OCCASION

This publication has been made available to the public on the occasion of the 50th anniversary of the United Nations Industrial Development Organisation.

DISCLAIMER

FAIR USE POLICY

CONTACT

Please contact publications@unido.org for further information concerning UNIDO publications.

For more information about UNIDO, please visit us at www.unido.org

UNITED NATIONS INDUSTRIAL DEVELOPMENT ORGANIZATION
Vienna International Centre, P.O. Box 300, 1400 Vienna, Austria
Tel: (+43-1) 26026-0 · www.unido.org · unido@unido.org

m2

05054

United Nations Industrial Development Organization

Distr[illegible]
[illegible]/WG.164/[illegible]
18 September 1973
Original: ENGLISH

Expert Group Meeting on the Manufacture of Proteins from Hydrocarbons

Vienna, Austria, 8 - 12 October 1973

CELL SEPARATION AND FERMENTER COOLING IN PROTEIN PRODUCTION FROM HYDROCARBONS[1)]

T. Winberg and
T. Johansson

ALFA-LAVAL AB
Tumba, Sweden

1) The views and opinions expressed in this paper are those of the authors and do not necessarily reflect the views of the secretariat of UNIDO. This document has been reproduced without formal editing.

Distribution
LIMITED

ID/WG.164/ 22 Summary
18 September 1973

Original: ENGLISH

United Nations Industrial Development Organization

Expert Group Meeting on the Manufacture of Proteins from Hydrocarbons

Vienna, Austria, 8-12 October 1973

SUMMARY

CELL SEPARATION AND FERMENTER COOLING IN PROTEIN PRODUCTION FROM HYDROCARBONS[1/]

T. Winberg and *
T. Johansson

In the processes for producing proteins from hydrocarbons, two important stages are separation of microorganisms and cooling of the fermenting broth.

After the fermentation stage the microorganisms are normally separated from the fermenting broth by means of high speed centrifugal separators. Depending on the process conditions the biomass concentrate is washed with water in one or two stages.

The cost for the yeast separation and washing stages is evaluated. Two main parameters influencing the cost are the cell size and the yeast concentration in the fermenting broth.

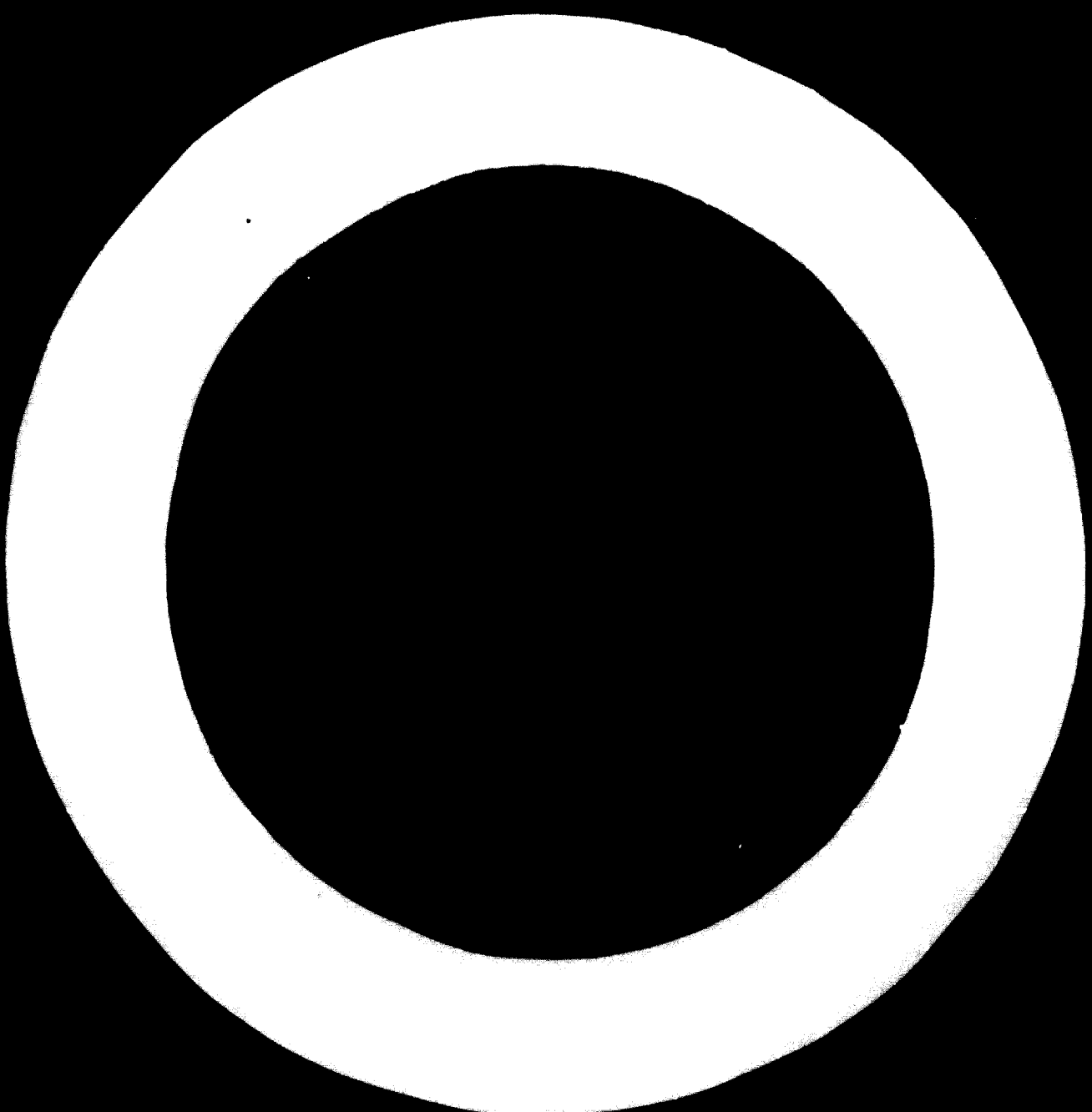
During the fermentation process vast amounts of heat are developed. In hydrocarbon fermentation at least 7,500 kcal/kg of biomass produced are released.

In order to maintain the optimum temperature the fermenting broth must be continuously cooled. The most efficient cooling systems use external plate heat exchangers for direct or indirect broth cooling. The special features of this type of heat exchanger makes it ideally suited for the cooling duty, not the least when sea water is used as cooling medium.

As the cooling costs are very high, the design of the cooling system ought to be optimized. Hence it is possible to find the most economical solution, considering both investment and running costs.

* ALFA-LAVAL AB - Tumba, Sweden

1/ The views and opinions expressed in this paper are those of the authors and do not necessarily reflect the views of the secretariat of UNIDO. This document has been reproduced without formal editing.



