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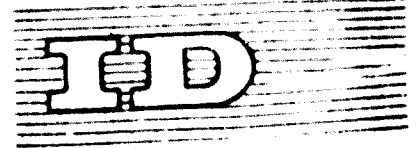
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Baku, USSR, 20 - 31 October 1969

CONTINUOUS PROCESS FOR PRODUCING  
NOVOLACK PHENOLIC RESINS<sup>1/</sup>

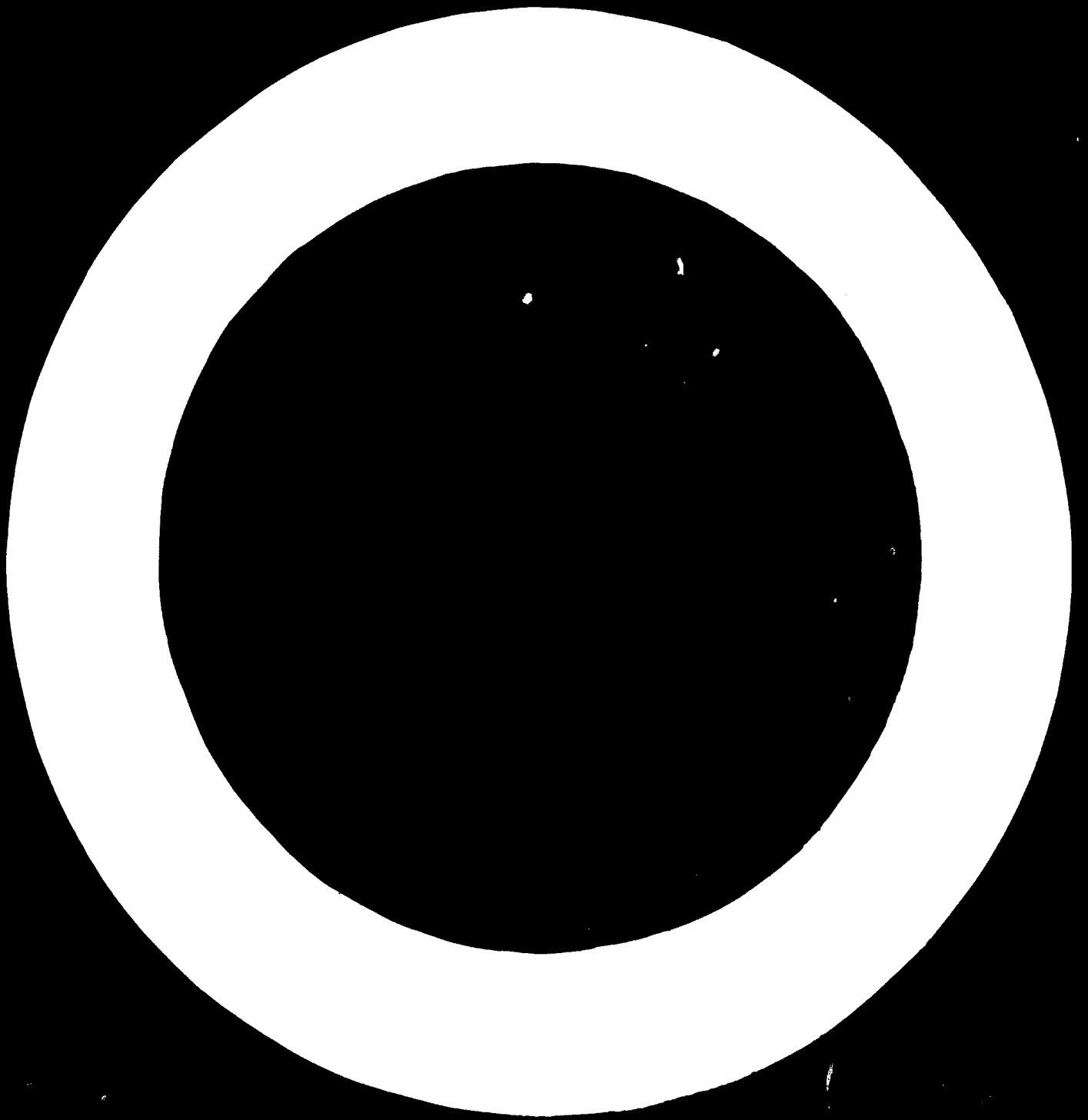
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Novolack phenolic resins, being the oldest type of synthetic resins, have retained up till now their significance of being a most important polymeric material and are used in evergrowing quantities for the manufacture of molding powders, abrasives, shell moulds and so on.

