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By H. R. Wyman

Part I

When fish-muscle is frozen and then defrosted, certain changes - chiefly of a mechanical nature - take place during the process. The popular antipathy toward cold-storage fish results in large measure from these changes. Perhaps the most objectionable feature of frozen fish is the behaviour of the fluids. As the fish thaws, a considerable amount of fluid exudes. This is objectionable in itself, but, in addition, it leaves the fish tough, fibrous, and rather tasteless. It is with a view to devising such conditions of storage as to minimize this effect that this research has been undertaken.

The first problem which presented itself was that of devising a means of comparing the various samples of fish as regards the expressibility of fluid. For this purpose a press used previously by Mr. MacFadyen was used. The construction of the press is shown diagramatically in Fig. I. Ice and water in equilibrium in the bath (B), maintain the press and its contents at 0°C. The fish (F) is wrapped in cheese-cloth to retain the actual tissue, and is enclosed on the sides and bottom by wire gauze (G) to give the fluid a free exit. The brass container (C), and the wooden piston (P) are cylindrical, the piston being heavily paraffined. A piece of flannelette loosely wrapped around the piston at (K) serves to prevent water condensed on the brass from the air running into the press. The lever (L) is of wood supported at (D) and (E) on steel knife-edges against steel plates. The basket (A), in which various weights are put, is of wood supported by wire.

