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Some observations on Mesh Measurement

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1) Introduction

It is now becoming generally accepted that greater uniformity and accuracy in the measurement of mesh size would be desirable. The purpose of this note is to present some data which it is thought may be of help in achieving this aim, and to describe a new form of mesh gauge which has been developed recently at Lowestoft.

2) The load-elongation characteristics of various meshes

The effect of tension on the size of mesh has been examined by Boerema (1954) and von Brandt (1955), but in each case the tension has been exerted indirectly by a spring-loaded wedge gauge. For reasons mentioned in para.5(b) below, it was thought desirable to repeat these tests using a direct-pull method of elongating the mesh. The apparatus consisted of a horizontal arm carrying a scale vertically below it; the mesh to be tested was hung from the arm and weights were attached to a stirrup placed over the lower end of the mesh and carrying a pointer which lay over the scale. The elongation of the mesh was recorded after one minute had elapsed from the moment when the weights were attached.

The load-elongation diagrams for the various meshes tested were all found to be of the same basic form, with the process of elongation under increasing load consisting of two phases. In the first of these, mesh size increased rather quickly with increasing load and was inclined to be irregular; the graph of mesh size against load for this phase is markedly curved. In the second phase the mesh size increased more slowly with load and elongation was more regular; the graph of the second phase is linear or only very slightly curved. These characteristics are seen in all the graphs of Fig. 1, where the change from the first to second phase is shown by the line drawn through the higher points of the diagram.

A number of factors were examined that were thought might influence the elongation-load characteristics of meshes; definite conclusions could be drawn in some cases but not in all.

(a) Material

No marked and consistent differences could be found between new white manila and sisal of similar runnage when wet (Graphs A and B of Fig. 1). The slope of the second phase of the elongation-load diagram of hemp (D) was shallower than that of manila or sisal; that for cotton (E) was steeper, very much so for the thinner of the two cottons investigated.

(b) Effect of use

No consistent differences were found between new and used white sisal (B), provided the net was not old and had begun to rot.

(c) Effect of tarring

Little difference could be detected between tarred and untarred sisal of similar runnage when wet (B and C).

(d) Tightness of knots

This had a marked effect on the first phase elongation, but relatively little on the second. Examples are C for tarred sisal and D for hemp.

(e) Moisture

White used sisal was found to have a slightly steeper second phase slope when wet than when dry, but the difference was well within the normal range of variation between similar meshes.

(f) Size of mesh

It might have been expected that the slope of the load-elongation diagram would increase with length of mesh so as to maintain a constant percentage elongation per unit load. Tests on white sisal and manila meshes ranging from 55 to 115 mm. (under a load of 6 lb.) showed only a slight tendency for the slopes to increase with mesh size. This was probably because the diameter of the twine was greater on the larger meshes, which would tend to offset their greater length.

(g) Recovery

No extensive measurements were made of the recovery of meshes after the load had been removed, but it was noticed that white sisal meshes that had been loaded when wet to 16 lbs. recovered only about 20% of the total elongation after 10 mins. Several weeks later, however, recovery was found to be nearly complete. Tarred sisal meshes recovered only 10% of their full elongation after 10 mins. From the point of view of practical measurement, it is therefore concluded that meshes cannot be regarded as truly elastic.

3) Elongation - time characteristics

The change of length with time following application of various loads were recorded for white sisal in a wet condition. The lower curve of Fig. 2 shows the result for a load of 6 lbs., for the first 2 mins. after application, although slight elongation continued up to 6 mins. The initial reading at zero time was made with a load of $\frac{1}{2}$ lb.

Table 1 gives differences in mm. between the reading after 3 mins. and those after 5 seconds (col. A) and 20 seconds (col. B) for the range of loads investigated. Thus differences between cols. A and B show the elongation occurring between readings taken at 5 seconds and 20 seconds.

Load (lbs.)	(A)	(B)
2	1.3	0.6
3	1.9	1.0
4	1.5	0.8
6	1.6	1.1
8	2.3	1.3
12	2.3	1.2
15	2.2	1.3
20	2.1	0.9

Table 1. Elongation - time characteristics of white sisal. Difference (mm.) between final reading and reading after 5 seconds (col. A) and 20 seconds (col. B).

