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United Nations Industrial Development Organization

Symposium on the Development of the Plastics Fabrication Industry in Latin America

Bogotà, Colombia, 20 November - 1 December 1972

TWIN SCREW EXTRUDERS[1/]

by

F. Burger

Krauss-Maffei AG
Munich
Federal Republic of Germany

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SUMMARY

TWIN SCREW EXTRUDERS 1/

by

F. Burger
Krauss Maffei AG.
Munich
Federal Republic of Germany

By the development of twin screw extruders the extrusion technique advanced to a new significant phase. Contra-rotating screws effect a forced material transport and make possible a satisfactory processing of plastic raw materials from powder. Herewith the granulating process, being necessary till now, is avoided what causes a reduction of the total material costs. Nevertheless the processing of raw material from powder requires a clear concept of the screw geometry and an extremely accurate knowledge of the exact temperature guide and temperature control. By the combination of compression-, mashing- and mixing zone and by the adjustment of the depth of thread of the screws, of the length of the screws and of the cylinder as well as of the screw speed, the optimum conditions for the plasticising process have to be found. Moreover the degasifying of the plasticised material, that means the separation of all volatile components, is of great importance in order to avoid some

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enclosures in the finished product. The power transmission on the screws rotating with little distance between centers and furthermore the back pressure produced during the plasticising process requires a screw- and gear bearing of special quality. The gear itself has to be qualified for highest leads in continuous work. The functional construction of the machine permits an easy exchange of spare parts and and easy execution of the regular service. Besides all these qualitative characteristics of a Krauss-Maffei twin screw extruder also the investment costs for the purchase of such a machine are of great importance as the desired return on investment is only guaranteed of there is a certain relation between output capacity per unit of time and capital investment.

Basing on a long lasting experience in the construction of heavy machinery and on the cooperation with a team of constructing engineers participating influentially in the development of the first twin screw extruders constructed in Europe, Krauss-Maffei has built an extruder in a development phase of several years, taking into account all the requirements expected from a modern twin screw extruder. Today Krauss-Maffei is in the position to offer machines of high quality for the production of pipes add profiles in rigid PVC that are in front of the international competition by reason of the extremely high output capacities. These machines shall be presented in a detailed report.

We regret that some of the pages in the microfiche copy of this report may not be up to the proper legibility standards, even though the best possible copy was used for preparing the master fiche.

CONTENTS

I. INTRODUCTION

In April 1972 Krauss-Maffei AG began with the construction work for the development of twin screw extruders. A team of specialists -being engaged in this branch since many years-was entrusted with these construction problems. Already in October of the same year it was possible to present the prototype of our extruder KM D 9o in Dusseldorf on the fair K 71. After the type KM D 9o, a twin screw extruder with a 9o mm screw diameter, we finished the type KM D 12o. In the meantime both types of extruders stood the tests in a continuous working for months in the works of our customers on continental Europe, in England, Skandinavia and in the USA.

These two machines shall be presented to you in a detailed report that specially concentrates on the constructional solution of today's requirements to a modern twin screw extruder. As far as possible we worked out relative values of the particular constructional characteristics to have a base for comparing with the values of our machines. In our opinion this comparison can contribute essentially to the appreciation of the problem.

II. TYPE PROGRAMME

Before beginning with the construction work for the first extruder, an extensive research about the determination of the complete production series had to be made. In any case the demand to the product and to the output capacity shall be covered by as few types of machines as possible.

In figure 1 there is shown a graphical representation of our type programme in such a way that the screw diameters are plotted on the abscissa and the output capacities on the ordinate. At the moment the extruders KM D 9o and KM D 12o with an average output capacity of 275 respectively 45o kg/h can be delivered of this programme. Our smallest type of extruder KM D 5o K with an output capacity of approximately 1o5 kg/h will be tested end of 1972 and taken up in our sales programme in March 1973. The success we had till now confirms us in our conviction that we will also prosper in marketing an extruder with an average output capacity of 7oo kg/h. This development project as well as the small extruder KM D 5o K is not presented in my report.

In the right diagram of figure 1 there is shown the optimum pipe diameter of each extruder when producing PVC pipes. Furthermore you can read off the minimum and maximum output capacity per pipe diameter. Nevertheless it is possible to produce a larger pipe diameter on a smaller type of extruder. In this case the rentability is decreasing as the costs for location and personnel are increasing.

The discharge pipe with a diameter of 4oo mm for example can be produced on the KM D 9o with a production speed of o,31 m/min. and on the KM D 12o with a production speed of o,51 m/min. This means a production of 15o m respectively 25o m of pipe per shift (8 hours). As the investment costs per kg output are the same for both types of extruders and as the subsequent units cause the same costs it is evident that the investment costs per kg output of the KM D 12o line are more favourable.

