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TECHNICAL NOTES

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No. 198

MICARTA PROPELLERS - I

MATERIALS.

By F. W. Caldwell and N. S. Clay.

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By F. W. Caldwell* and N. S. Clay**.

Products formed of fibrous material and a synthetic resin binder, may, from a structural standpoint, be divided into two classes, laminated and non-laminated. In the laminated construction, sheets of paper, cloth, or wood veneer are impregnated with the resin and formed between plates or in a mold under the action of heat and pressure. In the non-laminated construction, loose wood or asbestos fibers are impregnated with the resin and then formed under heat and pressure in a mold. A second class of material used to a limited extent in the non-laminated construction is obtained by shredding impregnated paper or cloth cuttings which would otherwise be scrapped.

The laminated and non-laminated materials differ considerably in their physical and molding characteristics. In general, the laminated material is stronger than the non-laminated but is more difficult to mold into irregular shapes. It is used mostly in sheets or in simple molded forms.

When the development of micarta propellers was begun, it was recognized that success depended on securing correct distribution

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of the material. Accordingly, the non-laminated structures were first considered because of the better flowing properties of the material. A few preliminary trials and calculations indicated, however, that this free flowing property would be actually a disadvantage as there would be no method of preventing the large bulk of material at the hub from flowing toward the tips when the pressure was first applied.

In the laminated construction the physical properties vary considerably with the kind of sheet material used. Kraft paper gives high tensile, compressive, and transverse strength, but low impact. Cotton duck fabric gives somewhat lower tensile, compressive, and transverse values, but very much higher impact strength. Because of its resistance to shock and good flowing properties the duck base material has been most generally used in propeller construction.

In the airplane propeller service the material is subjected to a very high stress in the direction of the longitudinal axis due to centrifugal and thrust forces and to rather low stresses in the other directions. It is desirable then, that the tensile strength of the material in the direction of maximum load be made as great as possible even at the expense of the strength in other directions. This can be done with a fabric base material by using a cloth having greater strength in the warp than in the filler. The weight of the warp threads can be made 90% of the total weight of the cloth without weakening the micarta too much in other directions.

In the following table values for tension, compression edgewise of laminations, and transverse flatwise of laminations, are given for micarta made with various kinds of sheet material. The corresponding values for white oak wood are also included for comparison.

Table.

	Tensile	Compression edgewise	Transverse flatwise
Micarta duck	9560	21000	20500
Micarta-kraft paper	15600	22000	25000
Micarta-special fabric	26000a	22800b	39300a
Micarta-wood veneer	36000c	7970d	41300c
Wood-white oak	5400c	1950	19700c

a - Warp threads lengthwise of test specimen.

b - Parallel to warp thread.

c - Grain lengthwise of test specimen.

d - Parallel to grain.

In regard to the application of these various materials to propeller service, it has been found by destructive and service tests that micarta made with a good grade of cotton duck will give satisfactory service with most designs. In propellers having detachable blades, whether of fixed or controllable pitch design, it is desirable that the root of the blade be of small cross-section to decrease the weight of the metal hub. Here the use of the special fabric or wood veneer offers advantages due to greater tensile

strength. These materials, especially the wood veneer, produce stiffer blades than duck. This is also of value in controllable and reversible pitch designs where it is desirable that the plan form of the blades be symmetrical. The tension-elongation curves of these materials are given in Figure 1.

Tension - Elongation Curves of Micarta.

With the laminated structure it is possible to distribute the impregnated sheets in a number of ways. The simplest method is to place the plane of laminations at right angles to the axis of rotation. The size and shape of each sheet, which will differ from every other sheet, can be easily determined from the drawing of the propeller and suitable templets or patterns made. It is also possible to place the plane of the laminations at some other angle than 90° to the axis of rotation. This can be done to advantage with blades for detachable blade propellers. Here, since the two blades are molded together in a similar manner to the usual fixed pitch design, and afterwards sawed apart, the pitch setting of the blades with respect to the mold can be made as desired and the templets determined accordingly.