There is only a slight increase with load in the amount by which the 5 second and 20 second readings differ from that after 3 mins.

Table 2 shows the same differences but for various materials with a load of 6 lb. throughout. All meshes were tested wet.

Material	A	B
Sisal, white	1.6	1.1
Sisal, tarred	4.7	2.8
Hemp, new	1.9	0.8
Cotton (2.3 mm. dia.)	5.2	2.9

Table 2. Elongation-time characteristics for various materials; load 6 lbs. See also Table 1.

These results show that cotton and tarred sisal elongated much more slowly than white sisal or hemp. The full data for tarred sisal are shown in the upper curve of Fig. 2.

4) Choice of standard load

It is clear from the above data that the size of a mesh can only be defined and measured in a standard way if the applied load is specified.

The ideal would perhaps be to stretch the mesh being measured to the same degree as it is when the net is being fished. However, we do not know of any direct measurements of the "working" tension in codends, but it is certain to vary greatly, both with size of vessel and weight of catch. Our impression is that the true working tension may be rather low; certainly, knots may not be pulled tight on a new codend until several hauls have been made, and it seems that tightening occurs mainly when the catch is lifted inboard.

Observation of meshes under elongation-load test showed that the change from the first phase of elongation to the second tended to coincide with tightening of knots and taking up of slack in the mesh; this being especially noticeable with heavily tarred meshes (see Fig. 1C). A feature of all but one of the materials tested and illustrated in Fig. 1 is that the change from the first to second phase of elongation occurred when a load of about 6 lb. had been reached; the exception being the thinner of the two cotton meshes (Fig. 1E) in which the two phases are scarcely distinguishable but, if anything, the second begins at about 5 lb. If it is wished to minimise the influence of factors such as stiffness of twine and tightness of knots, a load of about 6 lb. would therefore seem to provide something of a common basis on which to compare the size of meshes made of most kinds of materials.

It may be argued that differences in the true load-elongation characteristics of various materials (i.e. the second phase slopes) merit the adoption of different standard loads for some materials, on the basis that a given tension would stretch them to varying degrees. However, differential standards would presumably have to be based on differences in working tensions to which the meshes are subjected when fishing, or on observed differences in selectivity for fish, and information is scarcely adequate on these matters at present. In any event, our experience is that such differences as there may be between manila and sisal meshes (whether white or tarred, new or used, wet or dry and irrespective of runnage) are not enough to warrant differential standard loads for these two materials, and the same is true for hemp when new. This last conclusion is supported by Boerema's results. Of the materials we have examined only cotton differs substantially and in this case thickness of the twine is also critical; judging by von Brandt's results, synthetic materials may have to be classed with cotton in their load-elongation characteristics. It seems that it may be necessary to postpone a decision on whether cotton and synthetics should have a different standard load to other materials, and on how to allow for thickness of these twines, until further evidence on the definition and selectivity of "light" trawls is available. Meanwhile, it would appear from Fig. 1E that a standard load of 6 lb. would not result in too great a distortion of cotton meshes compared with those of other materials.

On the other hand, the length of time that a standard load is applied when measuring a mesh cannot readily be ignored in tarred twines and cotton (see Fig. 2 and Table 2), since it could possibly result in substantial differences between measurements obtained on the same meshes by different observers. It is suggested that a duration of about 5 seconds (by counting) would be sufficient for normal purposes, with perhaps an occasional check for a longer period to establish the properties of the particular net.

5) Mesh measuring devices

In what follows it will be assumed that when measuring a mesh a standard longitudinal tension shall be applied for a specified time.

(a) Hand wedge

It is clear that this method is open to personal error; relevant here is to record for comparative purposes the pressures normally exerted by those members of the Lowestoft staff who have undertaken the bulk of mesh measuring in recent years.

Six people were asked to measure a mesh (double tarred dry sisal) six times with a spring loaded wedge, without looking at the spring calibration. An observer noted the maximum load exerted in each test. The results are given in Table 3 below:-

Operator	Maximum load (lbs.)						Average (lb.)
A	7	5	5	4½	5	5	5
B	8	8	8	7½	7	7½	7½
C	7	8	8	8	8	9	8
D	10½	8½	8½	8	8½	8	8½
E	9	9	9	7	8	8	8½
F	5	4½	4½	3½	5½	7	5

Table 3. Pressures exerted by six members of Lowestoft staff when using a wedge gauge.