The increase of the production speed has its limits too, depending principally on the pipe extrusion head and on the calibrating system. Generally 6 m/min. are not exceeded using internal pressure calibrating system. To increase the production speed and simultaneously reducing the output capacity (use of large extruders for small pipe diameters) is rarely an optimum solution.

Besides the main application field, the extrusion of pipes, the extruders KM D 9o and KM D 12o are also qualified to manufacture the following products:

Profiles in rigid and plasticized PVC

minimum cross-section for KM D 9o ...... 1ooo mm^2

minimum cross-section for KM D 12o ...... 25oo mm^2

Sheets in rigid PVC

KM D 9o .....thickness o,5-6 mm max. width 15oo mm

KM D 12o.....thickness o,5-1o mm max. width 2ooo mm

Foils in rigid PVC, polypropylene, polyethylene and ABS

KM D 9o .....thickness o,o5-1 mm max. width 15oo mm

KM D 12o.....thickness o,o5-1 mm max. width 2ooo mm

Granulation of rigid and plasticized PVC.

III. CONSTRUCTIONAL CHARACTERISTICS (figure 2)

A base frame in welded construction takes up the following construction groups:

- Drive
- Reduction gear
- Distribution gear
- Centralized lubricating system
- Cylinder with dosing device and hopper
- Control panel with connection box for the tool

The vacuum and the cylinder cooling device is placed in a box of the base frame below the cylinder. The open construction of the machine is an essential characteristic that makes possible a quick and easy access to the particular aggregates and also facilitates service, control and repairs.

1. Drive

The driving motor is an infinitely variable speed controlled DC motor in compact construction. The driving motor consists mainly of a separately cooled shunt motor and a converter with the corresponding control- and regulating instruments that is installed in the extended motor casing. The regulation of the motor speed is effected by a motor potentiometer with return movement to the starting speed.

The overload protection is adjusted in a way that at a load of 95 % a signal instrument is actuated and at a load of 11o % the motor is disconnected automatically. By pressing a special button the machine can be run up to a maximum load of 115 %.

The rcouest of the pipe manufacturers to produce as far to the lower limit as possible of the wall thickness tolerances, forces the manufacturers of machines to develop extruders and take-off units with constant speeds. This and the fact that we just arrange for an automatic run of the pipe production line induced us to install DC motors in all types of extruders in our programme.

The speed variation of a DC motor at the charge of zero to 1oo % is 1 % of the maximum speed. This means for example the driving motor of the KM D 12o with maximum 26oo rpm in idle running drops by 26 rpm at full charge and therefore runs 2574 rpm.

The speed drop of the commutator motor being used frequently for the twin screw extruders amounts to 1o % in the lower speed range and to 8 % in the higher speed range under exactly the same conditions. This means a comparable commutator motor with a maximum speed of 22oo rpm at full charge drops for 176 rpm and consequently runs 2o24 rpm.

Operation under such extreme conditions allows the conclusion that at speed variations as they always arise during the production process, the constant speed of a DC motor is more favourable.

Normally speed variations cause variations in the wall thickness of the extruded product; in case the wall thickness decreases the quality of the product is inferior, in case the thickness increases material is being wasted.

Moreover I want to refer to further advantages of the DC motor:

Commutator motors are only equipeed with a speed adjustment device and not with a speed control. In case of variations of the line voltage the speed is changed. A device for holding constant the line voltage can avoid this but this aggregate is hardly used due to the high costs involved.

In case of an increase of voltage the speed of a DC motor would increase too. The speedometer being positively connected with the motor shaft produces,at the slightest increase of voltage,a higher tension that is compared with the nominal tension. A difference in tension is regulated by the controlling set within fractions of a second so that the difference of speed between actual value and nominal value is zero.

The expenses for servicing a commutator motor are higher due to the larger number of commutator brushes and collector rings. At a DC motor the current consumption is directly proportional to the speed of the driving motor. Consequently it is possible to indicate the motor load by means of an inexpensive instrument. The overload circuit breaker of a DC motor can be released exactly by a current limiting device. Commutator drives are mainly equipped with electromechanically working cut-off couplings or with shearing pins that work less exactly.

2. Reduction- and distribution gear (figure 3)

The connection between driving motor and reduction gear is set up by means of an elastic coupling (Stromag-Periflex). The reduction of the motor speed to the screw speed is effected in 3 phases. At the same time the third phase distributes the torque on two driving shafts. All pinion shafts and gear wheels are hardened and grinded. For the shaft bearings spherical roller bearings and cylindrical roller bearings were installed.

The centralized lubricating supplies the gear parts in a way that from oil tubes the injection is effected directly into the meshing. Roller bearings not reached by the injection oil are lubricated by means of separate oil tubes.