CONTENTS

CELL SEPARATION AND FERMENTER COOLING IN PROTEIN PRODUCTION FROM HYDROCARBONS

INTRODUCTION

Fifteen years ago the first research work started on growing yeast from hydrocarbon substrates. Intensive development in this field over these years has resulted in several industrial processes suitable for large scale protein production. The conversion from hydrocarbon is made by fermentation and generally the processes employ the following main stages:

- Raw materials preparation
- Fermentation
- Cooling
- Cell separation
- Drying

This paper will discuss in more detail the technical and economical aspects of

1) Cell separation by means of high speed centrifuges

2) Fermenting broth cooling by the use of plate heat exchangers.

I SEPARATION

After the fermentation the microorganisms are recovered from the fermentation media, the broth, and concentrated mechanically as far as possible before final drying. In most processes the initial separation is followed by one or more washing stages, in which the concentrated microorganisms are mixed with water and separated again. This washing removes the residual broth and produces a purified concentrate of biomass.

In the traditional fermentation industries, e.g. baker's and fodder yeast production from carbohydrates, centrifugal separators have for more than 70 years proved to be the most efficient equipment for yeast separation. Specially designed high speed centrifuges of the nozzle type are used and are normally referred to as yeast separators.

Also in the petroleum yeast processes the yeast separators are used in the separation and washing stages. Depending on the actual harvesting problems involved in the particular processes, yeast separators alone are employed, or they are used in combination with other techniques, e.g. gravity settling, the use of flocculants, etc.

There are basically three types of yeast separators. The differences are mainly characterized by the design of the discharge through the nozzles of the heavy phase containing the microorganisms. This is indicated in the figures 1, 2 and 3, which show the sectional views of the separator bowls. The bowl is the rotating part in the centrifuges where the separation takes place.

Figure No. 1 represents the traditional yeast separator. The process liquid, a dilute yeast suspension, is fed into the centre of the bowl where high-speed rotation forces it

to pass through a vertical stack of conical disks. Here the suspension is separated by centrifugal force into a solid and a liquid phase. The concentrate containing the yeast cells and a small amount of the liquid is forced outwards to the bowl wall. From the periphery the concentrate is fed through a number of channels in the bowl wall. At the end of each channel a nozzle is fitted and the concentrate leaves the nozzles under gravity and is collected by a stationary cover outside the bowl. In this machine the nozzles are located at a reduced diameter. The clarified liquid phase is displaced towards the centre and leaves the bowl through an open outlet.

Figure No. 2 shows a similar bowl configuration, the main difference being that the yeast phase is leaving the bowl through nozzles situated at the periphery of the bowl.

The liquid phase leaves the bowl under pressure from a built-in paring disk pump.

This type of separator is particularly used in the fodder yeast industry, where there are other particles than yeast, creating more difficult discharge problems.

Figure No. 3 shows the latest and most modern design of yeast separators. From the periphery the yeast phase is led through a number of tubes, each fitted with a nozzle at the inner end, into a chamber in the bottom of the bowl.

A stationary paring tube inside the chamber skims off the rotating concentrate and discharges it under pressure through an outlet pipe at the top of the bowl.

The clarified liquid is pumped out from the bowl under pressure by means of a paring disk.

This type of machine is designated the FEUX yeast separator.

Each of the above separator types has its particular merits, and the choice of machine has to be based on the requirements needed in each process.

Briefly one can describe the advantages with the two types shown in fig. 1 and 2 as machines of very simple design and therefore are relatively inexpensive. On the other hand the open discharge of the yeast concentrate means installation of extra tanks and pumps for collection and washing in connection with these separators.

The main feature of the FEUX type is the pressurized discharge of the yeast concentrate. This gives the advantage of more compact installations as extra tanks and pumps are not required. Furthermore this type is more hygienic in design as the closed concentrate outlet minimises air entrainment in the product. It is somewhat higher in cost than the other types, which of course is not very surprising as the FEUX is a more compact piece of separation equipment, also comprising two built-in pumps for discharging the separated phases.

Industrial plants for protein production from hydrocarbon fermentation have some common typical features:

- Large scale production
- Continuous fermentation
- High hygienic standard
- High degree of automation

This means that large amounts of yeast broth are continuously produced in the fermentation stage. Consequently these are important facts to consider when designing the next stage which is the separation plant. The use of the FEUX type separator has proved to be the most suitable solution in several processes. This separator combines high continuous flow capacity, compact closed pipe installations which

meet the hygienic and automatic requirements.

From process and hygienic aspects the equipment must be regularly cleaned. Preferably this is made without manually dismantling the machines, a time consuming operation leading to sub-optimal utilization of the separators.

Therefore the FLUX separator is specially designed for so called cleaning-in-place, CIP, which is performed by flushing cleaning liquids through the bowl and ancillary pipes without dismantling the machines. The CIP is carried out according to a special cleaning program which preferably is made fully automatic. An important part of the CIP program is back flushing through the concentrate pipe which is possible due to the nozzle and paring tube arrangement. This is very important in order to avoid blockage of the nozzles. Back flushing of the nozzle area is not possible to carry out in the other types of yeast separators, which are of the conventional design with open outlet for the yeast concentrate.

In order to give an idea of the size of the largest available yeast separators today the following capacity data might be of interest:

Nominal capacity: 200 m^3/h.
Separation performance for n-paraffin yeast broth is around 100 m^3/h, depending on the process conditions. This corresponds to 1-3 tons of dry yeast per hour.

The over all costs for separation are of course widely dependent on the process conditions and requirements. Without considering all the relevant factors it is quite impossible to make an accurate economical evaluation. Furthermore the actual parameters are combined in very complex relationships with each other.

In spite of the mentioned difficulties it is certainly of interest to discuss this matter from a more limited perspective. This will give an idea of the cost level for the separation stage. Fortunately there is a lot of practical experience available which will serve as a good basis to obtain proper figures.

In the example below the most important parameters will be studied and their influence on the investment costs for the separation plant will be given.

The chosen example is based on what today can be considered as a typical separation stage valid for harvesting of yeast grown on a pure n-paraffin substrate.

Assumed data:

Inlet yeast conc. in broth: 2% DS
Outlet yeast conc. in concentrate: 12-16% DS
Yeast losses in effluent: less than 0.05% DS
Yeast cell size: 5 microns
Density of yeast: 1.08-1.10 ton/m^3
Density of effluent: 1.00 ton/m^3

For one stage of separation, i.e. without washing stages, the investment cost for yeast separators complete with equipment for CIP and automation (installation costs not included) is approx. 8-9 US dollars per ton yearly yeast production capacity. This figure is valid for plants of 20,000 tons yeast production per year or larger. (Exchange rate: one US $ equal to 4.20 Sw Crs). The figure 8.5 dollars is chosen for the further study.

In order to obtain how the cost figures are related to other data, e.g. inlet yeast concentration, cell size, we must know how they will affect the separation capacity. The investment cost is inversely proportional to the separation capacity.

Basically the following simplified relationship can be used:

Separation capacity = $f(v_s, c, \text{machine parameters})$,

where v_s is the settling velocity of the particle and c the inlet concentration.