From data given in Table 4 and Fig. 10 for dry tarred sisal this range of average pressures could produce about 2-3 mm. differences in recorded mesh size and rather more if applied to white sisal or manila.

(b) Spring loaded wedge

Some, but not all, of the limitations of a hand wedge are overcome by a spring loaded wedge. Two possible causes of error that remain are (a) that if the prescribed loading happens to be exceeded, even momentarily, the mesh remains at the highest reading; and (b) that it is easy to allow the mesh to become "skewed" on the wedge and then to lever one side against the other when attempting to straighten it. In the latter case greater tensions can be exerted than are recorded on the loading scale. These two difficulties are aggravated by the fact that the mesh under test and the loading scale are usually too far apart to be watched simultaneously.

A further limitation, however, is that the stretching force on the mesh corresponding to any particular downward thrust on the wedge depends on the material being tested. This was found by measuring a mesh with downward loads of 5, 10 and 15 lb. on a spring wedge, and then finding the direct load needed to elongate the same mesh by the same amount, measurements being repeated until no further change occurred. Results of paired tests (A and B) are given in Table 4 below for double manila and sisal meshes.

Wedge Load (lb.)	Material and approximate size of mesh														
	Manila used, wet, white 115 mm.			Sisal used, wet, white 85 mm.			Sisal used, dry, white 90 mm.			Sisal used, wet, tarred 90 mm.			Sisal used, dry, tarred 90 mm.		
	A	B	Mean	A	B	Mean	A	B	Mean	A	B	Mean	A	B	Mean
5	5	5	5	6	5	$5\frac{1}{2}$	$6\frac{1}{2}$	7	$6\frac{1}{2}$	4	$4\frac{1}{2}$	4	3	$3\frac{1}{2}$	$3\frac{1}{2}$
10	$8\frac{1}{2}$	$9\frac{1}{2}$	9	13	12	$12\frac{1}{2}$	12	$14\frac{1}{2}$	$13\frac{1}{2}$	6	$6\frac{1}{2}$	6	$5\frac{1}{2}$	$6\frac{1}{2}$	6
15	$13\frac{1}{2}$	$13\frac{1}{2}$	$13\frac{1}{2}$	$15\frac{1}{2}$	$15\frac{1}{2}$	$15\frac{1}{2}$	$15\frac{1}{2}$	19	17	$9\frac{1}{2}$	9	$9\frac{1}{2}$	$6\frac{1}{2}$	$8\frac{1}{2}$	$7\frac{1}{2}$

Table 4. Longitudinal tensions corresponding to 5, 10 and 15 lb. wedge loads for various materials

The main differences are due to tarring, and imply that a 10 lb. wedge load, for example, may stretch an untarred mesh some 5 mm. or so more than it would if the mesh had been tarred (see Fig. 1, B and C).

The reason for this lack of consistency between downward thrust and resultant stretching force on the mesh is due to the large and variable nature of the friction between mesh and gauge. Thus the wedge used in the above tests had a slope of 1 in 8; if there was no friction between mesh and wedge a downward thrust of 10 lb. would produce a stretching force of 80 lb. on the mesh. The fact that downward and outward forces are of the same magnitude indicates the marked effect of friction in reducing the mechanical advantage of the wedge. It is not surprising, therefore, that the "stickiness" of tarred twine causes a substantial reduction in the outward force corresponding to the higher wedge loads, as apparent from Table 4.

To sum up, a spring-loaded wedge, though an improvement on a hand wedge, is not in our opinion an entirely satisfactory method of measuring a mesh. We believe that if the highest degree of accuracy and uniformity is desired, a device capable of exerting a direct longitudinal tension is essential.

(c) Direct tension devices

Provided such a device is capable of applying a constant tension for a prescribed period, it does not seem necessary to standardise the particular design of instrument. This can be left to choice, depending on factors such as (a) whether the instrument can easily be used single-handed and under difficult conditions - e.g. on board ship (b) proximity of mesh scale and loading mark, if such is employed, (c) whether the mesh scale is magnified and easily visible, (d) whether the device is robust and cheap to make.