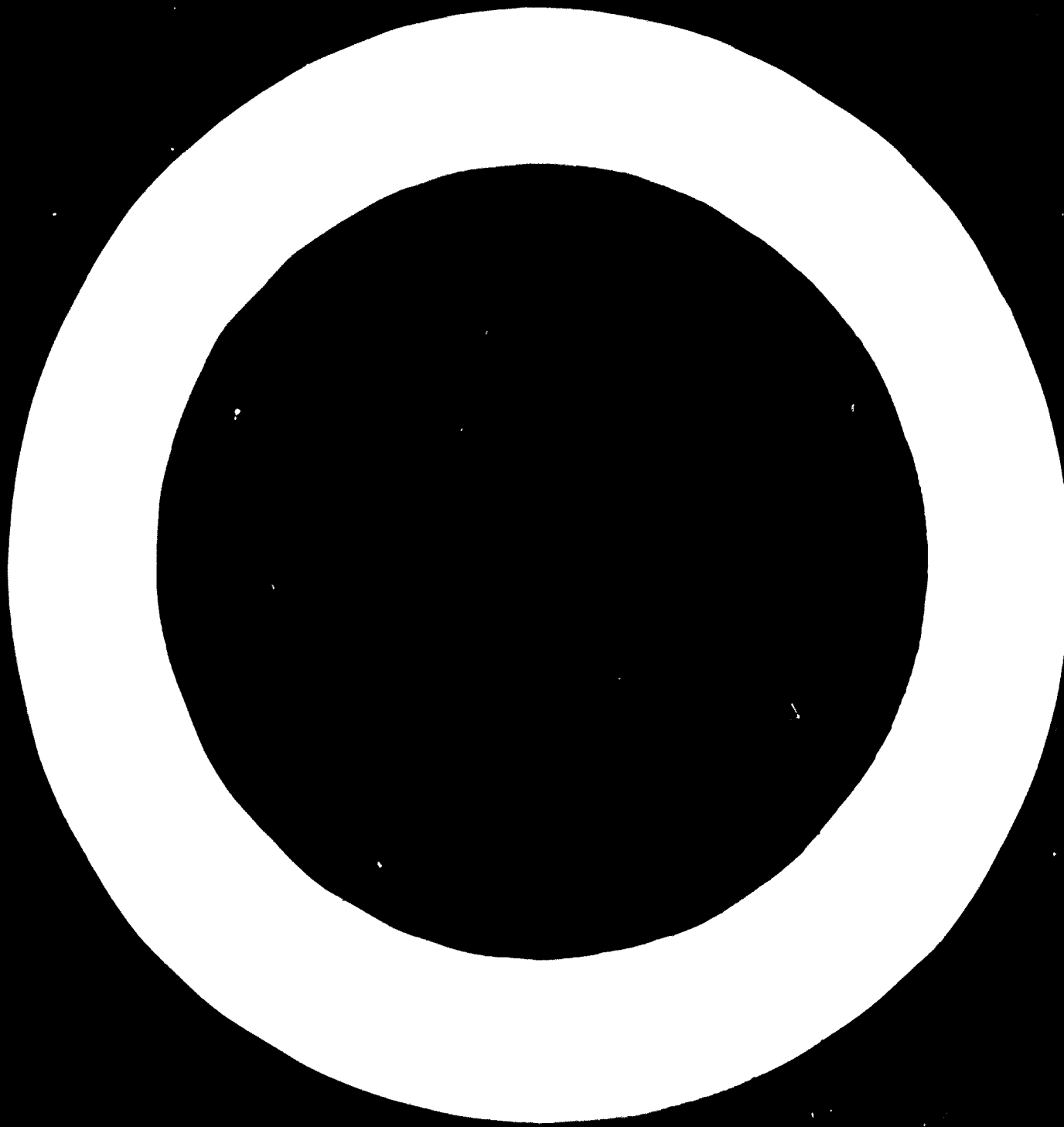
However, technology of the universally accepted batch manufacture of these resins from the very onset, has had few changes, and from the point of the technical level does not meet the requirements of the up to date large tonnage production.

In the Soviet Union there has been developed and commercialized a continuous process for the manufacture of novolack resins. Let us discuss various process engineering solutions of problems related to the process operations.