For one particular yeast separator we obtain

Separation capacity = $f(v_s, c)$

v_s is determined by Stoke's law, i.e.

$$v_s = k \cdot \frac{D^2 \cdot \Delta\varrho}{\mu} g \text{ , where}$$

k is a constant
D is the particle diameter
$\Delta\varrho$ is the density difference between the particle and the liquid medium
μ is the viscosity
g is the centrifugal force

Obviously the particle size is an important parameter.

If the other data are kept constant we will theoretically find that the separation capacity is varying according to the particle size squared.

Diagram 1 is showing theoretically how the investment cost is depending on the cell size.

As can be seen from the diagram the cost is drastically affected by the cell size. It rapidly decreases with increasing cell size.

Diagram 2 gives the investment cost in relation to the inlet concentration. The diagram is based on the practical experience of separator performances.

The diagram shows that the cost is decreasing with increasing yeast concentration.

It is obvious from the diagrams that the combination of high yeast concentration in the broth and the use of microorganisms with large cell size will positively affect the economy of the separation stage

This conclusion is generally true, but it should be realized that other factors are influencing the costs as well and that the indicated investment costs will show quite a variation from process to process.

As earlier mentioned, the yeast concentrate is often washed with water in one or two stages. The costs for yeast separators in these stages are normally somewhat lower than in the initial separation stage. This is mainly due to the fact that the inlet concentration is kept higher in the washing stages which means reduced costs as per diagram 2.

Regarding the operation costs for separation the main part is the cost for the electrical energy . Other operating costs are for spare parts and maintenance.

As an average value the energy cost for one separation stage might be of the order of 0.5 dollar per ton dry yeast.

Although there are rather high total costs involved in the use of yeast separators, these are relatively low in comparison with other harvesting methods, e.g. filtration or evaporation. If one considers the separation as a dewatering process, this is more easily observed. Starting from the dilute yeast broth going to the finally dried product,

about 80-90% of the total amount of water is removed in the separation stage.

II FERMENTER COOLING

During fermentation large amounts of heat are developed. In order to maintain the temperature at the right level, the fermenting broth must be continuously cooled.

In hydrocarbon fermentations vast amounts of heat are released, namely 7.500 kcal/kg of biomass produced, or even more. The optimum fermentation temperature is normally in a very narrow range just above 30°C. This leads to low driving forces at normal cooling water temperatures.

This requires highly efficient cooling methods. The added effects of the large heat release and the development of large, highly efficient fermenters have made the traditional cooling equipment inside the fermenters less efficient.

Therefore the most economical cooling systems employ large external plate heat exchangers, which are used for cooling the fermenting broth either by direct or indirect means.

Figure No. 4 shows the principal arrangement of circulation cooling. The broth is pumped directly through the plate heat exchanger and the cooled liquid is returned to the fermenter again. The temperature decrease of the broth is depending on the temperatures of fermentation and the cooling water and is normally ranging from 3-6°C.

Figure No. 5 shows the principal installation arrangements when the plate heat exchanger is used for indirect fermenter cooling. The broth is cooled in the fermentation tank by means of attached heat exchangers using fresh water as cooling medium. The fresh water is circulating in a closed cir-

cuit and is in turn cooled when passing through the plate heat exchanger.

The fermenter design is the major factor deciding the type of cooling system that is most suitable to use.

Figure No. 6 shows the flow principle of the plate heat exchanger. The heating surface consists of a number of thin metal plates clamped together in a frame and sealed at the edges by rubber gaskets. The plates are corrugated to improve heat transfer efficiency and to make them rigid. The plates are provided with corner ports so arranged that the two media between which heat is to be exchanged flow through alternate channels. The flow pattern is normally arranged for countercurrent flow.

Owing to its design, the plate heat exchanger can easily be dismantled for inspection and cleaning. Furthermore by adding or rearranging plates it can without difficulty be rebuilt to perform different duties.

The high thermal efficiency is depending on the fact that the corrugated plates are creating good turbulence, even at rather low flow rates. Heat transfer coefficients of more than 3.000 kcal/m^2, h, ^oC are normal.

In large petrofermentation plants the cooling costs are probably one of the major costs involved both as regards investment as operating costs. The cooling water demand is extremely high leading to the need for a coastal location where sea water can be used. This in turn leads to the need for corrosion resistant titanium heat exchange surfaces. Only a plate heat exchanger can give an economic solution when these factors are taken into account. Titanium plate heat exchangers are in fact available to very competitive prices due to the thickness of the plates being only 0.6 mm, thus reducing material costs

There are further benefits deriving from the use of plate heat exchangers. Low liquid hold-up gives good response to temperature control. The plate heat exchanger is very compact which means low installation costs and small space requirements.

As already mentioned the cooling costs are very high. Although the heat exchangers are rather costly they are only a part of the total costs for the complete cooling system also including large pipes, sea water intake, pump stations etc. Operation costs are also large and consists mainly of pumping costs.

In order to obtain the lowest possible cooling costs, the system must be designed in an optimal way. It is not possible to make this by optimizing each piece of equipment alone but the complete system must be studied. For instance it is easy to design the cheapest heat exchanger for a particular duty, but it is very seldom that this means the most economical design.

Among important factors to be considered is the cooling water temperature if sea water is used. The temperature is varying with the depth of the water intake. Only a few degrees´ change might mean large differences in running costs.

Also the cooling water temperature variations throughout the year ought to be taken into account as considerable reduction in pumping costs likely is obtained.

Optimization means complicated and tedious calculation work. Fortunately there are fairly developed computer programs available today which makes it possible to carry out optimization studies without too heavy manual work.

III CONCLUSION

It has been the authors' intention to present the various problems involved in two of the unit operations employed in large hydrocarbon fermentation processes.

As shown in the evaluations in this paper there are considerable costs regarding both the separation and cooling stages. However, these costs can be decreased to a great extent by better processing techniques.

The very rapid development work in this field also implies a challenge to the equipment manufacturing companies to meet the demand for suitable and efficient process equipment.

Best possible results are naturally obtained when close cooperation between process development people and machine manufacturers can take place. We are convinced that the results of these efforts will contribute to make this type of protein production even more economical.

