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FIAT FINAL REPORT 840

GESELLSCHAFT FUR LINDE'S EISMASCHINEN

CALCULATION OF REGENERATORS FOR LINDE-FRANKL INSTALLATIONS AND OVERALL UTILITIES REQUIREMENTS FOR LINDE-FRANKL OXYGEN PRODUCING UNITS

OFFICE OF MILITARY GOVERNMENT
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FIELD INFORMATION AGENCY TECHNICAL

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CALCULATION OF REGENERATORS FOR LINDE-FRANKL INSTALLATIONS AND OVERALL UTILITIES REQUIREMENTS FOR LINDE-FRANKL OXYGEN PRODUCING UNITS

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A B S T R A C T

Information, description and methods of calculating the regenerators used in the Linde-Frankl installations are given, as well as overall utilities and space requirements for oxygen producing units.

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INTRODUCTION

Objective:

The Gesellschaft für Linde's Eismaschinen A.G. in Hollriegelskreuth near Munich was visited on June 6th, 1946. The purpose of the visit was to obtain information on the regenerators and centrifugal expanders used in the Linde-Frankl installations.

Evaluation:

Dr. Rudolph Linde, Dr. J. Wucherer and Dipl. Ing. O. Hochgesand were interviewed. According to Dr. Linde the centrifugal expanders for all their installations were manufactured by "Surth Machinen-Fabrik", near Köln, and no information on performance data was available at Linde. This subject will be covered in a subsequent report after a visit to Sürth.

Guide to the Reader:

The reader is referred to a report by H.M. Weir, U.S., CIOS No. 30 - XXVII - 55, which covers the subject of gas liquefaction and fractionation plants built by Linde.

REGENERATORS

1. General

Until the appearance of a patent by Matthias Fränkl (DRP.490878) heat exchangers were employed for cooling air before its liquefaction and separation. The exchangers heretofore employed consisted of well known tube bundles, in which the warm air was cooled by the cold separation products leaving the fractionation columns. For greater efficiency of these heat exchangers it is necessary to provide larger transfer surfaces, longer gas paths and/or higher gas velocities. Transfer surfaces of this type are expensive; furthermore, increased gas velocities cause an increase in the pressure drop of the gases, which in the final analysis increases the overall power consumption. As a result of the above, the efficiency of the heat exchangers was limited.

2. Description

The cold regenerators proposed by Fränkl are of the same type as those frequently employed in the metallurgical industry. There, however, they reached a maximum efficiency of approximately 80%, while in the separation of air, cold regenerators with an efficiency of more than 99% have been constructed.

These regenerators are cylindrical vessels 4 to 5 meters high, of suitable diameter, filled with a packing having the greatest possible surface. The general arrangement is shown in Figure 1. The flow of gases is controlled by regulating equipment at the top of the vessel, which is actuated by means of compressed air, while automatic valves are provided at the lower end. Two cold regenerators always operate together. For this reason four regenerators must be provided for the separation of air: one pair for the heat exchange between the air and the oxygen produced, and one pair for the exchange between the air and the nitrogen.

The operation is as follows: the air flows downward through the first regenerator into the separating apparatus, warming this first regenerator and thereby cooling itself. The separation products leave the apparatus and flow upwards through the second regenerator, cooling it while they are warmed. After 1 to 4 minutes the valves are automatically reversed, the air is cooled in the second regenerator and the cold separation products are warmed in the first regenerator. From the fact that air and cold gases flow through the cold regenerators in opposite directions it is apparent that these vessels act as counter current exchangers. The reversal periods are set in such a way that the temperature fluctuations at the upper and lower ends of the regenerators do not become too great.

3. Construction

Figure 2 shows the packing material used by Linde, which was proposed by Fränkl and proved to be the best. This material consists of a 25 mm. wide corrugated aluminium strip wound in a flat spiral of such a diameter as to fit closely the inside diameter of the vessel. These "pancakes" are held together by clamping wire and are piled one on top of the other into the vessel.

4. Design Data

Figure 3 gives pressure drop data of Linde-Frankl regenerators.

According to Dr. Wucherer the apparent specific weight of this packing material is one third of the specific weight of aluminium. For air pressure at 4.5 atmosphere pressure they use 0.3 kg. of packing / 1 cu.m. of air / hour. For air at 1 atmosphere they use 0.38 to 0.4 kg. of packing / 1 cu.m. of air / hour. 1 cubic meter of assembled packing of this type gives approximately 1000 square meters of heat exchange surface.

