CHAPTER III

EXPERIMENTAL WORK

In this chapter the experimental work for the mechanical properties of plastics was divided into 6 parts as follow:

1. Objective
2. Test Specimens
3. Test models
4. Equipment
5. Calibration of Testing Machine
6. Experimental Program

3.1 OBJECTIVE

The aims of this experimental study were as follow:

1. To find the tensile strength and obtain Young's Modulus from stress-strain curve
2. To find the flexural strength
3. To calculate the flexural modulus from load-deflection curve
4. To find the coefficient of thermal conductivity
5. To find Poisson's Ratio
6. To find the specific gravity
7. To investigate the variations of stresses due to internal pressure in cylindrical tank with hemispherical ends.

3.2 TEST SPECIMENS

One hundred and eighty pieces of plastic were used for each test in the study of tensile strength, flexural properties and specific gravity. Twenty pieces of plastic were employed by Science Service Department for the study of coefficient of thermal conductivity. Sixteen pieces of plastics for determining Poisson's ratio were tested by employing strain-gage.

TABLE 3-1 THICKNESS OF TEST SPECIMENS (mm)

TYPE OF TESTED SPECIMENS		PURE PLASTIC	GLASS FIBRE REINFORCED PLASTIC	JUTE REINFORCED PLASTIC
Ply	Wt/Area			
3P	450	2	2	3
4P	450	3	3	4
5P	450	4	4	5
3P	600	3	3	4
4P	600	4	4	5
5P	600	5	5	6

Both 450 and 600 grams per square meter of braided jute which were specially produced by Laem Thong Industry.

Company Limited were used. Fig. A-34 show that single jute was used in lengthwise and twin jute was used in crosswise.

Chopped strand mat which was used in experiment weigh 450 and 600 grams per square meter. All were made from chopped strands distributed in a random pattern to ensure uniformity of strength in all direction. Figl A-35 show the structure of chooped strand mat.

Pure plastic in the experiment implies thermosetting plastic. A gereral purpose polyester resin with 1.0 % by weight of catalyst was used.

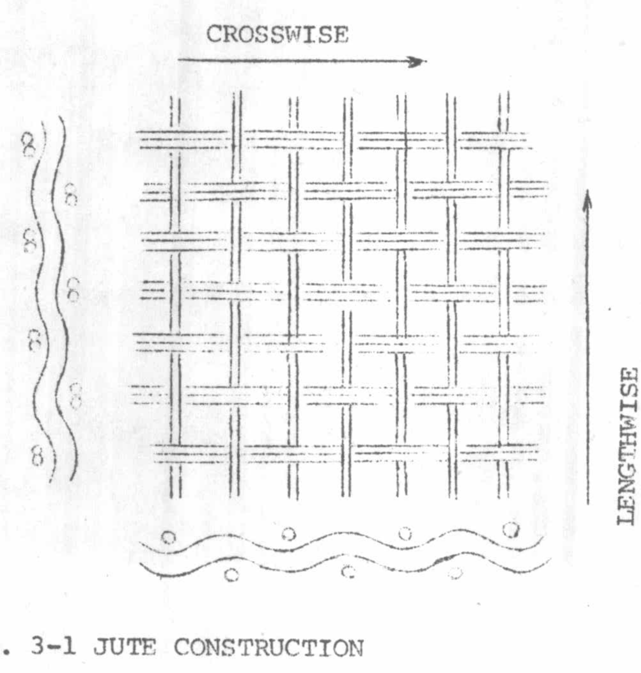

Fig. 3-1 JUTE CONSTRUCTION

1. <u>TENSILE TEST SPECIMENS</u>. The dimensions of the specimens tested are shown in Fig. 3-2.