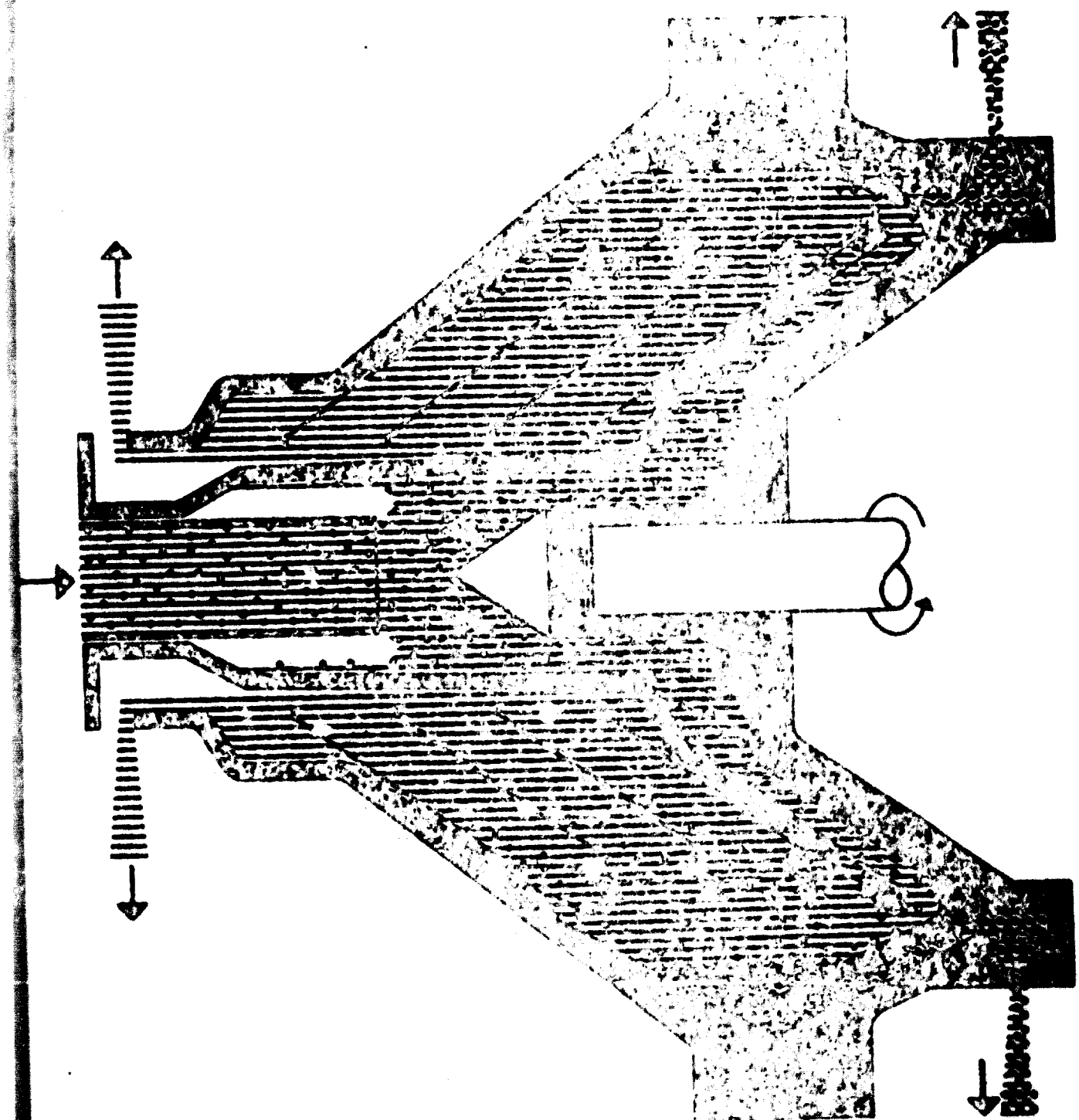


Fig 1

Alfa-Laval Yeast Separator, type DX
Sectional view of bowl

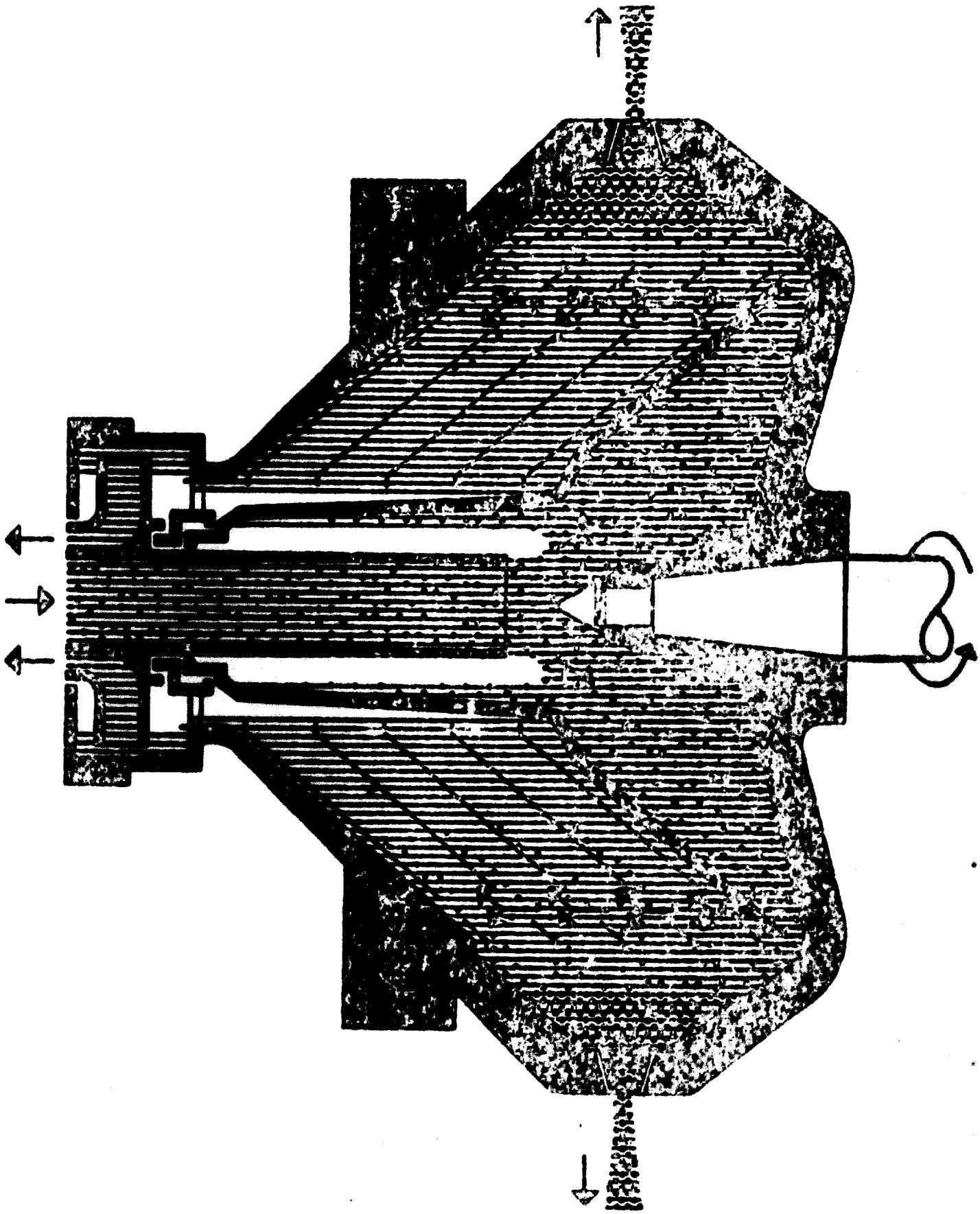


Fig 11

Alfa-Laval Yeast Separator, type FESX
Sectional view of bowl