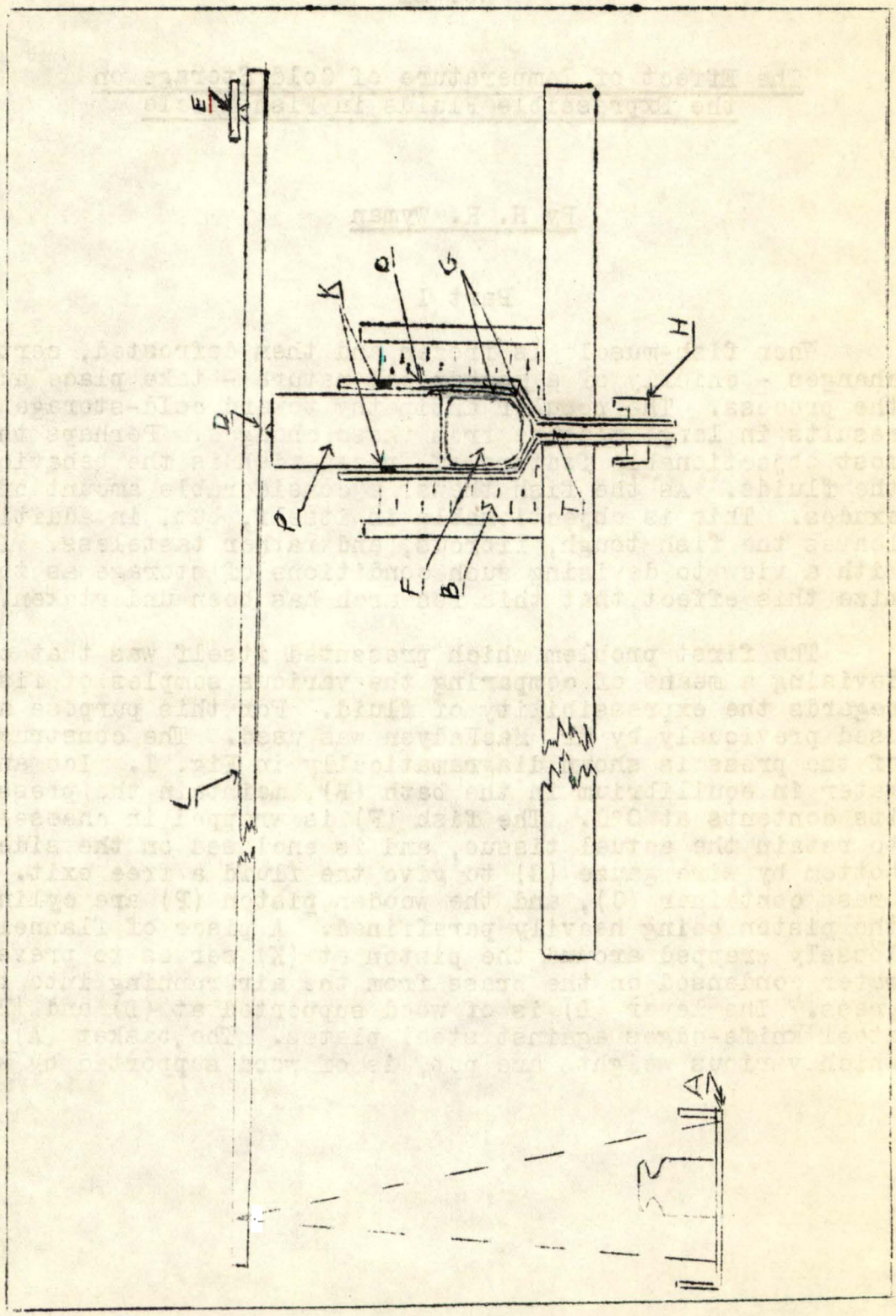

Fig. I

The wire is so wound that the surface resting on the lever is cylindrical, amounting, therefore, to a point contact. The fluid expressed from the fish passes out through the tube (T), and is received in a vessel and weighed. The stopper (H) cut as shown, prevents the condensate from the air on the cold brass from passing into the collecting vessel.

The calculation of the pressure on the fish is as follows:

Weight of basket	2.0 lbs.
Weight of lever	7.5 lbs.
Weight of piston	1.5 lbs.
Length of lever	84.6 ins.
Distance from fulcrum to basket	79.5 ins.
Distance from fulcrum to piston	10.5 ins.
Distance from fulcrum to centre of lever	39.7 ins.
Diameter of piston	2.8 ins.

Therefore the force acting at the base of the piston

$$= P = \frac{7.5 \times 39.7 + 79.5\ (2 + w)}{10.5} + 1.5 \text{ lbs.},$$

or, the pressure on the fish $= P_1 = \frac{P}{\pi(1.4)^2}$ lbs./in.^{2},

where W is the weight in the basket.

Since the area on which the pressure acts is always the same, the force P, which is proportional to P_1, may be used in the consideration, and this quantity is that which is meant whenever pressure is mentioned in this report.

The total fluid expressed from a sample of fish was divided into two classes:-

First, that fluid which exuded without the application of pressure, while the fish was defrosting. This fluid is referred to as the Drip.

Second, the fluid actually expressed in the press. This is referred to as the Expressed Fluid.

The sum of these two is the Total Fluid.

In the earlier part of the work, the comparison of samples was carried out by subjecting a 100 gm. sample to a pressure of 424 lbs. in the press, immediately after defrosting, and determining the curve obtained by plotting total fluid against time of pressing. This method gave distinct differences between fresh, brine-frozen and air-frozen fish, but, when the finer differences due to different storage conditions were investigated, this method proved to be lacking in precision. The method presented another difficulty in that there was no quantitative manner found of expressing the shapes of the curves. It was the shape of the curve that distinguished one class of fish from another. Typical curves are shown in Fig. II. Further investigations revealed a simple and fairly precise technique which was adopted throughout the greater part of the work. The new method being adopted, a considerable number of comparative runs was carried out, and from the results of these, results of the first method can be corrected to the same basis as those of the second. In this report all values of the total fluid will be given on the basis of the latter method.

The new method is as follows:-

A piece of the fish to be tested is taken from storage and a sample of 100 gm. (± 1 gm.) is cut from it and weighed. The sample is then left for three hours to defrost at room-temperature. At the end of this time the surface of the sample is carefully dried with filter-paper and the sample is weighed again. The loss of weight is the drip. The sample is then wrapped in moist cheese-cloth, placed in the press, and left for fifteen minutes to take up the temperature of the press. This amount of time is sufficient, since, at the end of three hours at room-temperature, although the fish has defrosted, its temperature has risen very little above the freezing point. A pressure of 172 lbs. is then applied, the fluid from the press being caught in a weighed flask placed with its neck just not touching the stopper on the delivery-tube of the press. This precaution is to prevent evaporation of the fluid from the flask and from the surface of the drops as they form. At the end of exactly ten minutes the flask is removed and weighed. This gives the weight of expressed fluid in ten minutes under 172 lbs., and thence, the total fluid under the same conditions, which is the figure used for comparison. A correction was worked out for initial weight of the sample in cases where it might not be exactly 100 gm., and was found to be negligible if the sample were within 1% of that weight.