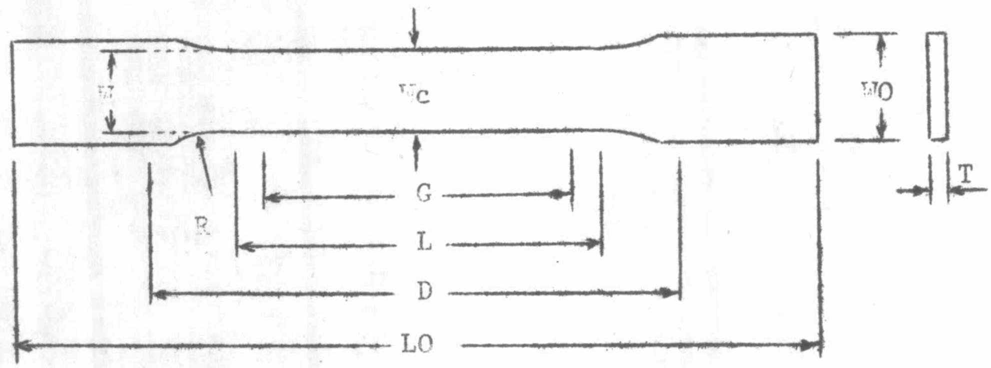

Fig. 3-2 DIMENSIONS OF TENSILE TEST SPECIMENS

W - Width of narrow section, mm	13
L - Length of narrow section, mm	57
WO - Width over-all, min, mm	19
LO - Length over-all, min, mm	165
G - Gage length, mm	50
D - Distance between grips, mm	115
R - Radius of fillet, mm	76

2. <u>FLEXURAL TEST SPECIMENS</u>. The dimensions of the specimens tested are shown in Fig. 3-3 and table 3-2.

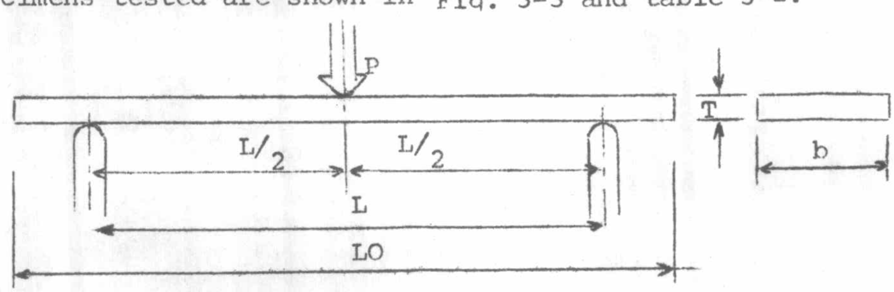

Fig. 3-3 FLEXURAL TEST SPECIMEN SUBJECTED TO LOAD

TABLE 3-2 DIMENSIONS OF FLEXURAL TEST SPECIMENS

TYPE OF TESTED SPECIMENS			450 g/m²				Rate of Cross Head Motion (mm./min)	600 g/m²				Rate of Cross Head Motion (mm/min)
			T mm	b mm	Lo mm	L mm		T mm	b mm	Lo mm	L mm	
3 Plies	Pure Plastic	Lengthwise Crosswise	2	25	50	25	0.8	3	25	60	40	1.0
3 Plies	Glass Fibre	Lengthwise Crosswise	2	25	50	25	0.8	3	25	60	40	1.0
3 Plies	Jute	Lengthwise Crosswise	3	25	60	40	1.0	4	25	80	50	1.3
4 Plies	Pure Plastic	Lengthwise Crosswise	3	25	60	40	1.0	4	25	80	50	1.3
4 Plies	Glass Fibre	Lengthwise Crosswise	3	25	60	40	1.0	4	25	80	50	1.3
4 Plies	Jute	Lengthwise Crosswise	4	25	80	50	1.3	5	13	100	80	2.0
5 Plies	Pure Plastic	Lengthwise Crosswise	4	25	80	50	1.3	5	13	100	80	2.0
5 Plies	Glass Fibre	Lengthwise Crosswise	4	25	80	50	1.3	5	13	100	80	2.0
5 Plies	Jute	Lengthwise Crosswise	5	13	100	80	2.0	6	13	130	100	2.8