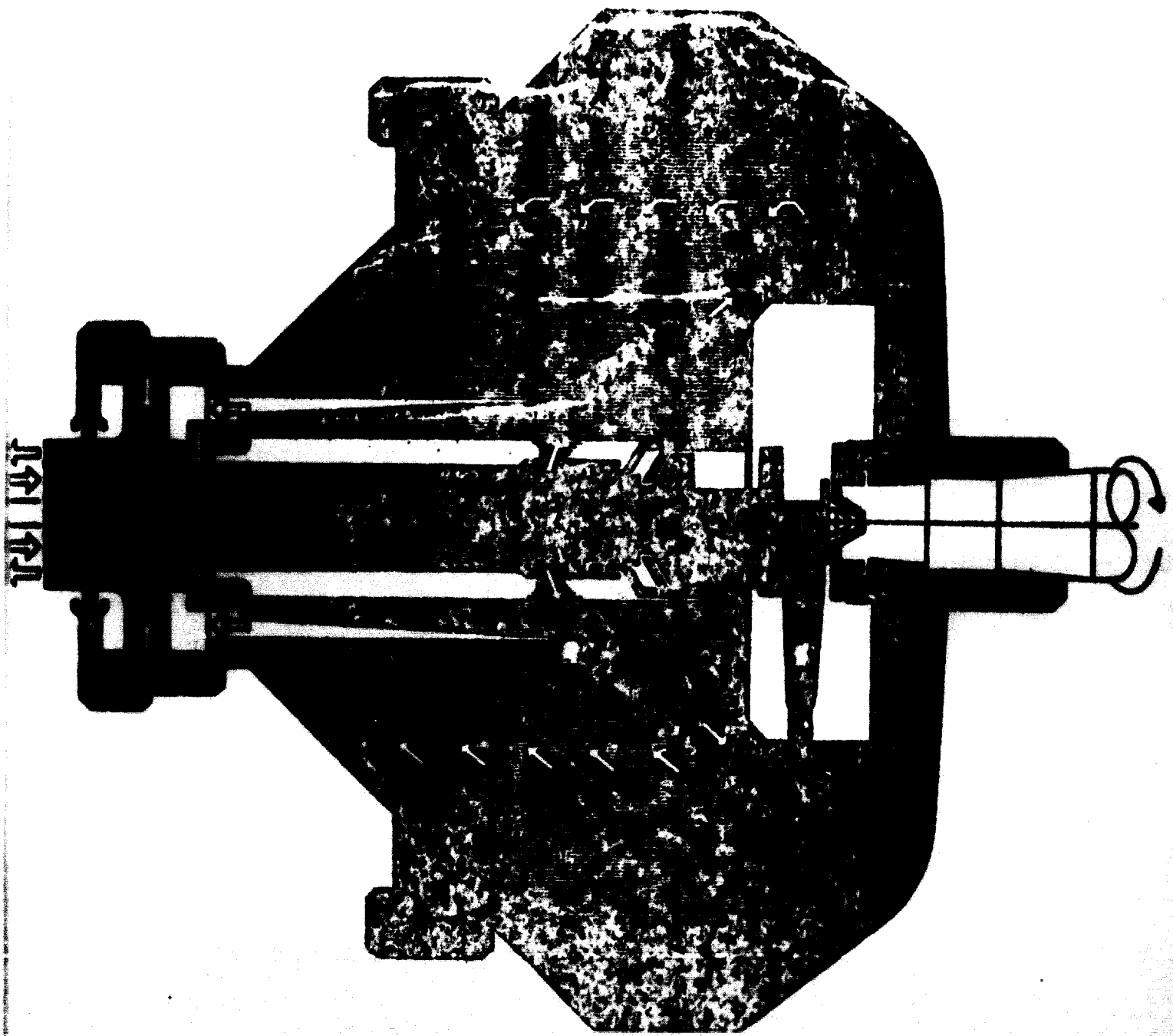


Fig III

Alfa-Laval Yeast Separator, type FEUX
Sectional view of bowl

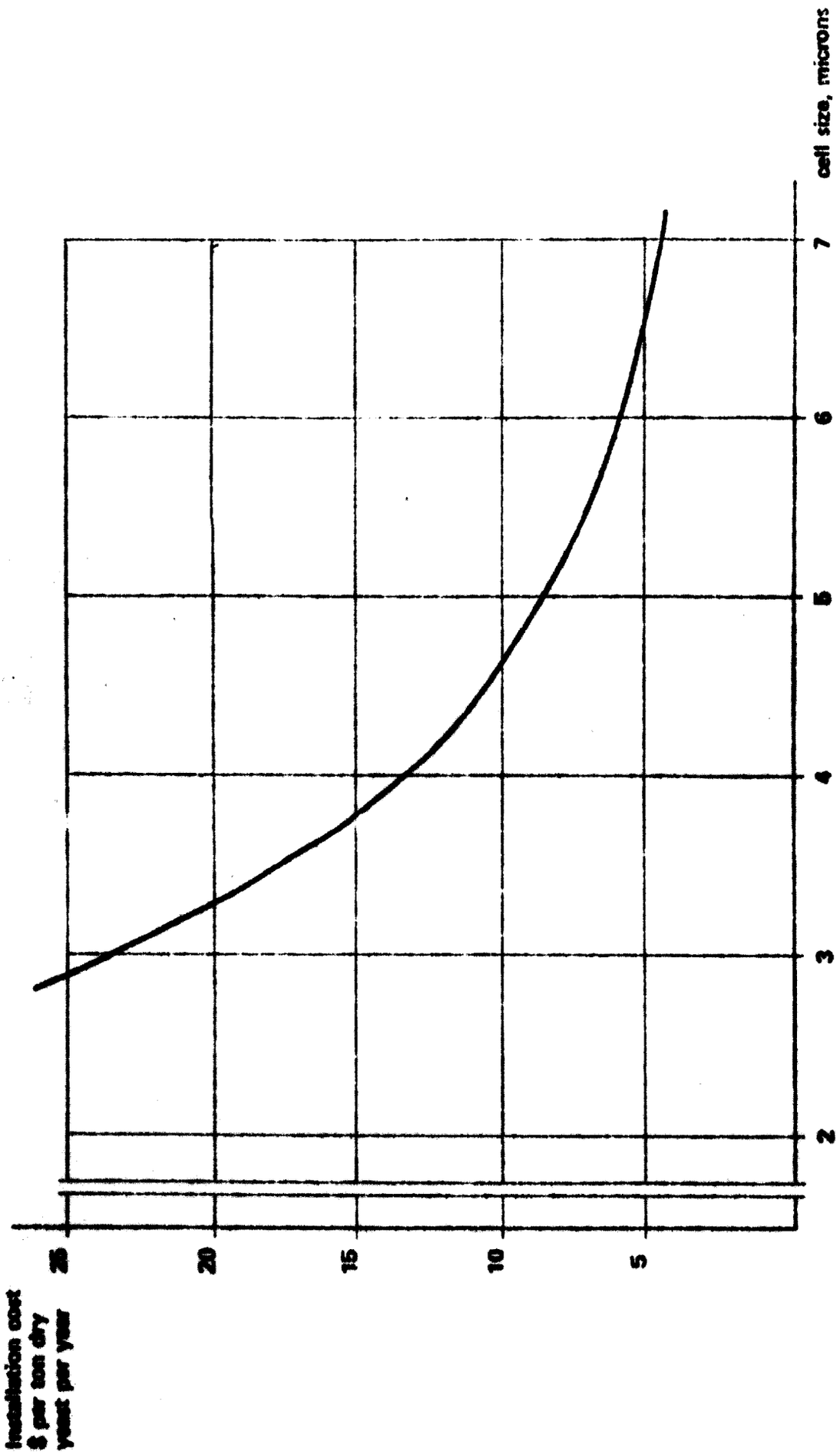

cell size, microns
2
3
4
5
6
7
25
20
15
10
5
Installation cost
$ per ton dry
yeast per year