### Polycondensation.

At present there are available two main types of continuous action reactors: apparatuses of displacement and apparatuses of mixing.

A number of patents are known which claim for displacement apparatuses (tubular reactors) for polycondensation of phenol with formaldehyde. However, these patents have not

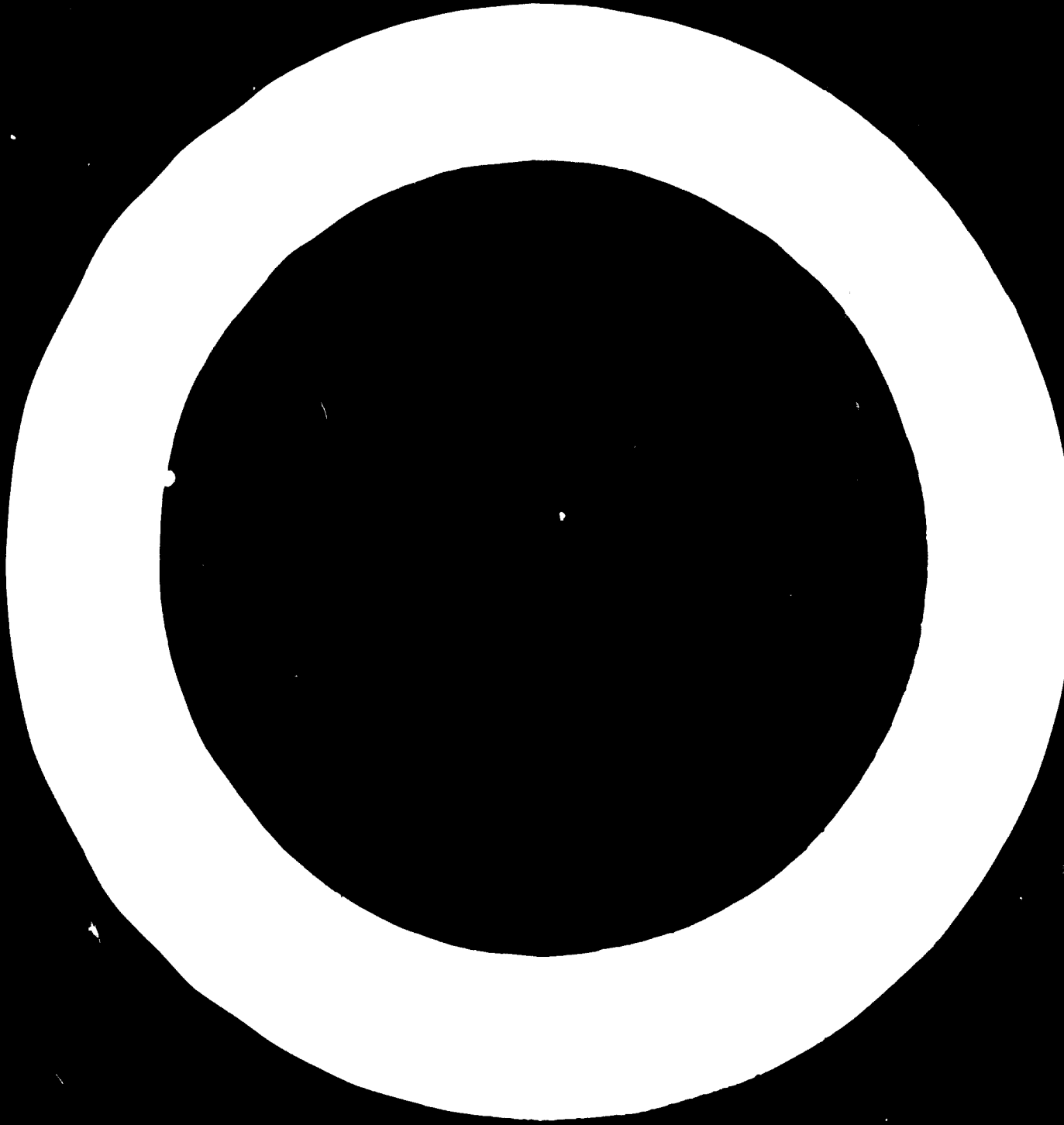


been industrialized due to the simplicity of the construction of such processes, which can be done by hand. The first great benefit of these air whisks is that in view of the high efficiency of heat transfer on the internal surface of the reactor resulting in the impairment of exothermic reactions and the danger of the time of the thermal conditions of the reactor.