3. COEFFICIENT OF THERMAL CONDUCTIVITY TEST SPECIMENS.

The dimensions of the specimens tested are shown in Fig. 3-4

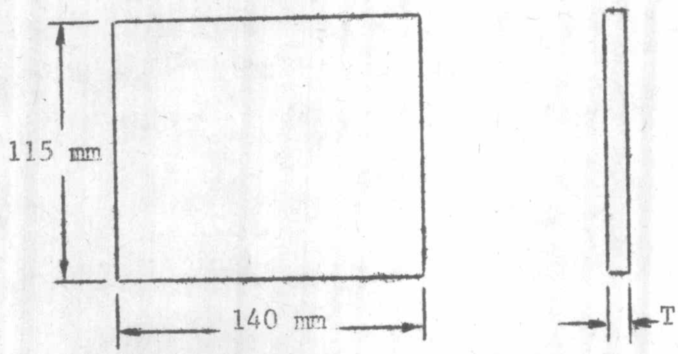

Fig. 3·4 DIMENSIONS OF COEFFICIENT OF THERMAL CONDUCTIVITY TEST SPECIMENS.

4. POISSON'S RATIO TEST SPECIMENS. The dimensions of the specimens tested are shown in Fig. 3-4

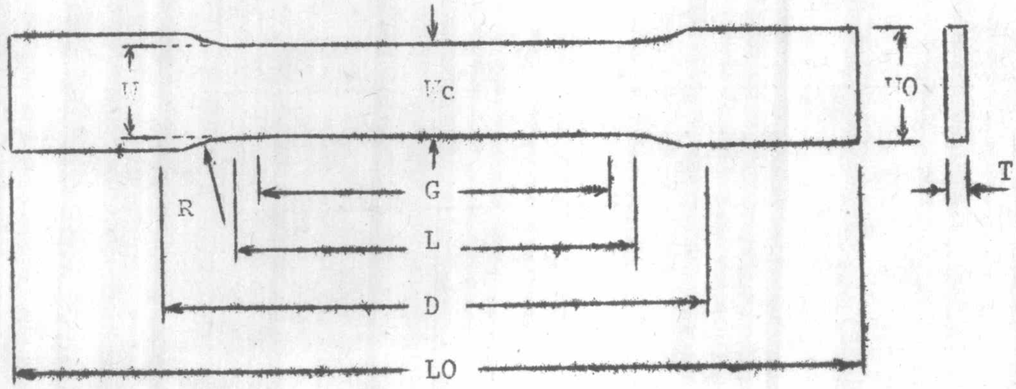

Fig. 3-5 DIMENSIONS OF POISSON'S RATIO TEST SPECIMENS.

W - Width of narrow secton, mm	19
L - Length of narrow section, mm	57
WO - Width over-all, mm	29
LO - Length over-all, mm	246
G - Gage length, mm	50
D - Distance between grips, mm	115
R - Radius of fillet, mm	76

5. SPECIFIC GRAVITY TEST SPECIMENS. The dimensions of the specimens tested are shown in Fig. 3-6

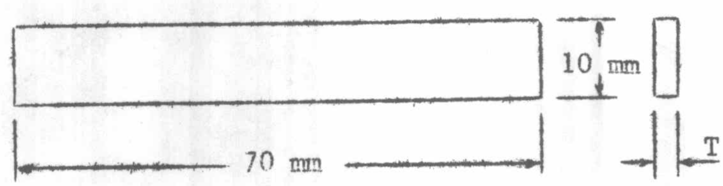

Fig. 3-6 DIMENSIONS OF SPECIFIC GRAVJTY TEST SPECIMENS.

3.3 TEST MODELS

Two closed tanks in the type of Cylindrical tank with hemispherical ends were used. The first was made of glass fibre reinforced plastics by using 1 ply of 450 grams per squaremeter glass fibre. The second one was made of jute reinforced plastics by using 1 ply of 450 grams per squaremeter jute.