Another method of distributing the material has been tried out with a fair degree of success. In this case, the laminations at the hub are normal to the axis of rotation but out in the blade they twist and gradually become parallel to the thrust face, at some section near the tip. Each lamination has then a warped surface.

The advantage of this method lies in the shape of the templets produced. Instead of the tip of the propeller being constructed of a number of long narrow laminations a smaller number of rather broad sheets are used.

Theoretically, with any of these patented methods of construction, each lamination would have a distinctive shape and require a separate pattern. Practically the number of templets can be reduced 80% or more because of the flowing of the materials in the molding operation.

In applying a certain kind of sheet material to micarta propeller construction, this first question arises: Will the resulting product have sufficient strength, and second, Will the material flow so as to produce a satisfactory molded job? The poor flowing properties of paper and wood veneer make the use of these materials difficult. Impregnated fabrics on the other hand flow more readily under heat and pressure and form perfect molded products.

The necessity for using a material that will flow to a certain extent in the molding operation can be readily seen from Figure 2.

Sections of Micarta Propeller Showing Initial and Final Distribution of the Material.

In this drawing an attempt has been made to show the position of the stacked sheets of impregnated duck and the amount of compression of the material during the molding operation. Three sections of the propeller are illustrated, the hub, the 24 and the 48-inch stations.

	Material	Ultimate tensile strength	Modulus 0 to 5000 lbs./sq.in.
1	Micarta-Wood	36000	3,200,000
2	" Paper	15600	3,270,000
3	Wood-White Oak	5400	2,040,000
4	Micarta-Special fabric	26000	2,000,000
5	" Cotton duck	9560	1,180,000

