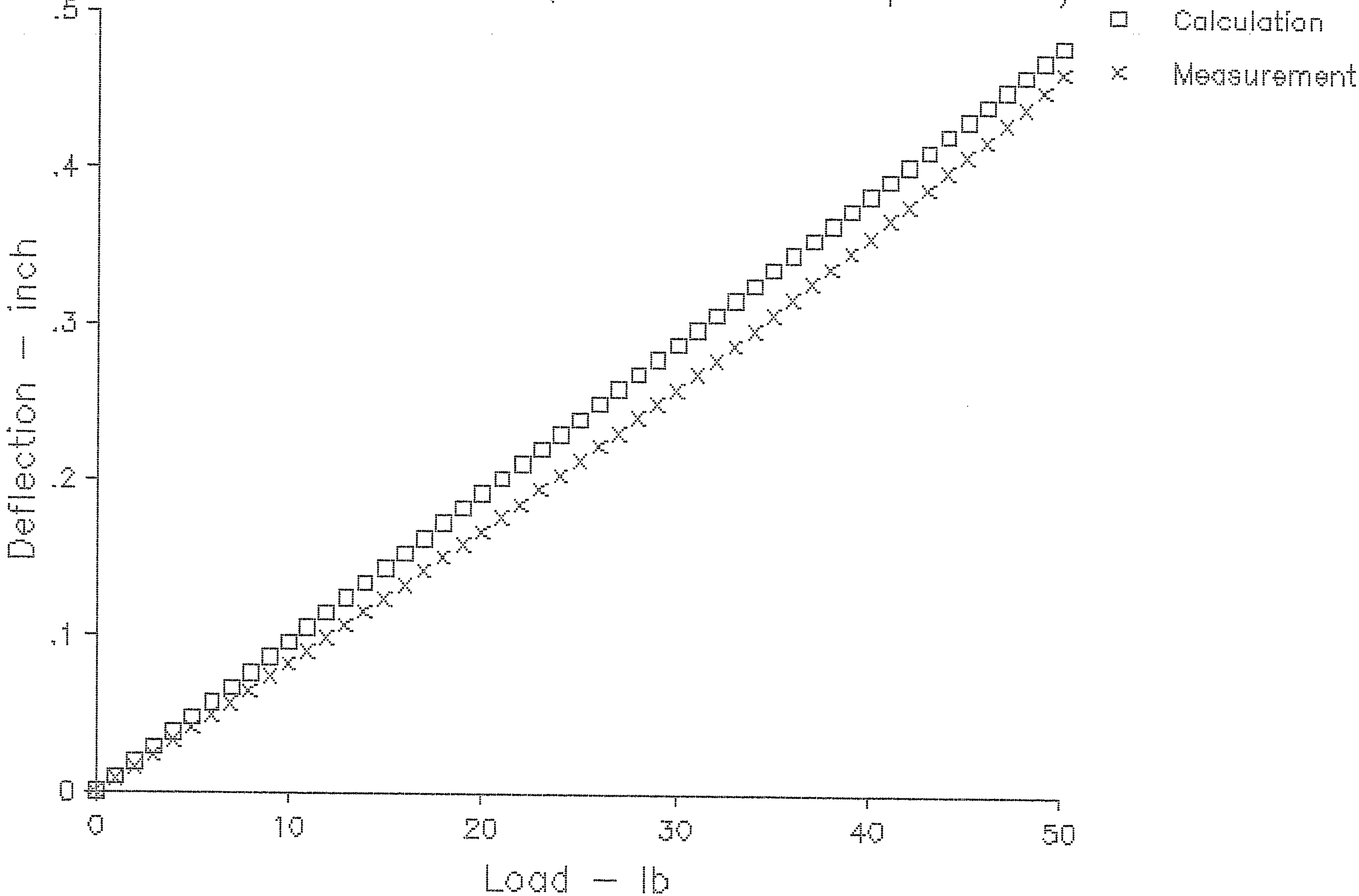

Fig.9 Radially Compress the Outer Tube

11-9-1987 (1 inch section specimen)