Therefore multi-section mixing type apparatus are chosen when developing continuous processes for novel chemical manufacture. It was understood when calculating the number of sections that their increase in number along with the reduction of the residence time of reaction components in the reaction zone and, therefore, with decrease in the reactor volume leads to the design complication.

Thus, the choice of the optimal number of sections is, essentially, an economic problem coming down to minimizing capital investments. The calculation also shows that the minimum weight of an apparatus is achieved when four sections. Design-wise four-section reactor has a column consisting of the four sections arranged directly one above the other. The advantage of the column compared to the conventional case, connected in a consecutive order lies in the simplicity of design and compactness. It should be also noted that the column does not have moving parts.

It has been decided for the continuous polymer condensation process to carry out the reaction at atmospheric pressure and at the boiling temperature of the reaction mass, additional advantage of this being simplicity of controlling temperature conditions in the sections. From the polymer condensation heat balance it follows that in each section heat efficiency occurs only in the first section of the column. There is surplus of heat in the other sections which is removed by evaporation. Utilization of surplus heat of the last sections for the heating of initial mixtures is possible to maintain necessary temperature conditions in the reactor without an outside source of heat.

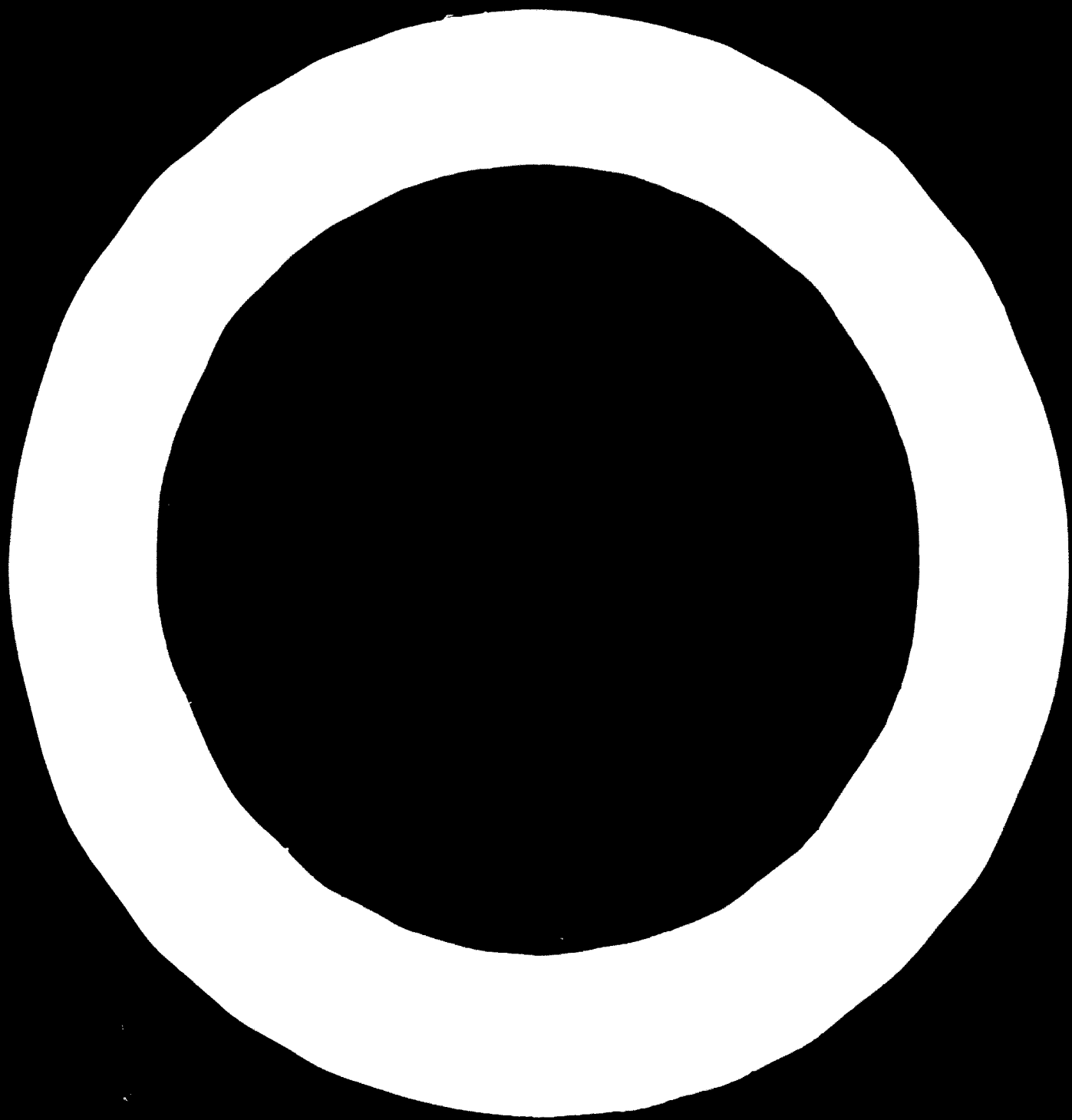




Evaporation

The phenomenon of liquid film evaporation at high speed of stream of gases moving together with the liquid along a horizontal pipe was laid into the foundation of conditions of liquid film evaporation of resin, polymer and other volatile substances from the resin obtained on the surface of polymerization. The conditions of the two-phase liquid-gas flow in a horizontal pipe depends on the stream velocity. At a low velocity the liquid flows along the bottom of the pipe, the gas moves above the liquid. The increase of the gas speed results in the curvature of the liquid phase surface, the edges of the liquid film move along the