Diagram I

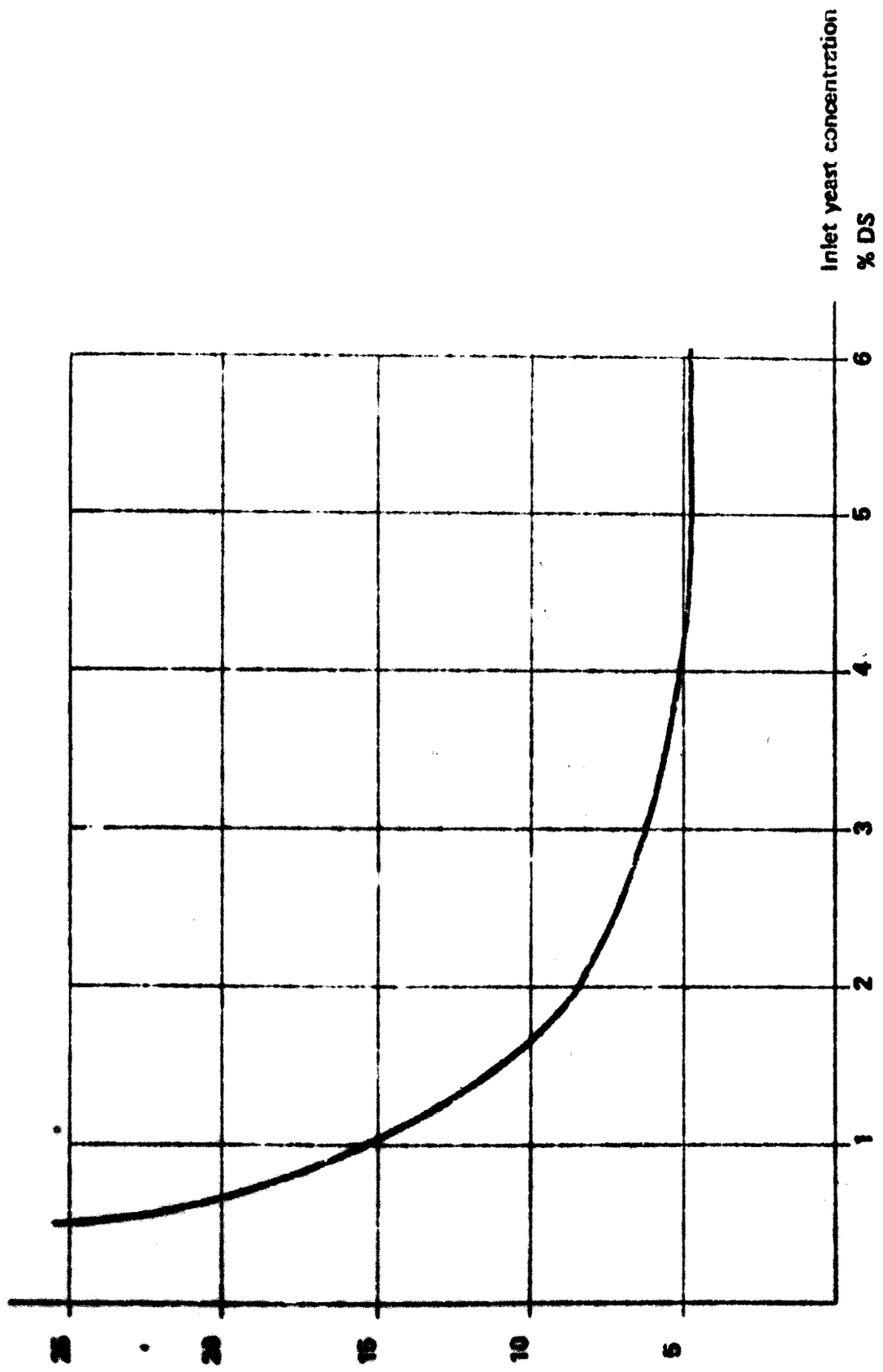


Diagram II

ALFA LAVAL

Circulation Cooling

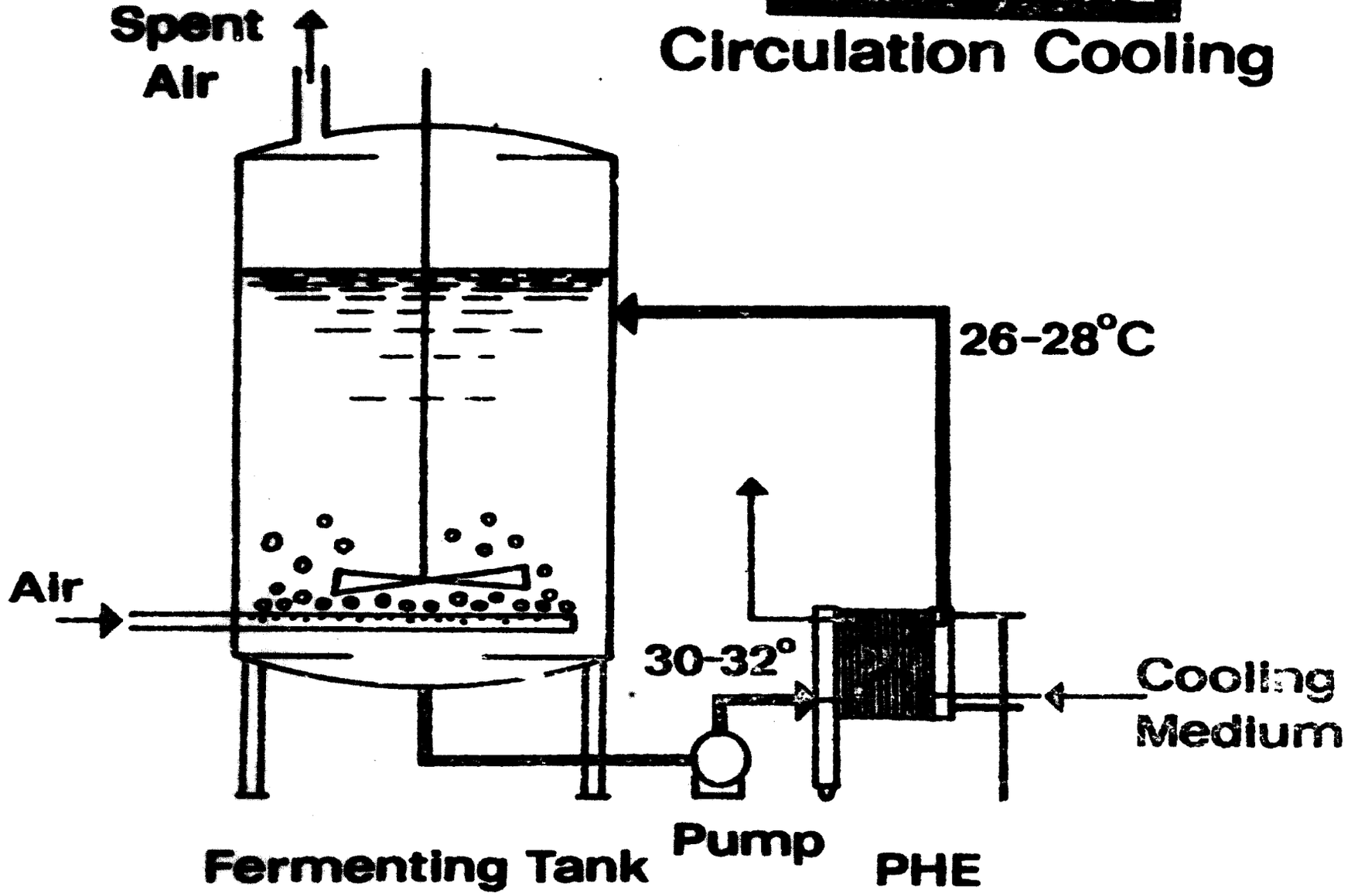