The fish for this investigation was cod obtained from the fishermen on their way in, within three hours of being caught. This was handled as carefully and as uniformly as possible. It was filleted, cut into half-pound cakes, and frozen in brine at -18°C., the plates being left in the brine for thirty minutes. Freezing of the fish was complete eight hours after being caught. The frozen cakes were weighed and tagged, and were mixed up together in such a way that twenty random cakes represented a fair sample of the lot. The dimensions of the cakes were approximately 3 x 6 x 1 ins. They were packed in galvanized iron containers 3 x 12 x 15 ins., being packed in layers of two cakes each which fitted tightly, thus decreasing the possibility of drying. Twenty-six cakes were packed in each of five such containers, and these were closed by means of a block of wood covered with lead foil to make it fit tightly. One of the cold-storage rooms was maintained at about -23°C. and in it were placed five constant-temperature boxes. These boxes were of wood, thickly lined with cork, all spaces in which were sealed with asphalt. The openings were in the bottoms of the boxes, and the heaters were on one of the sides. Each heater was a 40 W. tungsten filament lamp enclosed in a polished copper reflector to prevent direct radiation from the lamp to the stored samples. The reflector was open, top and bottom, thus acting, by convection, as a circulator for the air. A DeKhotinsky Bimetallic Thermoregulator was placed in the top of each box, and a thermometer in the centre of the front. The containers of samples were stored in these boxes on the side of each remote from the heater. Temperature regulation of the boxes was accurate to within 0.5°C. The boxes were regulated as follows:-

Four of the boxes were regulated to maintain constant temperatures of -5°C., -10°C., -15°C., and -20°C. respectively. The regulator of the fifth was set to break the heater circuit if the temperature exceeded -3°C., and there was also a single-throw knife-switch in the circuit. By means of this switch the heat was turned on in the morning and off at night, giving a daily variation of the temperature from -15°C. up to -4°C. and back down to -15°C. A typical curve for the temperature variation of this box is shown in Fig. III. The regulator on this box serves as a safety device to prevent any accidental heating above the melting point of the fish.

One container of frozen cakes was put in each of the five boxes. Each cake on removal, before defrosting, was weighed and the loss due to drying in storage determined. The half-pound cakes were sufficient for two 100gm. samples, and check runs were made on all samples in the press. The difficulty of removing the closely packed cakes from the container makes the values of the drying loss only approximate.

Below are recorded the results found during the work of the summer:-

Series	No.	Time Stored	Wt. Fish	Drying Loss	Drip	Total Fluid
Fresh Cod		-	-	-	-	3 gm.
Sample brine frozen		0 dys.	-	-	5 gm.	12 "
Sample air frozen		?	-	-	6 "	35 "
Sample of lot investigated		0 dys.	-	-	6 "	13 "
I	26	7 "	252 gm.	3 gm.	4 "	16 "
I	24	14 "	212 "	2 "	5 "	20 "
I	23	28 "	229 "	4 "	8 "	28 "
I	21	68 "	239 "	4 "	12 "	32 "
I	22	102 "	244 "	5 "	7 "	34 "
II	26	7 "	218 "	3 "	4 "	15 "
II	25	14 "	230 "	1 "	4 "	14 "
II	23	29 "	209 "	2 "	7 "	19 "
II	24	67 "	227 "	3 "	9 "	26 "
II	22	101 "	238 "	5 "	4 "	20 "
IV	26	6 "	211 "	1 "	4 "	12 "
IV	25	16 "	211 "	3 "	1 "	12 " (?)
IV	24	38 "	268 "	1 "	6 "	17 "
IV	23	65 "	268 "	6 "	7 "	27 "
IV	22	98 "	248 "	4 "	4 "	29 "
V	26	9 "	209 "	7 "	4 "	18 "
V	25	20 "	255 "	6 "	6 "	21 "
V	24	39 "	212 "	5 "	5 "	24 "