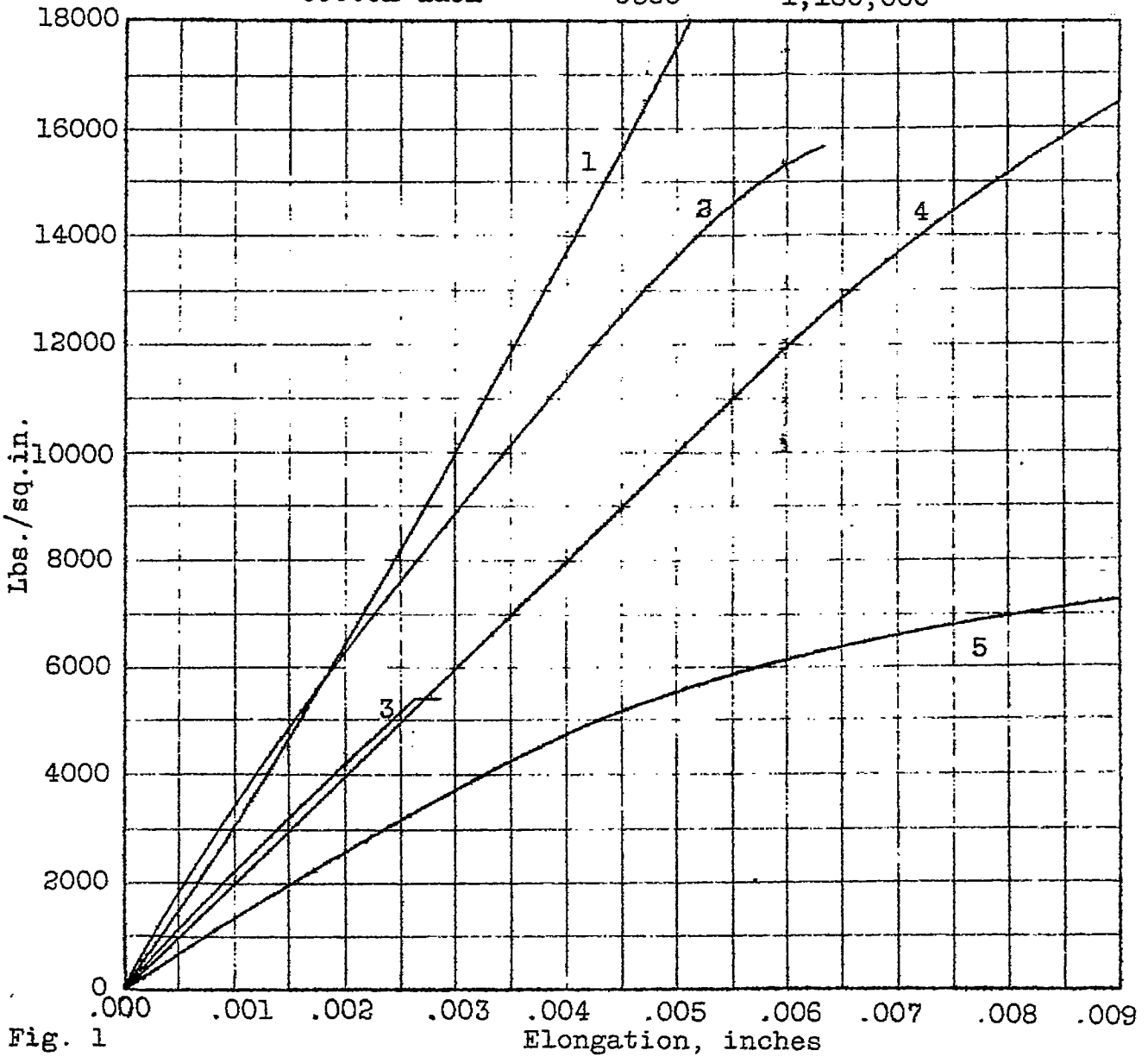


Fig. 1

a=Stacked material. No pressure
b=Under pressure. Heat not applied
c= " " 1/2 hr. baking
d= " " 1 to 2 1/2 hrs. baking
e=Mold closed cold