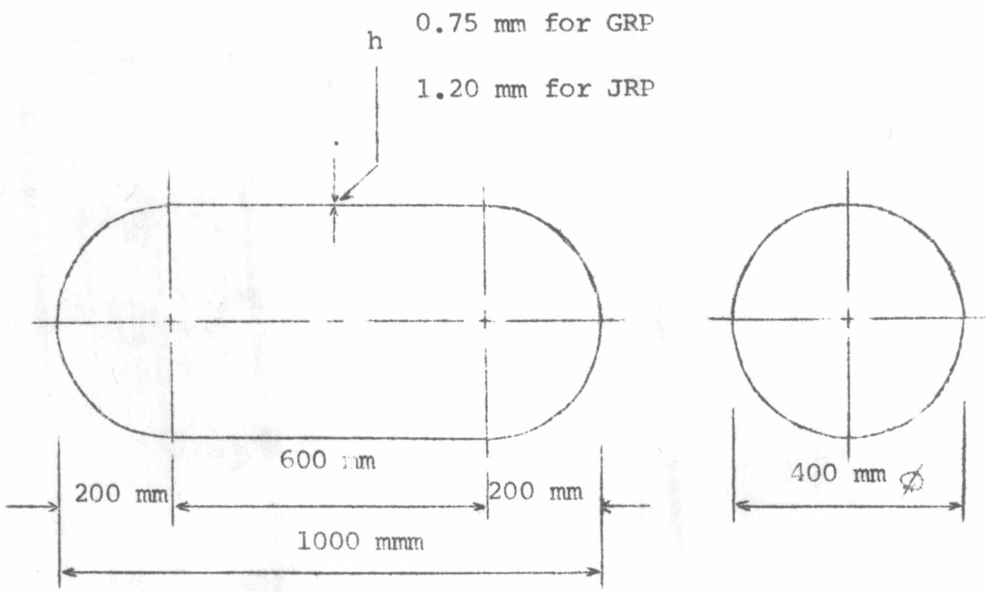

Fig. 3-7 DIMENSIONS OF TEST MODEL

3.4 EQUIPMENTS

The equipments used in this experimental study are:

1. Testing Machines

a) AVERY UNIVERSAL TESTING MACHINE[10] type 7108 DCN. This machine has capacity of 15,000 lb, with 1.5 hp. 380/3/50 motor. There are six load ranges available namely, 0 to 300, 600, 1,500,3,000,6,000 and 15,000 lb with 1, 2, 5, 10, 20 and 50 lb divisions respectively. To change the unit to kg a conversion factor of 2.207 lb = 1 kg is used. Thus the range 0 to 300 lb becomes 0 to 136 kg and 0 to 3,000 lb becomes 0 to 1,360 kg. These range were used in the experiment. This machine was used to find tensile strength, Young's modulus, flexural strength, flexural modulus, and Poisson's ratio.

b) Proving Ring. To calibrate the AVERY Universal Testing Machine, the OLSEN proving ring as shown in Fig. A-20 was used. This ring has capacity of 10 tons produced by TINIUS OLSEN TESTING MACHINE CO., WILLOW GROVE PA,USA.

c) Loading Nose and Supports[1]. The loading nose and supports have cylindrical surfaces. In order to avoid excessive indentation, or compressive failure, that is, nonrecoverable deformation or compressive failure due to stress concentration dircetly under the loading nose, the radius of nose and supports shall be at least 3.2 m.m. ($\frac{1}{8}$ in.) in thickness or greater, the radius of the supports may be up to $1\frac{1}{2}$ times the specimen depth, and the radius of the loading nose may be up to 4 times the specimen depth, and shall be this large if significant indentation or compressive failure occurs. The chord defining the are of the loading nose in contact with the specimen is sufficiently large to prevent contact of the specimen with the sides of the nose. A mininum chord length of twice the specimen depth shall be used where possible.

d) Analytical Balance.[1] A balance with a precision within 0.1 mg, accuracy within 0.05 per cent relative (that is, 0.05 per cent of the weight of the specimen in air), and equipped with a stationary support for the immersion vessel above the balance pan ("pan straddle") was used.