An instrument has been developed recently by us which it is thought satisfies to a reasonable degree the above requirements; a photograph of it is attached to some copies of this report. A brief description, with reference to this photograph, is as follows.

The device consists of a pair of main arms (A) pivoted at (B) to which the me suring jaws C and D are attached. The right hand jaw C is fixed rigidly, but the other jaw D is pivoted at E and extended to form a pointer F lying along the left hand main arm. This pivoted jaw is held against a stop H by a spring G which can be adjusted by the threaded rod J to exert any desired force up to about 10 lb. The size of mesh is read from the position of pointer F on a scale carried by quadrant K attached to the right hand main arm. In this particular model the scale has a range of 50 to 120 mm. and a magnification of $1\frac{1}{2}$ times, but by decreasing the distance of the jaws beyond pivot B, greater scale magnification can be obtained if a smaller range is acceptable (as, for example, in routine measuring at ports).

In use, the apparatus is held as shown in the photograph and the jaws inserted in the mesh in the closed position. The fingertips grip a rail running below and parallel to the left hand main arm which is not visible in the photograph. The main arms are then brought together by closing the hand, until the longitudinal tension exerted on the mesh is just sufficient to begin to pull the pivoted jaw D away from its stop. That this has happened is shown very sensitively by movement of the pointer F. To obtain the mesh size the hand is clenched until the end of the pointer has moved slightly to a mark at the extreme end of the left hand main arm adjacent to the scale. In this position the pointer F records the reading of the mesh under a tension determined by the adjustment of spring G. Strictly, the tension needed just to move the pointer varies with the angle to which the jaws are opened; however, by setting the spring with the jaws half open the effective tension is reduced by 2% when the jaws are fully shut and increased by 5% when fully open. On a load of 6 lb. this variation is negligable.

To obtain an idea of the true accuracy of this instrument a stretched mesh was measured repeatedly by several observers with the adjustable spring set at a tension of 3 kilo ($6\frac{1}{2}$ lb.). The gauge was removed and reinserted between each measurement. Provided the jaws always rested on the same side of the knot measurements differed by less than 0.5 mm; if they lodged on the opposite side on the knot the readings were 3 mm. less but again consistent within themselves to within 0.5 mm.

As a practical test of the comparability of measurements made by hand wedge and the above device (3 kilo load), 46 meshes (double tarred sisal, wet) were measured by both methods; for 23 of them the spring gauge was used first, and in the other 23 the hand wedge, to avoid bias through stretching of the mesh. The trawl was stowed against the rail of a trawler and the hand wedge was used by one of the Ministry's Inspectors who carries out routine mesh measurement and enforcement duties. The difference between the averages of the two sets of readings was just under 1 mm., the spring gauge giving the higher value.

As a further test a series of meshes were selected which were in the region of 75 mm., and measured by the spring gauge after applying the load for 5 seconds. The Inspector was then asked to test the same meshes with the parallel-sided 75 mm. enforcement gauge used in the U.K., and a note made of whether each mesh was passed or failed. The result was as follows:-

Mesh size (mm.) by $6\frac{1}{2}$ lb. gauge	69	70	71	72	73	74	75	76	77	78	79	80
Failed	3	-	1	4	4	1	1					
Passed						2	-	3	3	2	2	1

There is good agreement between the two methods of testing the meshes, and it seems that the spring gauge would be practicable for enforcement tests as well as for mesh measuring.

Conclusions

1) From an investigation of the load-elongation characterists of meshes, it is suggested that a load of about $6\frac{1}{2}$ lb. (3 kilo) applied longitudinally to a mesh for about 5 seconds would provide a reasonably consistent basis for measurement of all the sisal, manila and hemp nets normally used for deep-sea trawls; and, provisionally, for cotton nets also.

2) A load of this amount is within the range of tensions exerted by members of the Lowestoft staff using a hand wedge gauge.

3) The force with which a mesh is stretched by inserting a spring-loaded wedge gauge with a given pressure is dependent upon the material of which the mesh is made.

4) It is concluded that a gauge capable of exerting a direct longitudinal stretching force should be used if the maximum degree of accuracy and comparability is desired.

5) A direct-tension gauge, developed recently at Lowestoft, is described.