Fig IV

ALFA-LAVAL

Intermediary Cooling

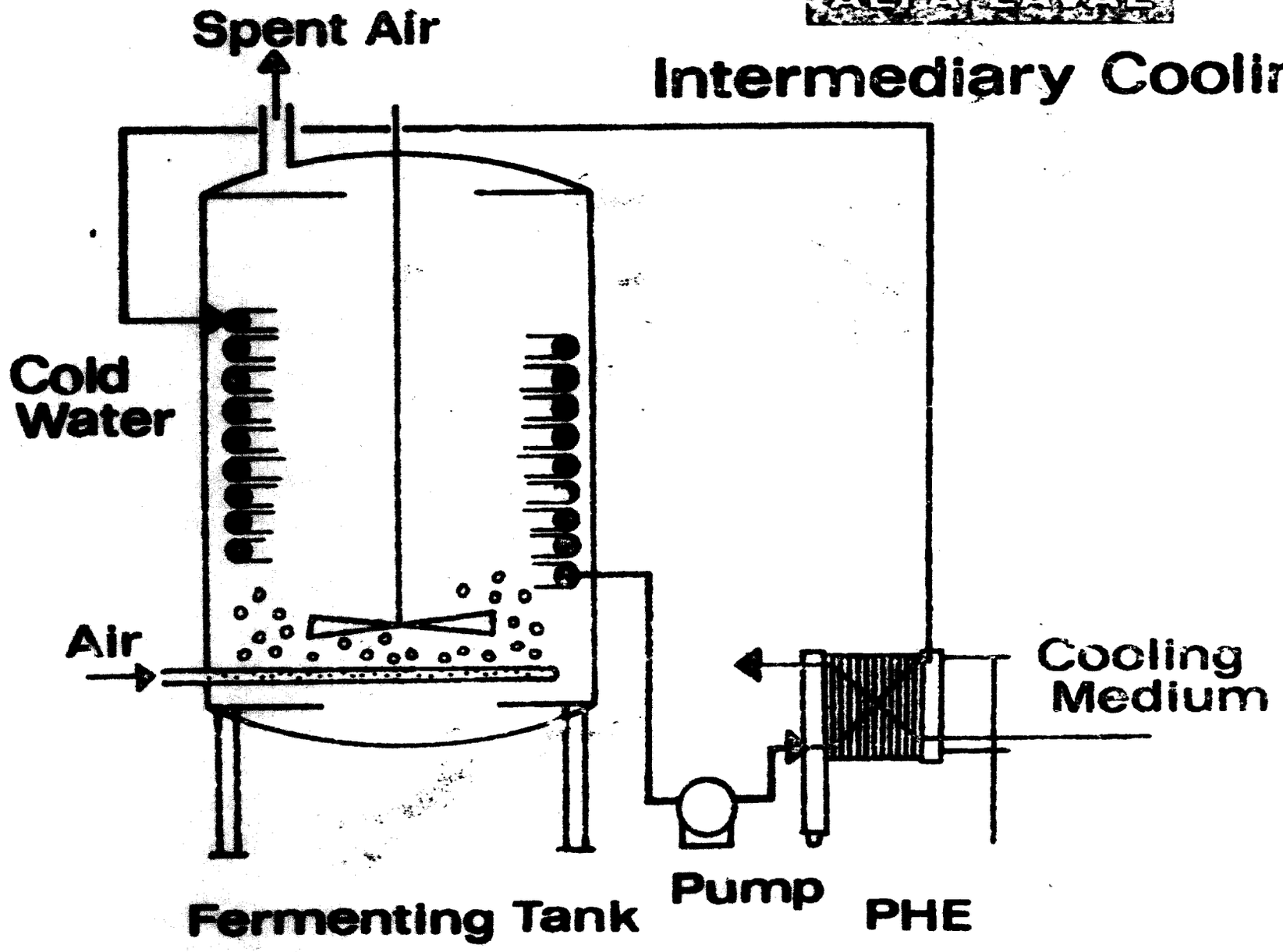


Fig V