e) Wire.[1] A corrosion-resistant wire for suspending the specimen made of copper.

f) Immersion Vessel.[1] A beaker or other wide-mouth vessel was used for holding the water and immersed specimen.

g) Thermometer.[1] A thermometer with an accuracy of 1 °C (1.8 °F) was required since the test was not performed in the Standard Laboratory Atmosphere of Methods D 618, Conditioning Plastics and Electrical Insulating Materials for Testing.

h) Strain Gage and Cement[5]. KYOWA Japanese strain gage type KFC-1-C1-11, KFC-2-D17-11 and KFC-2 -D4-11 with strain gage cement 20 gm type BC-11. These were produced by KYOWA ELECTRONIC INSTRUMENTS CO., LTD. TOKYO,JAPAN. The gage type KFC-1-C1-11, type KFC-2-D17-11 and KFC-2-D4-11 has gage length of 1 mm, 2 mm and 2 mm; resistance 120.0 ± 0.30 ohms, 119.4 ± 0.6 ohms and 120.0 ± 0.6 ohms with gage factor 2.11 ± 1 % 2.09 ± 1 % and 2.05 ± 1% respectively.

i) Strain Gage Bridge[5]. The KYOWA portable digital strain indicator Model SD-520 A as shown in Fig. A-23 combined with the Model ASB automatic multipoint switch box, measures multipoint static strains at a speed of 0.2 seconds per point by fully automated operation. Unlike the conventional manual initial balance adjusting mechanism, it is of the fully electronic type, which employs a unique semiconductor memory and digital arithmetic operation unit for improved measuring speed. The employment of the d-c constant voltage system for the bridge power supply makes the instrument best suited to the 1 -gage 3-wire connection method, free from the influence of the floating capacity of the lead wire to the strain gage, and ensures high accuracy of measurement.

Specifications

SD-520A digital indicator

Measuring range (automatic range selection)	1μ range 0 to $\pm$ 29,999 $\times 10^{-6}$ strain 10μ range 0 to $\pm$ 399,990 $\times 10^{-6}$ strain
No. of automatic Multipoint switch boxes connectable	10 for ASB-52D, 52E, 4 for ASB-55D, 55 E
Measuring accuracy	1μ range $\pm$ (0.5 % + 2 numerals of indicated value)
Measuring time	0.2 sec per one measuring point
Initial value Storing range	0 to $\pm$ 7.999 $\times 10^{-6}$ strain (intial value over singal can be stored)
Initial value storing capacity	Equivalent to 200 measuring points
No. of display digits	Measuring point No. in 3 digits, polarity in 1 digit, measured value in 5 digits, unit in 1 digit, over, sampling and 10 display
Display element	7 segments, LED display, character height 15 mm

No. of print-out digits	Measuring point No. in 3 digits, polarity in 1 digit, measured value in 5 (6) digits, unit in 1 digit
Printer	Electrosensitive type, 5×7 dot matrix, digit serial print-out
Digital input	8 digits BCD code
Digital output	BCD code
Gage factor	2.00 constant
Bridge voltage	2V DC (with remote sensing) constant
Stability against temperature	Zero point 0.5×10^{-6} strain/°C or less (1μ range)
	Sensitivity 0.01 % / °C or less
Stability against time	Zero point 2×10^{-6} strain /hr or less (1 range)
	Sensitivity 0.01 % /hr or less
Guaranteed temperature and humidity range	0 to + 40 °C
	0 to 85 % relative humidity
Power source	220 V ± 10 V AC, 50/60 Hz (changeover) Approx. 1.0 A
Outside dimensions and weight	425 (W) × 160 (H) × 450 (D) mm (not including protrusion) Approx. 15 kg

j) Automatic Scanning Box[4] This unit Type ASB-55E as shown in Fig. A-24 will be connectable with the SD-520A digital strain indicator exclusively. Quarter (1-gage), Half (2-gage) and Full (4-gage) bridge configurations can be set up at each channel respectively. ASB-55E has 50 measuring channels.