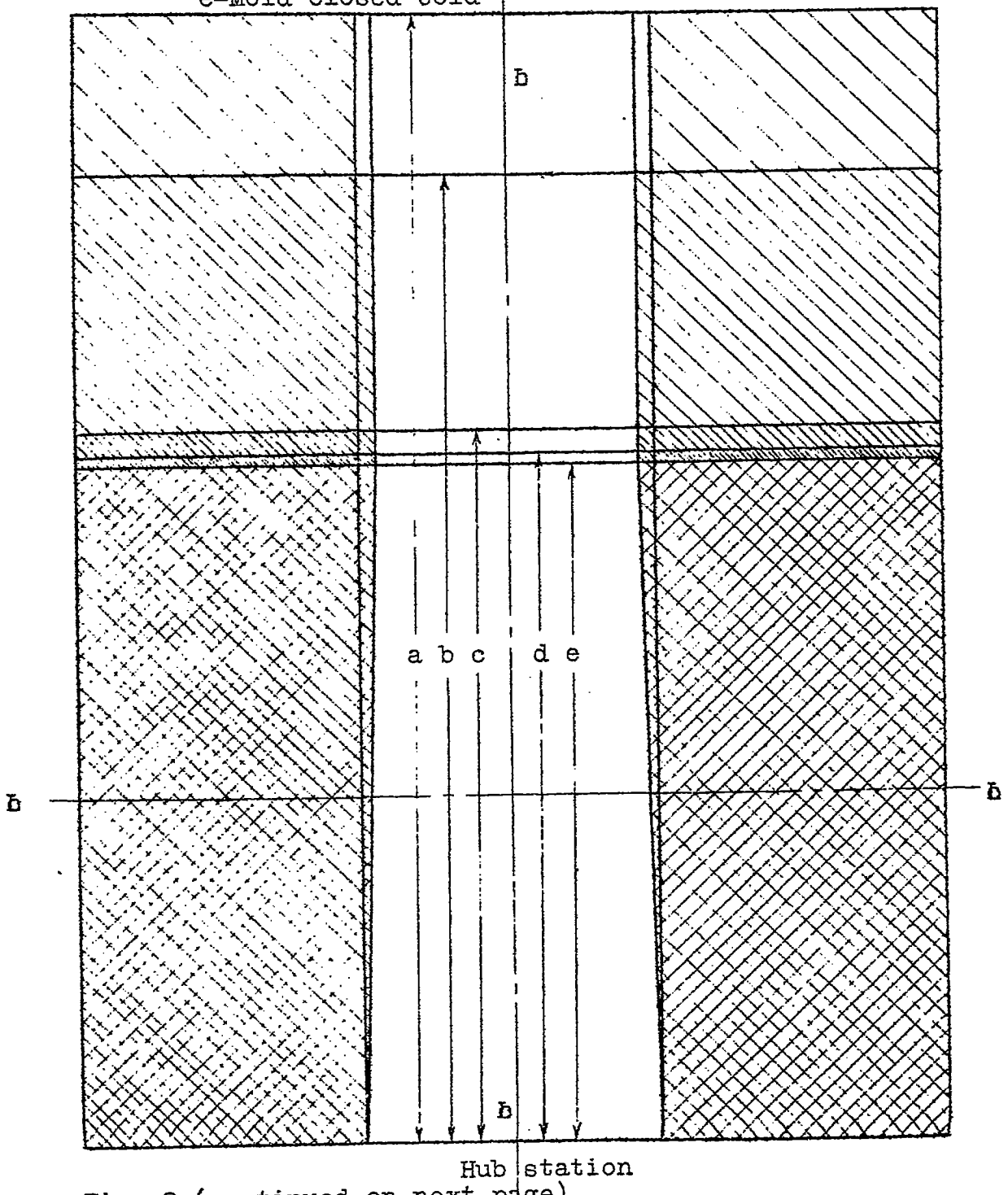
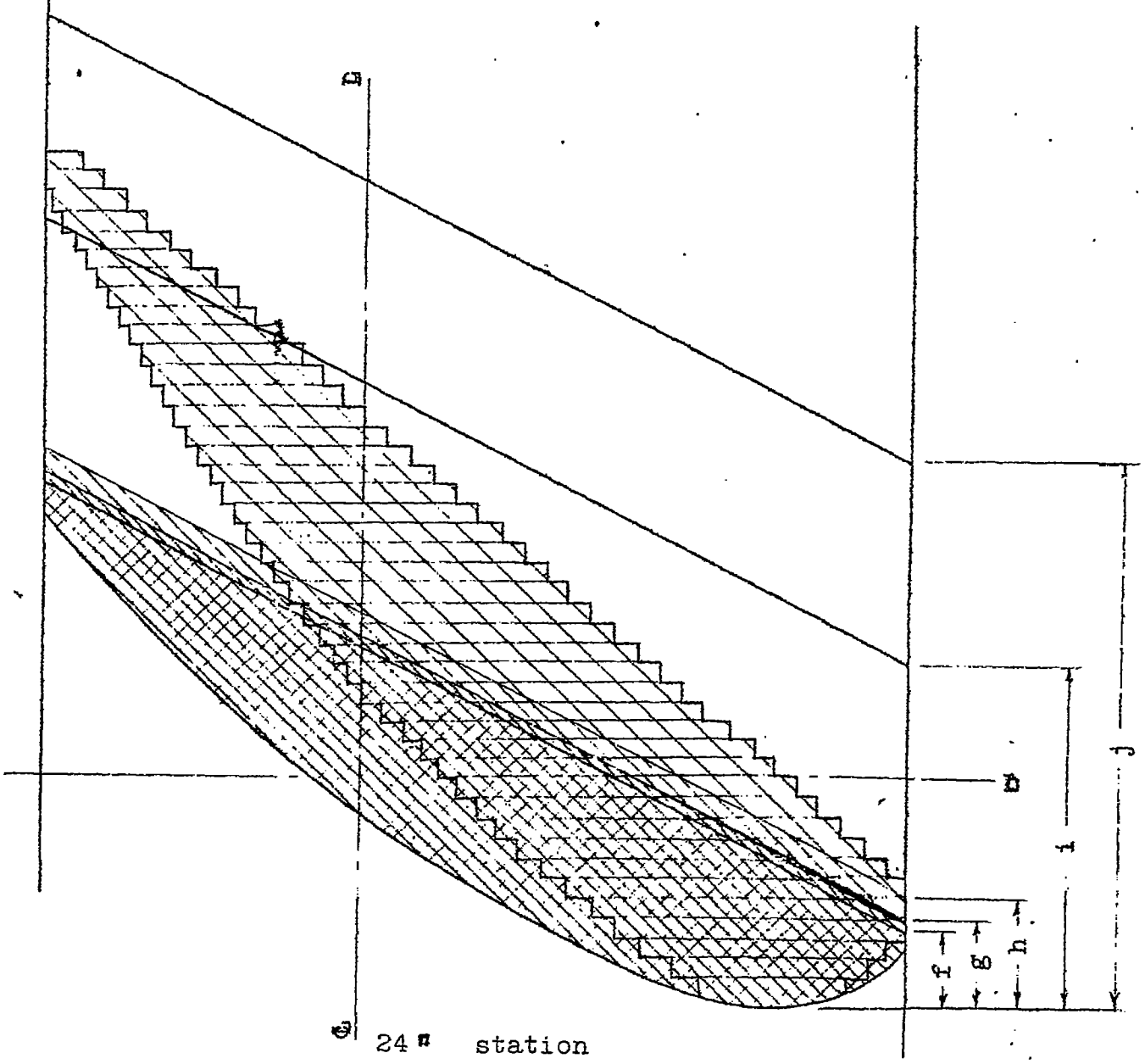