For more details on calculating regenerators the reader is referred to an article by H. Hausen entitled "Approximation process for calculating Heat Exchange in Regenerators" Z.Angew. Math. Mech. Vol.II (1931) No. 2.

5. Advantages

The high efficiency of these regenerators has already been mentioned. Also, it can readily be seen that their cost is very much lower as compared with tubular units.

To the above must still be added an important advantage of the cold regenerators. In the old processes all moisture and carbon dioxide contained in the air had to be carefully removed prior to the introduction into cold heat exchangers. If not - ice and solid carbon dioxide obstruct the exchangers very rapidly. With the cold regenerators, the ice and solid carbon dioxide are deposited on the packing, and following a reversal of the flow, are sublimed and thereby removed from the regenerator during its operation.

6. Disadvantages

As explained above, the air and the separation products flow consecutively through the same vessels. Therefore it is not possible to produce absolutely pure fractions; at each reversal the volume of the air trapped in a regenerator is mixed with the fractions. Furthermore, the products are also polluted with the water vapor and carbon dioxide picked up from the accumulator.

As a consequence of the above when using regenerators, it is not possible to produce oxygen at 99.7% which can be made by standard methods, nor nitrogen at 99.98% purity required for the synthesis of ammonia. The real field of application of regenerators is the production of oxygen of 40 to 98% purity.

UTILITIES REQUIREMENTS OF LINDE-FRANKL OXYGEN PRODUCING UNITS

Figure 4 gives the power consumption and costs of Linde-Frankl installations.

Figure 5 gives power consumption and cooling water requirements for different types and sizes of oxygen and nitrogen producing units.

Figure 6 gives space requirements and weights of different oxygen and nitrogen producing units.

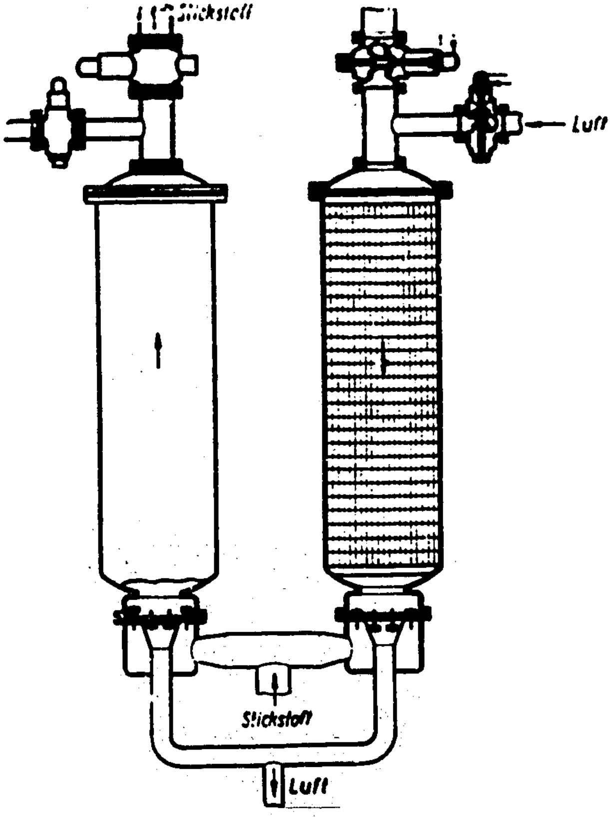
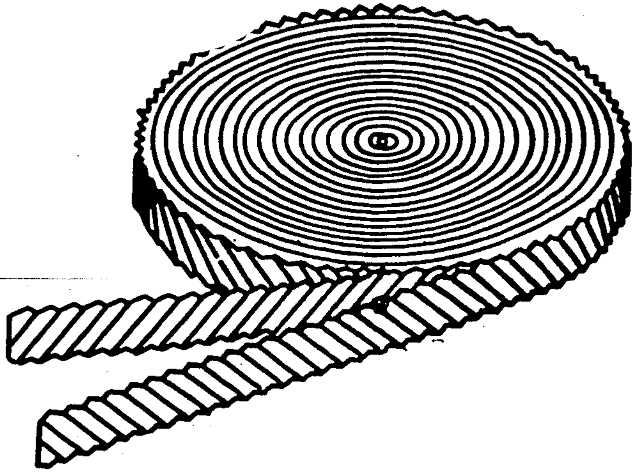
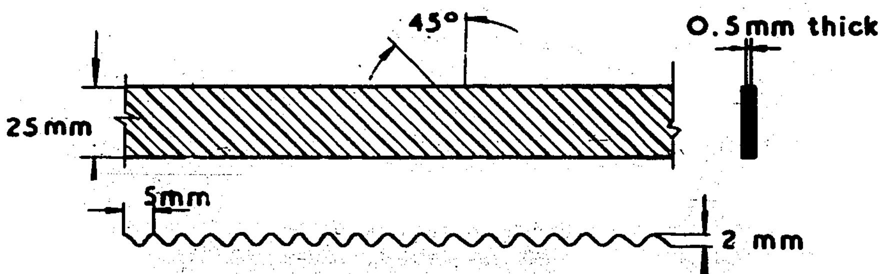