3.5 CALIBRATION OF MEASURING EQUIPMENTS

Testing Machines Calibration[2]

Three methods commonly used for calibration of the testing machine are:

1. the use of weights alone
2. the use of levers and weights (proving levers)
3. the use of elastic calibration devices

The testing machines which used in this experiment were calibrated by the first method for 0 to 300 lb range and the third method for calibrating large capacity machines. The third method consists of an elastic metal member or members combined with a mechanism for indicating the mangitude of deformation under load. Two forms of this device are

1) a steel bar together with an attached strainometer, and

2) a"calibration ring" or " proving ring" which is a steel ring or loop combined with some type of deflection indicator.

The steel bar is suitable principally for use in tension, although some bars are used in compression. The proving ring is a ring transducer or loop device, which is widely used as a calibration standard for either large tensile or compressive testing machines with static load. A compressive load shortens the vertical diameter and this deflection is measured by the sensitive micrometer as shown in Fig. 3-8 This micrometer has threads about 40 to 60 micrometer threads per inch. To obtain a precise measurement, one edge of the micrometer is mounted on a vibrating reed device which is pulcked to obtain a vibratory motion. The micrometer contact is then moved forward until a noticeable damping of the vibration is observed or contract is indicated by the marked damping of the vibration. Deflection measurements may be made to one-or two-hundred thousandths of an inch with this method. From these measurements and the calibration results of the ring, the applied load can be determined. Calibration rings of this sort are available in capacities range from 300 to 300,000 lb, but compression bars having capacities up to 3,000,000 lb are equipped with electronic strain gages. Also, for calibrating very large machines in compression, several calibration rings or bars can be used in parallel.

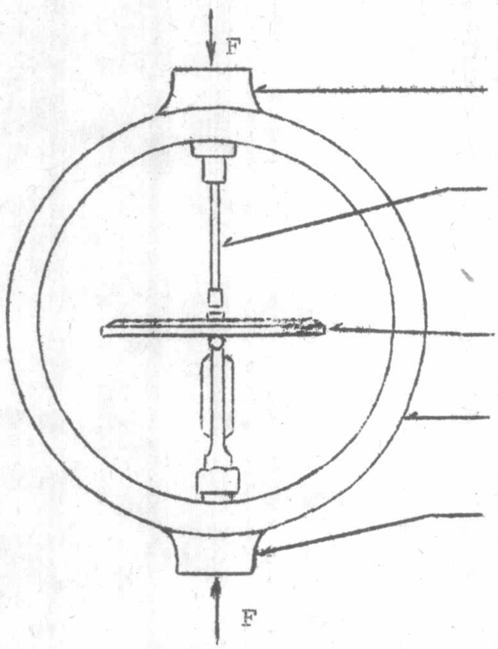

Fig. 3-8 COMPRESSION TYPE PROVING RING WITH CALIBRATING REED.

The followings are three important requirements of an elastic calibration device (proving ring)

(1) It should be so constructed that its accuracy is not impaired by handling and shipping and that parts subject to damage or removal can be replaced without impairing the accuracy of the device.

(2) If should be provided with shackles or bearing blocks so constructed that the accuracy of the device in used is not impaired by imperfections in the shackles or blocks.

(3) It should be calibrated in conjuction with the strainometer to be used with it, and the strainometer should be used in the same range as that covered by the calibration.

Care must be taken to minimize any temperature changes during the use of proving ring. Furthermore, the actual temperature at time of use and at time of its own calibration must be known, since the elastic properties of the device change with temperature. In general, the reading of a ring type device changes by about 0.015 per cent for each degree Fahrenheit change in temperature from the standard.

In all ordinary calibration work, the calibration load should be applied so that the resultant load acts as nearly as possible along the axis of the weighing head. In special instances, calibrations may be achieved with the load applied at known eccentricities.