Series	No.	Time Stored	Wt. Fish	Drying Loss	Drip	Total Fluid
V	23	66 dys.	227 gm.	4 gm.	6 gm.	26 gm.
V	22	98 "	223 "	7 "	5 "	33 "
VI	25	23 "	229 "	5 "	6 "	23 "
VI	26	66 "	204 "	10 "	7 "	33 "
VI	23	98 "	213 "	15 "	3 "	35 "

Series I is that in the variable-temperature box; II, that at -20°C.; IV, that at -15°C.; V, that at -10°C.; VI, that at -5°C. Dr. Leim has kindly continued making determinations on these samples during the winter so as to complete the series for a year. The results for I-22, II-22, IV-22, V-22, and VI-23 have been obtained by him. The result for II-22 has some doubt attached to it due to the loss of the check sample through an accident. The result for either II-24 or II-22 is anomalous, and the next determination on this series will show which it is. IV-25 is doubtful as the two samples did not check well. The above values for drip and total fluid are the means of two samples of each cake. The weight of the whole cake is given for comparison of the drying loss. The results show that for 100 days storage the increase in total fluid is as follows:-

at -20°C.	13 gm. (?)
at -15°C.	16 "
at -10°C.	20 "
at - 5°C.	22 "
temperature variable	21 "

The indication is that a constant low temperature is the most advantageous. As near as can be distinguished the drying also seems to be a minimum at the lowest temperature. An analysis of a number of samples of expressed fluid, made by Miss Wilson showed a protein content of from 5.32% to 5.60%.

Part II.

The Drying of Fish During Cold-Storage

The drying of fish in cold-storage, that is, the distillation of water from the fish to the colder container, walls of the room, or cooling coils, is also of considerable importance. Fish that has dried in storage has an unpleasant appearance and is dry and fibrous. Commercially, it also has the disadvantage that the water that evaporates in storage is bought at the same price by weight as the fish, but after storage this water is lost and cannot be sold with the fish. Or, if the fish is in a container or wrapper, the latter is coated on the inside with frost or ice which is a decided disadvantage in marketing. Consequently, along with the main problem of the expressible fluid, a few experiments on drying were carried out.

First the effect of various forms of containers and wrappings was investigated. Frozen cakes of cod muscle of uniform size and shape, the average weight being 220gm., were placed in various wrappings and containers and suspended by fine wires to allow freedom for evaporation from all surfaces, and placed in the cold-storage room maintained at -17.8°C. After twenty-three days storage they were weighed and the loss in weight due to drying found. The results were as follows:-

Kind of Wrapping	% Loss in Wt.
None	3.3
Brown Wrapping Paper	3.2
30 lb. Parchment	2.9
Fibre Paper Waxed on one side	2.3
Waxed Kraft Paper	2.2
Cake suspended in Wooden Fillet Box	2.1
30 lb. Waxed Paper	1.6
40 lb. Waxed Paper	1.6
Cake suspended in Air-tight Tin	0.7
Metal-coated Paper	0.4

In putting the wrappings on they were all cut the same size and folded alike in such a way as to make them as nearly air-tight as possible. In the case of the air-tight tin the behaviour was as might have been predicted. At the end of four days the cake had lost 0.7% of its weight and the weight from that time on was constant, an equilibrium having at that time been reached between the vapour pressure of the water in the surface of the fish, the partial pressure of the water vapour in the air, and the vapour pressure of the condensate on the inside walls of the tin.

This led to the investigation of the effect of various temperatures on the drying of fish stored in air-tight tins. Samples similar to the above were stored for seventeen days in air-tight tins at various temperatures and the loss due to drying determined:-

Temperature	% Loss in Wt.
Variable	1.0
-5°C.	1.4
-10°C.	0.7
-15°C.	None observable
-20°C.	0.3
Fresh cod allowed to freeze in tin stored at variable temperature	4.1
Fresh cod allowed to freeze in tin stored at -17.8°C.	1.8

Here again the lower constant temperatures seem to produce the least drying.