Fig. 1
Couple of cold accumulators.
(Luft = air, Stickstoff = Nitrogen)



PACKING FOR COLD REGENERATOR



DETAIL OF THE PACKING

FIGURE 2

PRESSURE DROP OF AIR FLOWING THROUGH LINDE REGENERATORS BY GLASER.

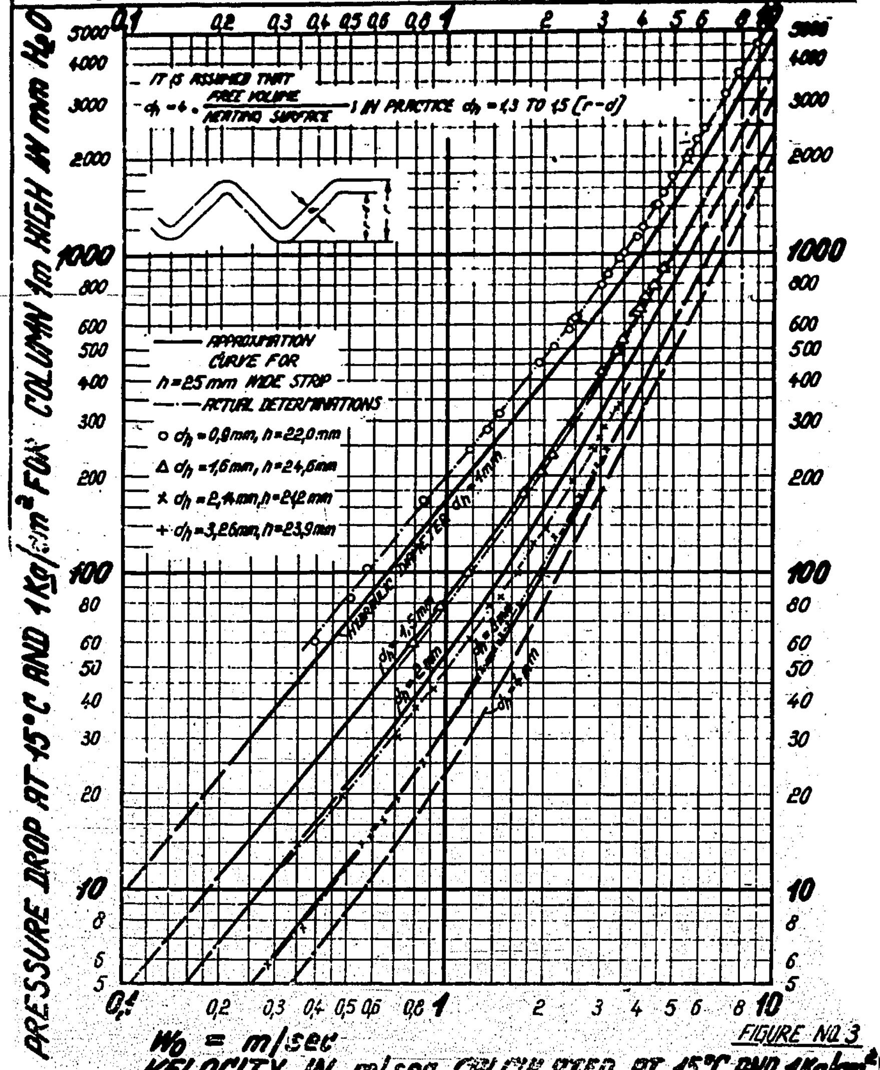


FIGURE NO. 3

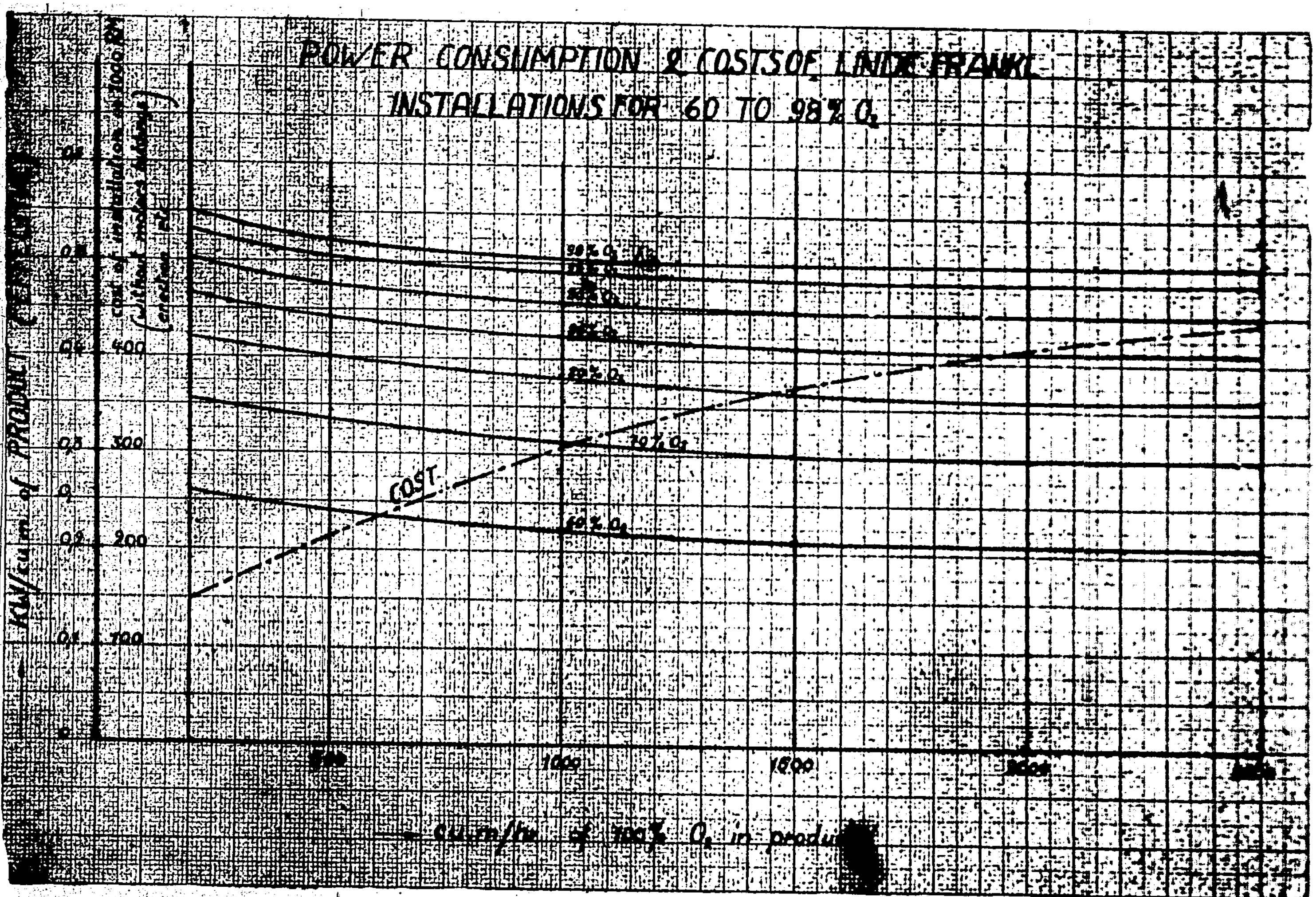

POWER CONSUMPTION & COSTS OF LINDE FRANKL
INSTALLATIONS FOR 60 TO 98% O_2
KW/cu m of PRODUCT
COST
60% O_2
70% O_2
80% O_2
98% O_2
400
300
200
100
1000
cu m/hr of 100% O_2 in product

FIGURE NO. 4

POWER CONSUMPTIONS AND COOLING WATER REQUIREMENTS FOR DIFFERENT TYPES OF OXYGEN AND NITROGEN PRODUCING UNITS.