walls of the pipe. When the gas stream reaches a critical speed (approximately 15-30 m/sec) the edges of the stream of liquid film and the liquid moves along the internal walls of the pipe in the shape of a layer with a thin-shaded cross-section. The gas stream moves along the central part of the pipe holding liquid film on the walls and moving the liquid along the pipe by means of friction forces.

The method developed involves for the evaporation of volatile substances from the resin using its angle. As a result of the externally heated, horizontal pipe of the evaporator; in the above pipe a circular flow of a thin layer of resin is maintained. The vapours of the volatile substances evolve from the heated resin and moving along the pipe due to the pressure drop maintained between the inlet and the outlet of the above gaseous phase and outlet of the apparatus. The conditions of the circular flow secure good heat exchange and removal of volatiles, resulted in considerable reduction of the evaporation time, which usually does not exceed one minute. The apparatus used for the continuous evaporation is marked for compactness, good heat characteristics and absence of moving parts.



THE FLOW OF FLUIDS

In the first part of the paper, the general principles of hydrodynamic stability are discussed. It is shown that the onset of instability is determined by the balance between the stabilizing effect of the shear and the destabilizing effect of the curvature of the velocity profile. The Rayleigh stability criterion is derived, and it is shown that the flow is stable if the velocity profile is such that the velocity is a maximum at the center of the pipe and decreases towards the walls. The effect of viscosity is also discussed, and it is shown that the onset of instability is delayed in the presence of viscosity. The paper then discusses the growth of disturbances in a pipe flow, and it is shown that the disturbances grow exponentially in time. The effect of the Reynolds number is also discussed, and it is shown that the onset of instability occurs at a lower Reynolds number for a pipe flow than for a flat plate flow. The paper concludes with a discussion of the experimental results of Taylor and Görtler, and it is shown that their results are in good agreement with the theoretical predictions.