In these experiments the differences in drying with the various wrappings is slight. Therefore, in order to distinguish better between the effects of the various wrappers, samples similar to those above were used to make up two series. The first was made up of eight cakes wrapped as in the former series above, and was stored in the room maintained at -17.8°C. The second was made up similarly and stored in the room maintained at -23°C. These were to be left for several months when the loss from drying will be determined.

These are the results of this investigation up to the present. Further determinations are necessary before the final conclusions can be drawn. The results indicate, however, that low, constant temperatures of cold-storage are the best, form the points of view both of expressible fluid and of drying.

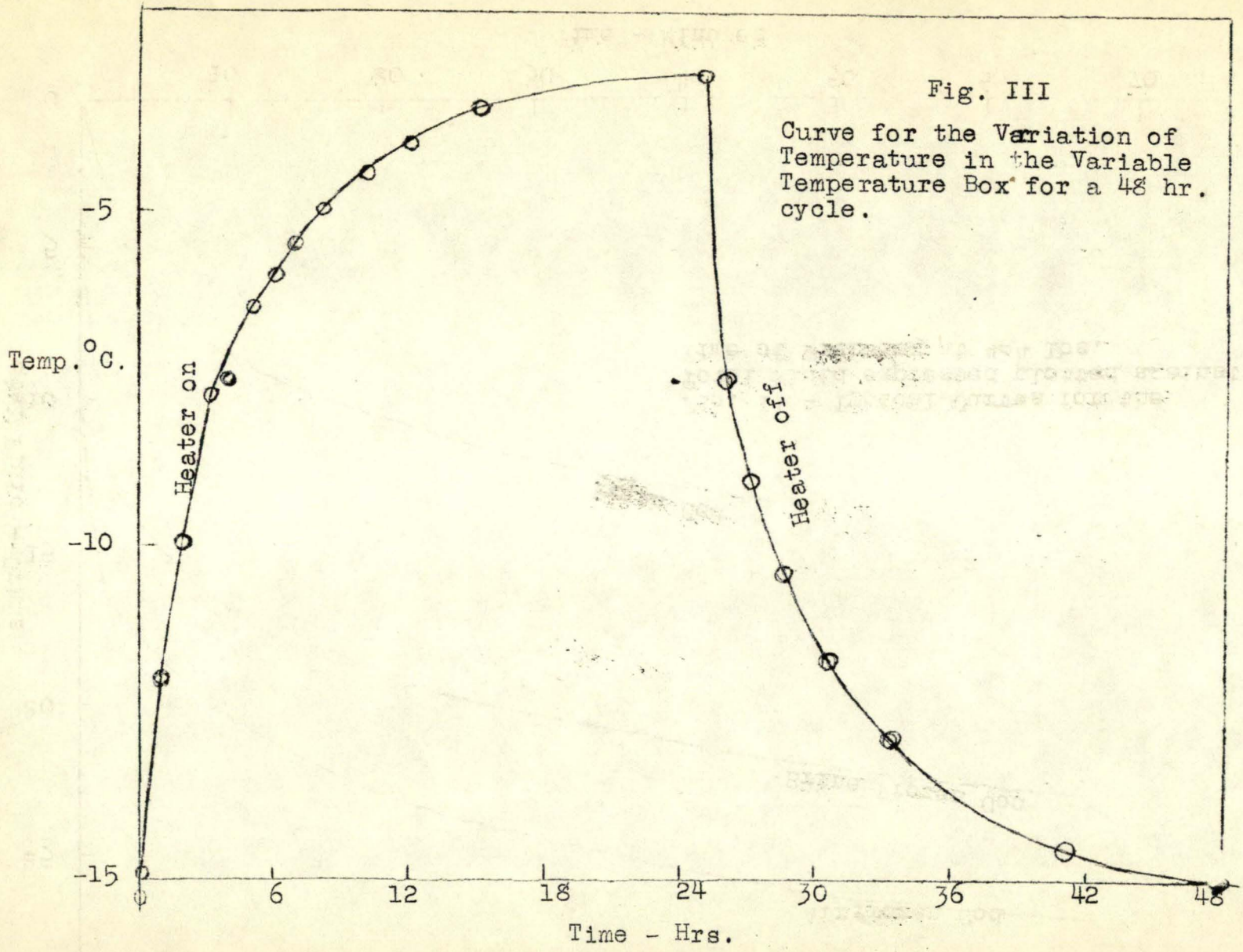

Fig. III

Curve for the Variation of Temperature in the Variable Temperature Box for a 48 hr. cycle.