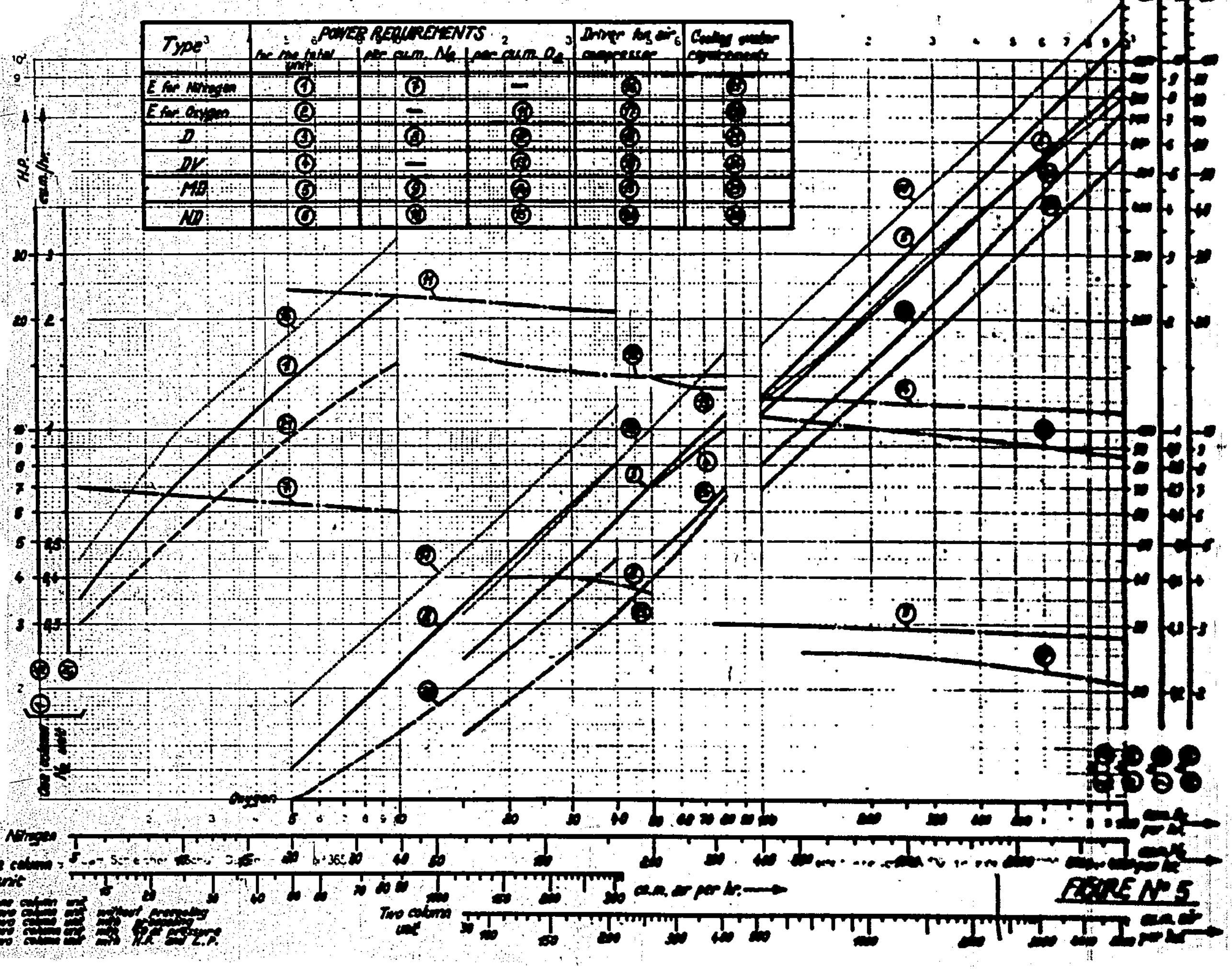


FIGURE Nº 5

SPACE REQUIREMENTS AND WEIGHTS OF DIFFERENT TYPES OF OXYGEN AND NITROGEN PRODUCING UNITS

TYPE	TOTAL WEIGHT	HEAVIEST ERECTION WEIGHT	AREA	MAX. HEIGHT OF LIFTING HOOK
E for Nitrogen	①	[illegible]	[illegible]	[illegible]
E for Oxygen	①	[illegible]	[illegible]	[illegible]