Care should be taken in obtaining the initial micrometer reading which is the reading at no deflection of the proving ring. This in fact is the micrometer-reading at no load. Since the actual deflection are given by the subsequent readings less the initial value, these figures will not be the true ones unless the intial deflection is read correctly. It can be seen from the graph of the proving ring that the calibration factors will also be affected by this initial reading.

The deflection equation and deflection constant are derived for circular rings with the assumption that the radial thickness of the ring is small compared with the radus, these equations are:

deflection equathion :

$$Y = \frac{1}{16}\left(\frac{\pi}{2} - \frac{4}{\pi}\right)\frac{FD^3}{EI}$$

deflection constant (force per unit length)

$$K = \frac{16EI}{\left(\frac{\pi}{2}-\frac{4}{\pi}\right)\cdot D^3}$$

where F = Applied load

D = Diameter of ring

E = Young's modulus

I = Moment of inertia of section about centroidal axis of bending section.

But most proving rings are made of section with appreciable radial thickness. However, the use of thin-ring rather than thick-ring relations introduces errors of only about 4 % for a ratio of section thickness to radius of ½ Increased stiffness in the order of 25 % is introduced by the effects of intergral bosses.

It is, therefore, apparent that use of the simpler thin-ring equation is normally justified.

Stress may be calculated from the banding maments, M determined by the relation.

$$M = \frac{FR}{2}\left(\cos r - \frac{2}{\pi}\right)$$

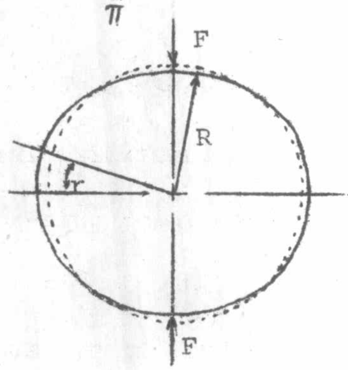

Fig 3-9 PROVING RING SUBJECTED TO LOAD

TABLE 3-3 THE CALIBRATION OF " AVERY" TESTING MACHINE CAPACITY 15000LB,

LOAD RANGE 0-3000 LB AGAINST STANDARD PROVING RING NO. 56180

Load Increased					Load Decreased				
Indicated Load		Deflection of Proving ring division	Calibration Factor kg/div	Corrected Load kg	Indicated Load		Deflection of Proving ring division	Calibration Factor kg/div	Correated Load kg
lb	kg				lb	kg			
0	0	0	32.000	0	7	3.17	0.20	31.999	6.40
270	122.34	4.40	31.994	140.77	250	113.29	4.10	31.995	131.18
500	226.59	3.10	31.987	259.09	500	226.59	8.30	31.987	265.49
750	339.88	11.50	31.983	367.80	750	339.88	11.60	31.983	371.00
1,020	462.17	18.00	31.974	575.53	1000	453.17	18.30	31.973	585.11
1,250	566.47	23.30	31.966	744.81	1250	566.47	23.00	31.967	735.24
1,500	679.76	26.60	31.962	850.19	1500	679.76	26.20	31.963	837.43
1,750	793.05	28.10	31.960	808.08	1750	793.05	28.40	31.959	907.64
2,050	928.86	33.50	31.952	1,070.39	2000	906.343	34.00	31.952	1,086.37
2,240	1,014.73	34.75	31.951	1,110.30	2250	1,019.64	34.95	31.951	1,116.69
2,650	1,200.73	38.20	31.945	1,220.30	2500	1,132.93	39.70	31.944	1,268.18
2,750	1,246.22	42.90	31.938	1,370.14	2750	1,246.22	42.90	31.938	1,370.14

TABLE 3-4 DATA FOR CALIBRATED TESTING MACHINE BY

STANDARD WEIGHT RANGE 300 lb.