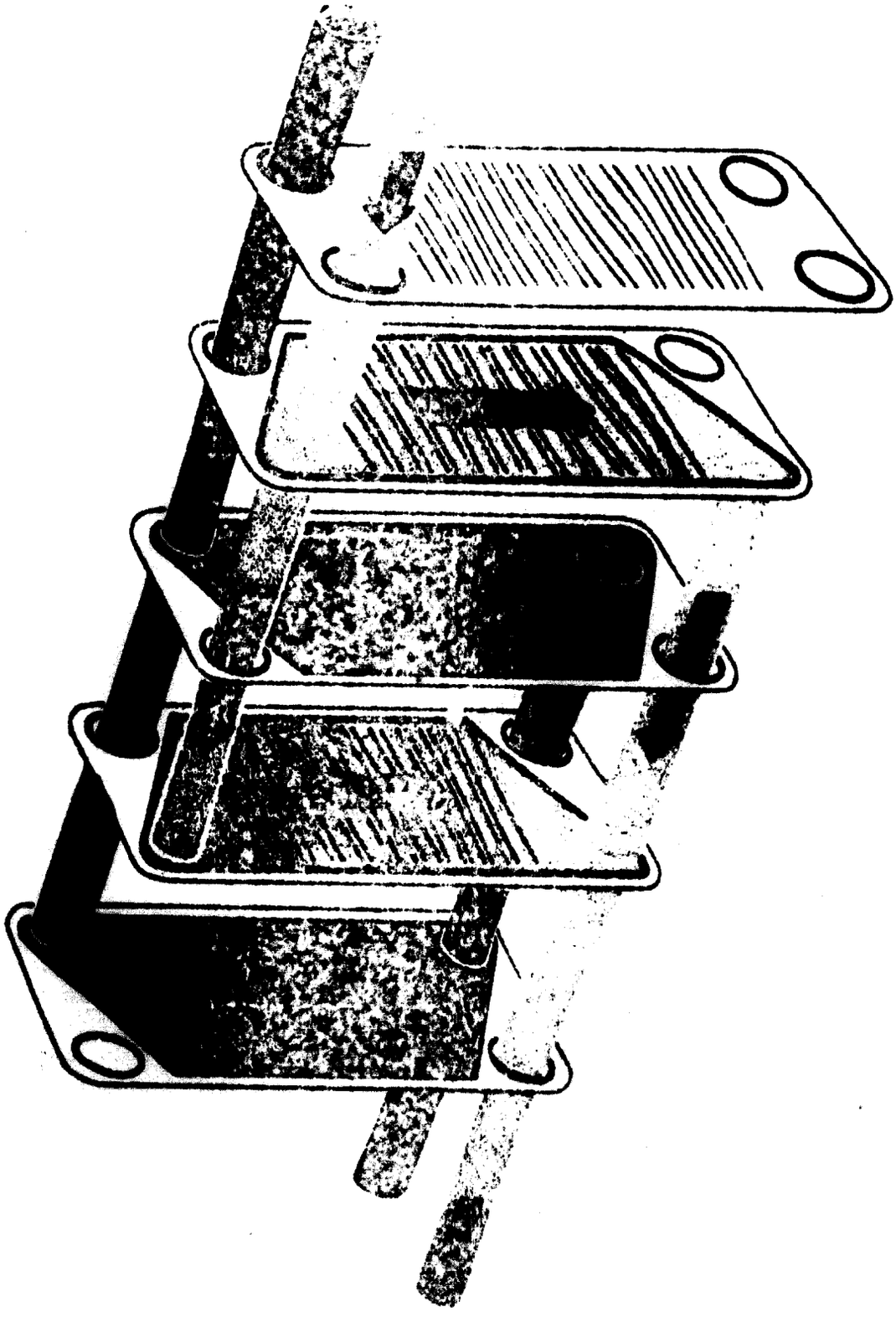
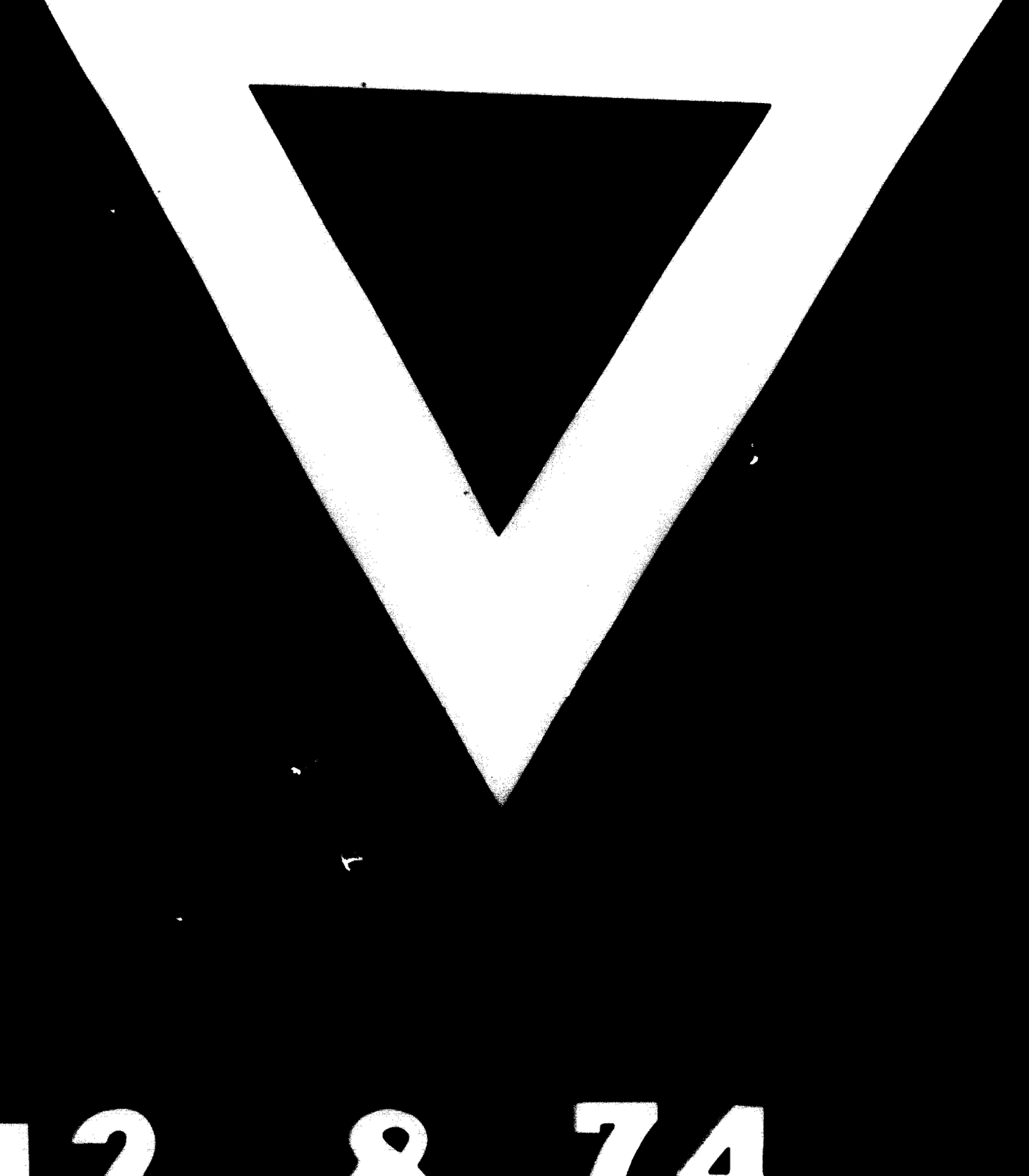


Fig VI

Flow principle of the plate heat exchanger



12.8.74