D	[illegible]	[illegible]	[illegible]	[illegible]
DV	[illegible]	[illegible]	[illegible]	[illegible]
MD	[illegible]	[illegible]	[illegible]	[illegible]
ND	[illegible]	[illegible]	[illegible]	[illegible]

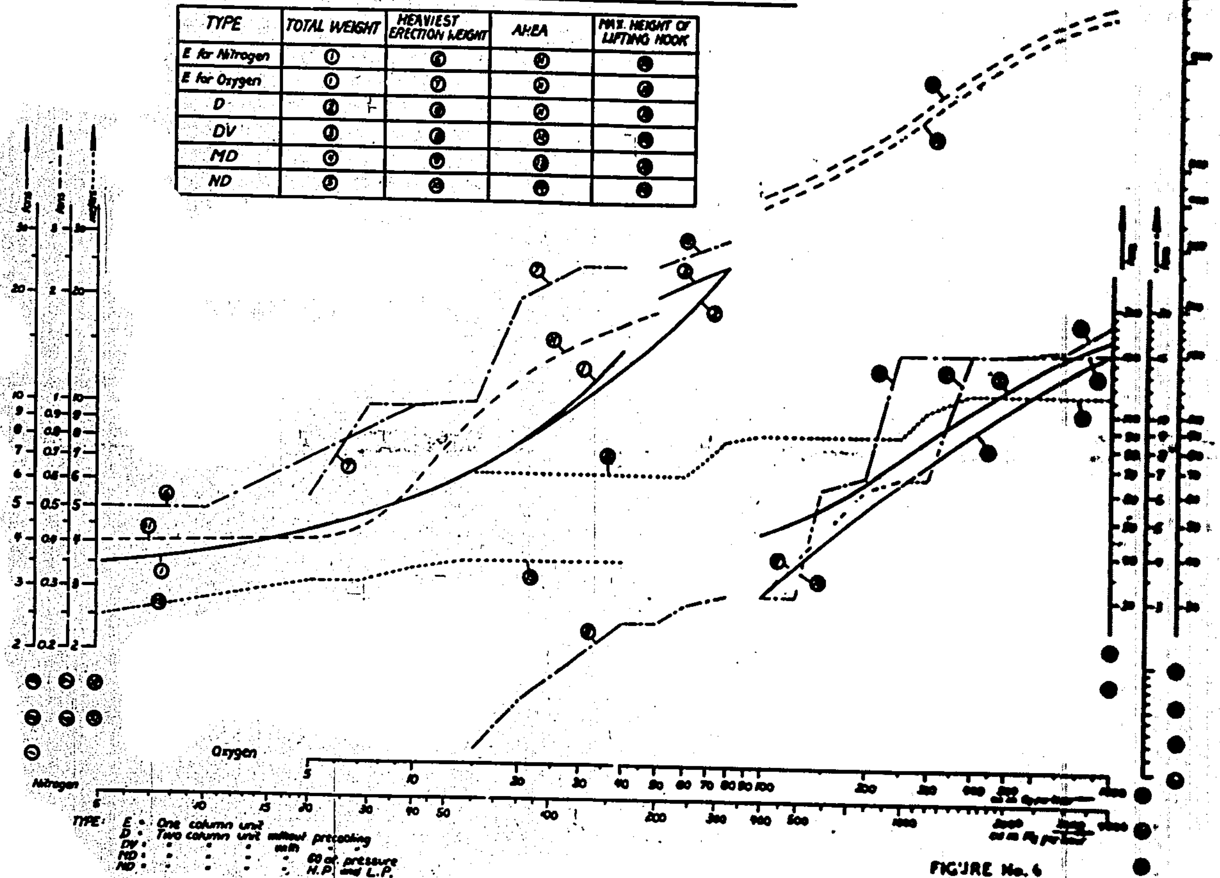


FIGURE No. 6

10.

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