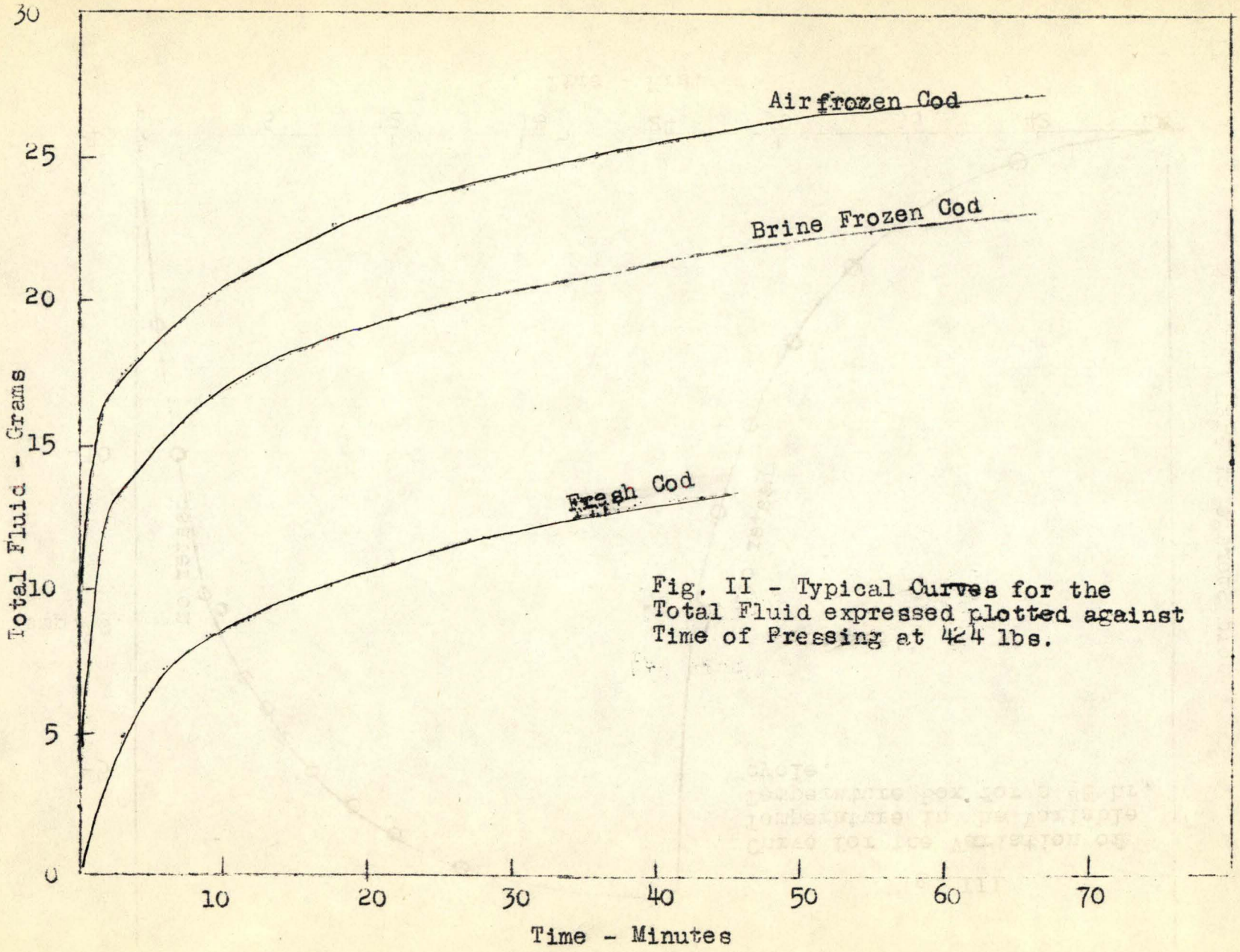

Fig. II - Typical Curves for the Total Fluid expressed plotted against Time of Pressing at 424 lbs.