Fig. 2 (continued on next page)

f=Mold closed
g=1 to 2 1/2 hrs.
h=1/2 hr.
i=Pressure. No heat
j=Upper pressing block held by hub material. No pressure. No heat.



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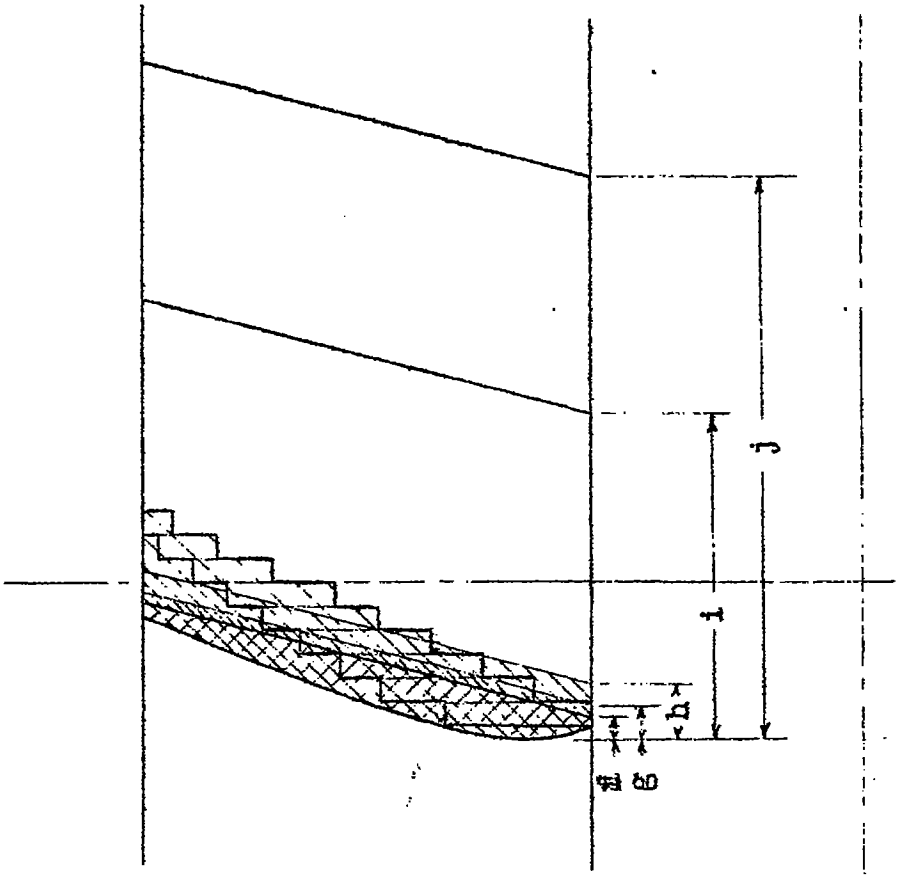

48" station

Fig. 2 (concluded)