References

BOEREMA, L. K. 1954. 'Some experiments on factors influencing mesh selection in trawl nets.' Paper submitted at North Sea Sub-Committee

BRANDT, A. v. 1955. 'Zur Technik der Bestimmung der Meschengrösse.' Arch. Fisch. Wiss., 6, 54.

Addendum

A description of the twines concerned in Fig. 1 is as follows:-

A	Manila:	125 yds./lb., 3-ply
B	Sisal :	125 yds./lb., 3-ply
C	Sisal :	125 yds./lb., 3-ply
D	Hemp :	303 Italian netting cord; 3-ply, 175 yds./lb. (approx.)
E	Cotton:	thick, 2.3 mm. dia. } 3-ply
		thin, 1.8 mm. dia. } 3-ply

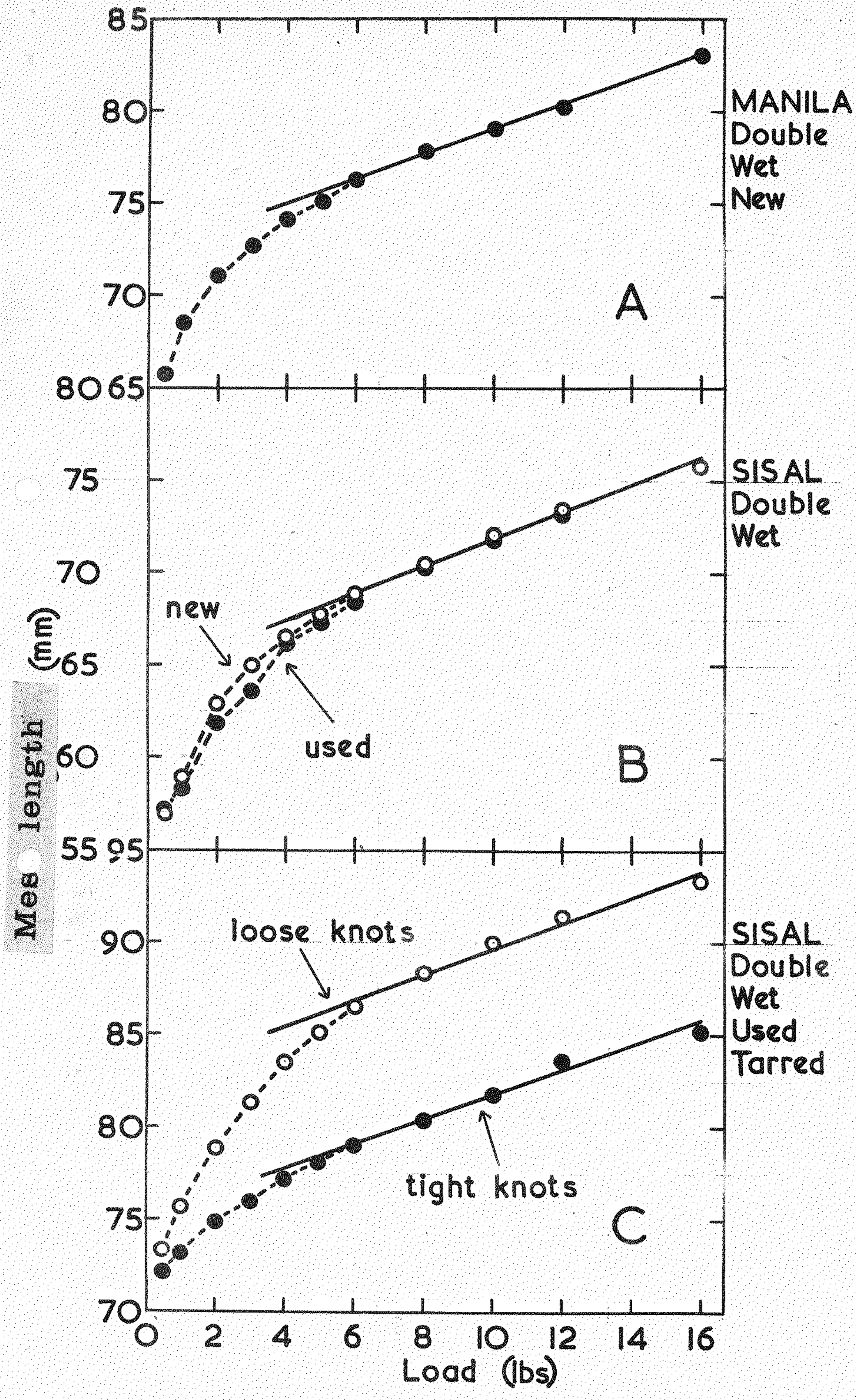

Fig. 1

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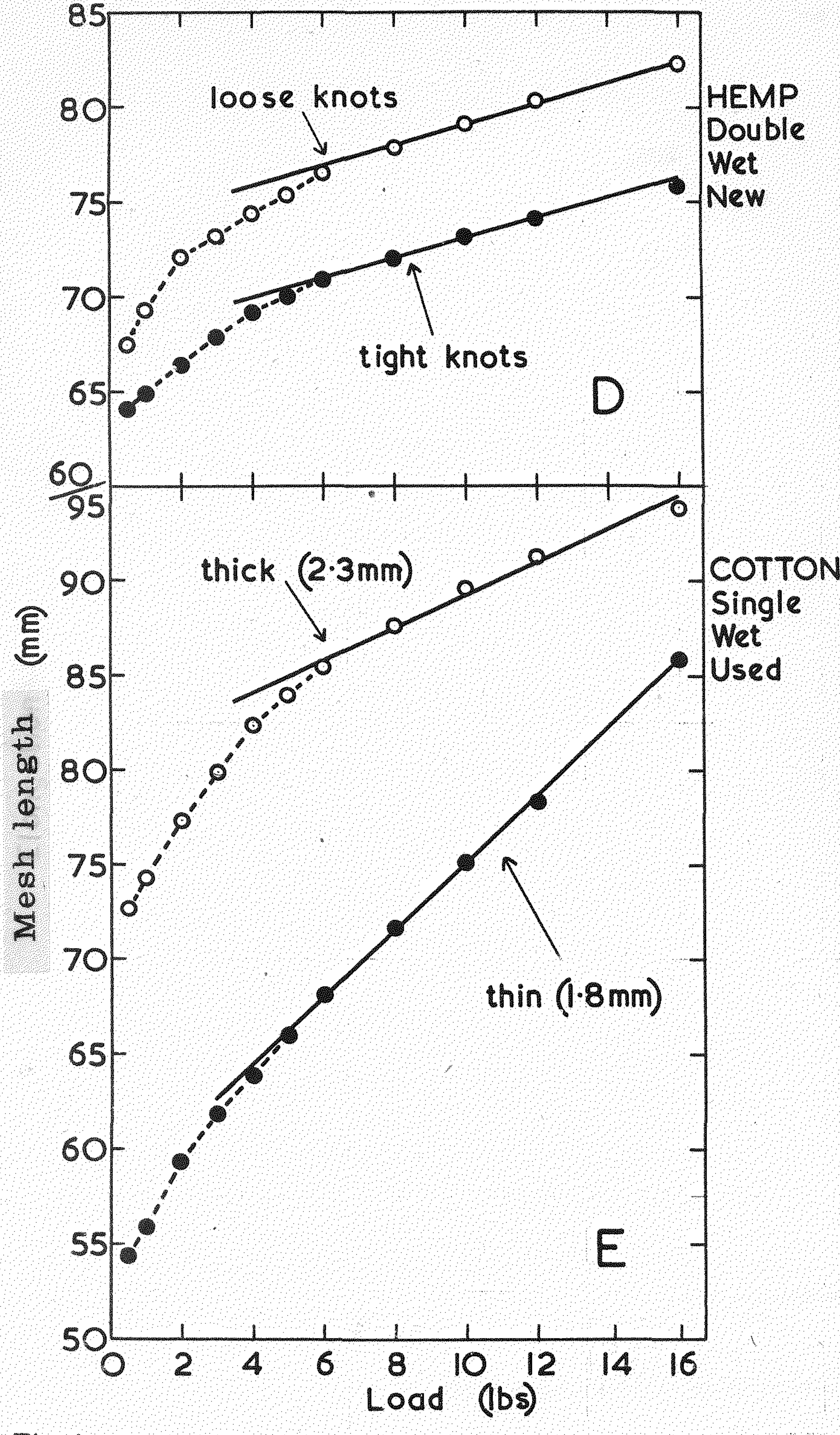