CORRECTED LOAD (kg)	INDICATED LOAD			
	INCREASING LOAD		DECREASING LOAD	
	lb	kg	lb	kg
0	0	0	0	0
10.00	22.0	9.98	22.0	9.98
20.00	43.3	19.64	43.2	19.60
30.00	64.0	29.03	78.5	36.61
40.00	85.0	38.56	87.2	39.55
50.00	106.4	48.26	111.0	50.35
60.00	133.2	60.42	132.3	60.01
70.00	152.7	69.26	155.6	70.58
80.00	179.6	81.47	178.7	81.06
90.00	198.0	89.81	201.6	91.45
99.07	219.0	99.34	227.5	103.19
103.61	221.6	100.52	236.2	107.14
110.86	241.0	109.32	253.8	115.12
118.12	250.5	113.63	273.1	123.88
125.38	262.6	119.12	281.9	127.87
132.64	276.0	125.19	288.0	130.64
139.90	296.2	134.36	296.2	134.36

3.6 EXPERIMENTAL PROGRAM

The experimental program was divided into 2 parts.

Part I

1. Tensile strength of composites

Two hundred and sixteen pieces of composite material were tested, to find the tensile strength of both plastics. and composite plastics. One third of these were pure plastics, glass fibre reinforced plastics, and jute reinforced plastics. The specimens were tested as:

Measure the width and thickness of rigid flat specimens with a suitable micrometer to the nearest 0.025 mm. (0.001 in.) at serveral points along their narrow sections.

Record the minimum values of cross-sectional area so determined.

All of these plastics were tested until they broke.

They were loaded by AVERY Testing Machine.

Testing Machine was calibrated by the use of proving ring for the range 0 to 3,000 lb.

Record the maximum load carried by the specimen during the test (usually this will be the load at the moment of repture).

Record the extension at the moment of rupture of the specimen.

2. Flexural strength of composites

Two hundred and sixteen pieces of plastics were tested. One third of these were pure plastics, glass fibre reinforced plastics, and jute reinforced plastics. The specimens were tested as:

Measure the width and thickness of the specimem to the nearest 0.03 mm (0.001 in.) at the center of the span.

All of these plastics were tested at the moment of break.

They were loaded by AVERY Testing Machine. Testing Machine was calibrated by the use of standard weight for the range 0 to 300 lb.

Load-deflection curves may be plotted to determine the flexural yield strength, secant or tangent modulus of elasticity, and the total work measured by the area under the Load deflection curve.

3. Coefficient of thermal conductivity of plastics. Twenty pieces of plastics were tested by Science Service Department.

4. Poisson's Ratio of plastics. Sixteen pieces of plastics were tested by strain gage technique.

5. Specific gravity of plastics. Two hundred and sixteen pieces of plastics were tested. One third of these were pure plastics, glass fibre reinforced plastics, and jute reinforced plastics. The spceimens were tested as:

Weigh the Specimen in air to thenearest 0.1 mg or 0.05 per cent relative whichever is greater.

Attach to the balance a piece of fine wire sufficiently long to reach from the hook above the pan to the support for the immersion vessel.

Attach the specimen to the wire such that it is suspended about 2.5 cm (1 in) above the vessel support.

Mount the immersion vessel on the support, and completely immerse the suspended specimen in water (the water shall be substantially air-free, distilled, or demineralized water.) at a temperature of $23 + 2\,^{\circ}C$. The vessel must not touch wire or specimen.

Remove any bubbles adhering to the specimen, wire, on sinker, paying particular attention to holes in the specimen and sinker. Usually these bubbles can be removed by rubbing them with another wire.

Weigh the suspended specimen to the required precision.

Record this weight as b (the weight of the specimen, sinker, if used, and the partially immersed wire in liquid).

Weigh the wire in water with immersion to the same depth as used in the previous step.

Record this weight as w (weight of the wire in liquid).

Part II

To investigate the variations of stresses due to internal pressure in 2 cylindrical tanks with hemispherical ends.
The first tank was made of glass fibre reinforced plastics by using 1 ply of 450 grams per squaremeter glass fibre.
The second tank was made of jute reinforced plastics by using 1 ply of 450 grams per squaremeter jute. The air was pressed into the tank and increased step by step. The strain gages were bonded to the surface around the tanks, so that at each level of pressure the corresponding values of strain could be obtained.