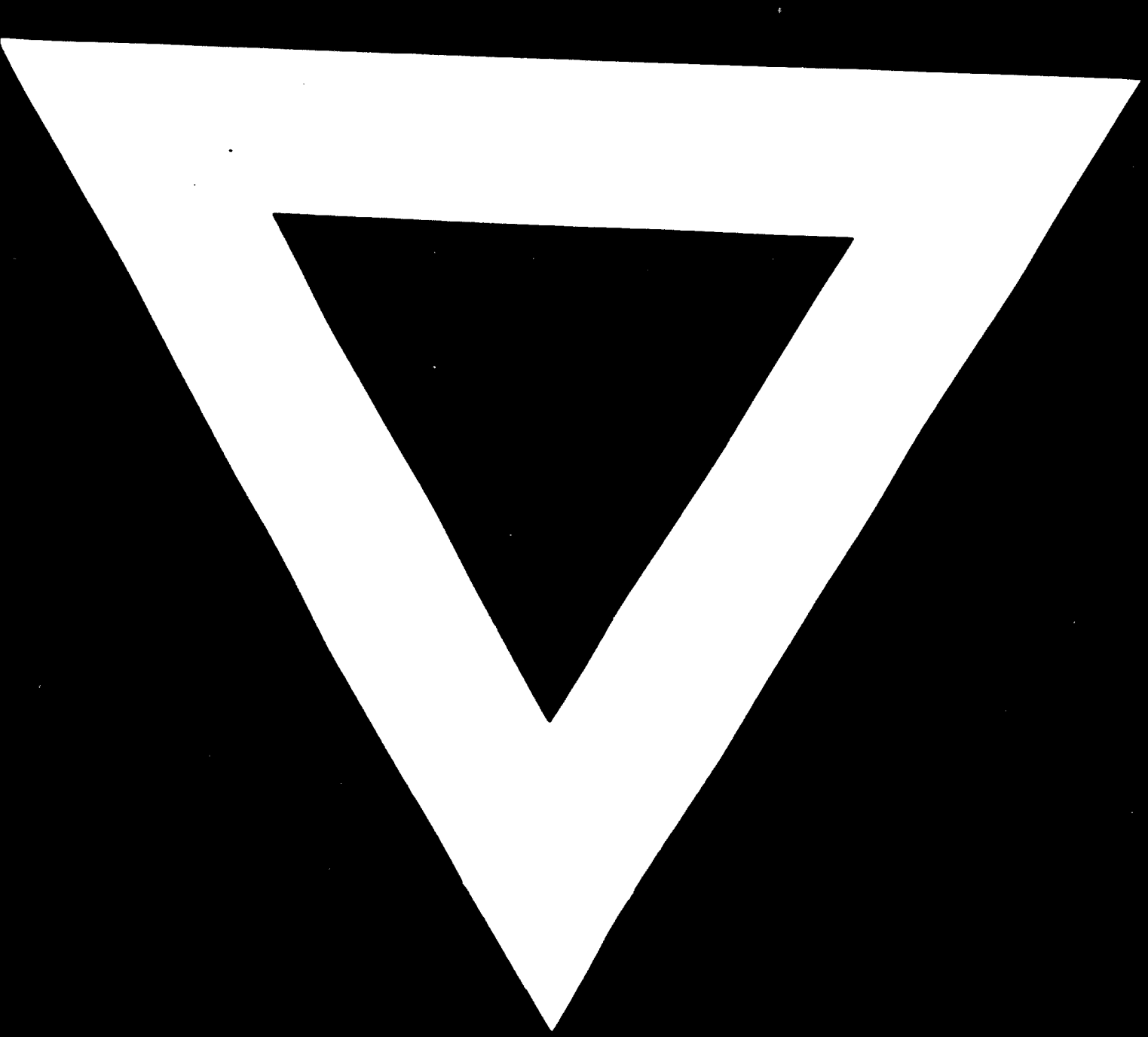
The basic flow is assumed to be a steady, incompressible, laminar flow in a pipe. The velocity profile is assumed to be parabolic, and the pressure is assumed to be constant across the pipe. The disturbances are assumed to be small, and the linearized equations of motion are used to determine their growth. The results are compared with the experimental results of Taylor and Görtler, and it is shown that the theoretical predictions are in good agreement with the experimental results.

substances evolved during boiling of the reaction mass are cooled in the condenser, section for all the sections, the condensate from this condenser returning to the first section. The resin formed at the polycondensation stage is separated in the Florence flask from the water layer which is the only waste product. The resin separated from the water is fed by the pump to the tubular evaporation apparatus. Waxed resin and vapours of volatile substances enter the homogenizer equipped with a steam jacket and an anchor agitator. The vapours of volatile substances are condensed in the condenser. The distillate formed returns to the polycondensation stage as phenolic raw stock. Waxed resin from the homogenizer is continuously fed onto the surface of rotating drum cooled from inside, and is converted to the solid state and then is cut from the drum surface in the shape of flakes.

Industrial plants with the annual capacity of 3000, 5000 and 10000 tons per year have been developed on the basis of the above continuous method. Resins designed for manufacturing molding powders and adhesives are produced on these plants. The experience of operation of these plants during a long period of time has shown that the continuous method has a number of the following basic advantages as compared to the available batch process.

1. Consumption of phenol and formaldehyde per unit of the end product decreases.
2. Consumption of electric power and steam is considerably reduced.
3. Due to the reduction of the construction site 1,5-2 times, and volume of the shop and the weight of the process equipment as well the capital investments are reduced accordingly.
4. Complete mechanization and up-to-date level of automation of the technological process is achieved resulting in the reduction of labour.





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