Fig. 1

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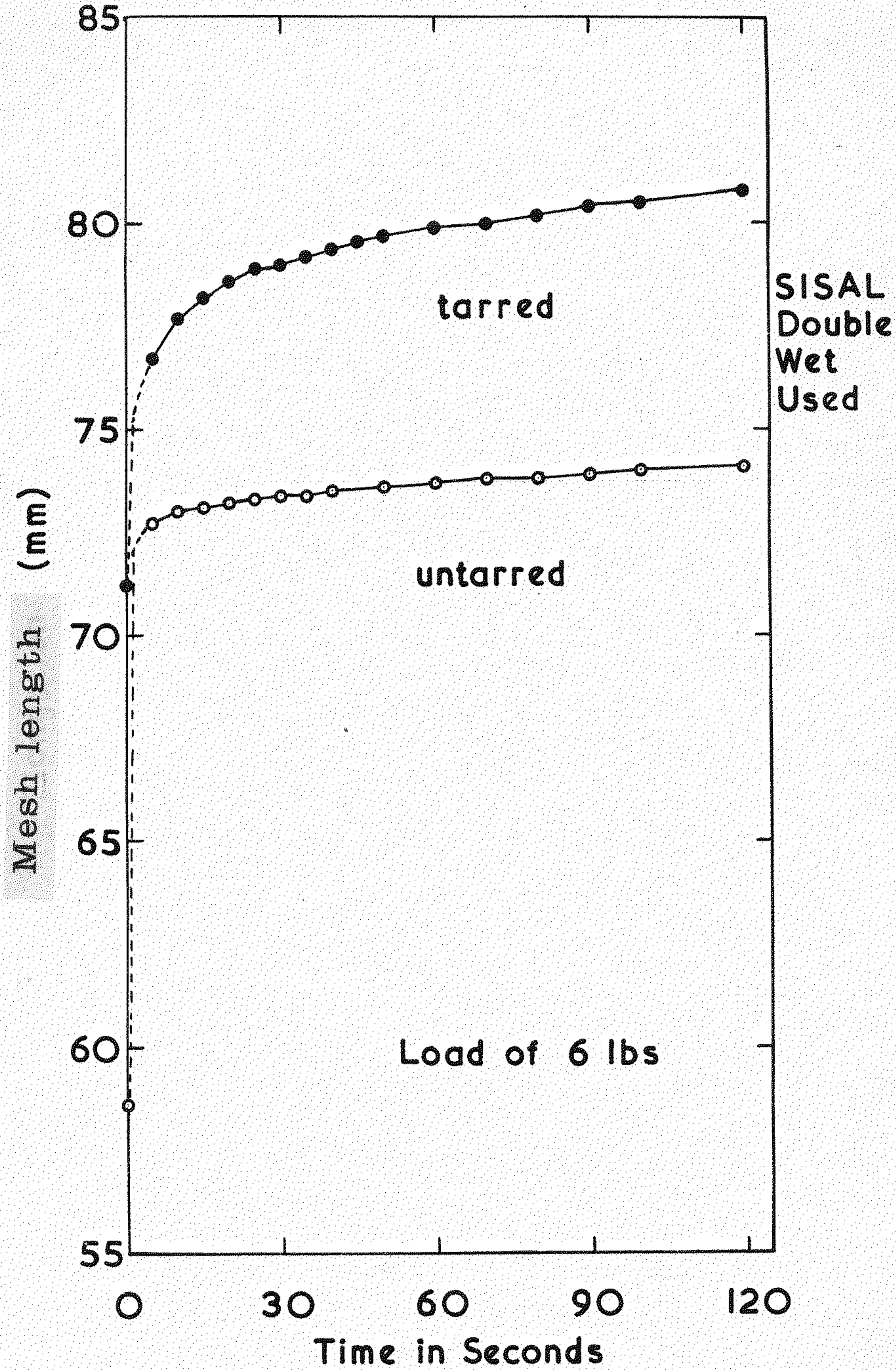
85
80
75
70
65
60
55
Mesh length (mm)
tarred
untarred
SISAL
Double
Wet
Used
Load of 6 lbs
0
30
60
90
120
Time in Seconds

Fig 2