The casing of the reduction gear is located on the power take-off side to be connected with the distribution gear by means of a flange.

Distribution gear

It is often said that the distribution pinions don't respond in service durability with the pinion bearings and the back-pressure bearing. - It is right that a constructing engineer at first finds a very unfavourable situation as a high torque must be transmitted within a tight space. Moreover a high back pressure must be absorbed by axial bearings in screw distance.

The original arrangement of the distribution pinions in the screw distance is no longer used as this does not meet the requirements. The different torque load on the distribution pinions results in a different torsion of the wheel body. The consequence of such a system was that the power transmission occurred only to a part of the width of tooth face.

The next very important action was that for the elimination of different torsional strain the distribution of the torque was just effected in the last phase of the reduction gear. One screw is directly driven from the reduction gear by a continuous shaft, the other screw is driven by an auxiliary shaft. In view of this arrangement a greater axle distance is available than only the screw distance for the toothing of the auxiliary drive. These gears have essentially higher durability values but they are not endurance gears.

To construct endurant gears we have executed in our distribution gear the auxiliary drive in a double arrangement, for also under extreme conditions (1oo % load and maximum screw speed) we are sure to be in the range of endurant gears. As an example we indicate the calculated values for the extruder KM D 12o:

The security against pitting amounts to 1,9. Values higher than 1,3 are just in the range of the endurance gear. The security against fracture is 2,2. Values higher than 1,8 are in the range of unlimited durability.

Description of the distribution gear (figure 3)

The left screw in the cylinder is directly driven by the continuous shaft 1o. The right screw is driven by the auxiliary shaft 3 over the pinions 4 and 7 resp. 5 and 6. By this arrangement it is reached that different torsion strain is kept off from the pinion shafts and that the total tooth width participates in the power transmission. Moreover by the arrangement of two pinion shafts one after another the torque is distributed again on two pairs of gear wheels. The pinion shafts are connected by couplings 8 and 9.

3. Comparison of the installed torque in current type twin screw extruders

It is very difficult to undertake a power comparison of the distribution gear systems of current type extruders , as just the choice of the torque of comparable machines is very different. In a diagram (figure 4) the torque values were plotted above the screw diameters. For conical screws there was chosen an equivalent diameter to parallel screws being found from $\frac{Dmax - Dmin}{3} + Dmin$.
From this diagram you can see that the manufacturer A has chosen very high torques and the manufacturer D very low torques. Krauss-Maffei has determined torques representing the average value.

With reference to our extruder types KM D 9o and KM D 12o the following torques result from the torque characteristic curve of the particular manufacturers of extruders:

Manufacturer	Screw Ø 9o	Screw Ø 12o
A	125o kpm	3ooo kpm
B		265o kpm
KM	86o kpm	2ooo kpm
C	6oo kpm	155o kpm
D	7oo kpm	12oo kpm

From the table you can see that referring to a screw diameter of 12o mm the manufacturer A conceived a torque of 3ooo kpm, the manufacturer D only a torque of 12oo kpm whereas KM indicates 2ooo kpm. These enormous differences in the basic conception seems confusing but there can also be stated some reasons.

The manufacturer A principally works with full hopper. He has the possibility either to provide a large number of screw types for the adaption of the properties of the material (apparent density, fluidity, etc.) or, and that seems to be the case, to install a very high torque. The advantage of this system is the fact that the screws work fully and by reason of the good insertion in the material cylinder and screws have a slight wear. A disadvantage are the high costs.

The manufacturer D works with a relatively high speed and a low torque. In order to stay within the torque limit the use of a dosing device is absolutely necessary. Due to the low filling of the screws they are deficiently imbeded in the cylinder hole that leads to a high wear especially with high screw diameters. The very low chosen torque sets small limits to the field of application for a manufacturer. To obtain the transformation of energy necessary for the plasticizing process by means of a high screw speed does not always lead to success. High peripheral speed on the screws causes an over-heating of the material and consequently by reason of the poor caloric conductibility of PVC to damages of the product. The gear concept of the manufacturer D does not allow an increase of the torque. There had to be created an all new machinery generation.

In designing twin screw extruders, Krauss-Maffei has installed torques being really usable. For the adaption to the material to be processed adosing device is available with which only the sharp tuning is effected. Test runs of the machines processing showed that it is possible to work with a full hopper. When working from regenerated material,a dosing feeder is absolutely necessary.

In general it can be said that for the valuation of the extruder gear also the usable torque value has to be considered. Extruders with a high torque allow more diversification to the manufacturer and are therefore to evaluate higher,under the condition that the high investment costs for gear and alternative screws are accepted.

4. Back-pressure bearing

The problem of the absorbtion of the back-pressure having his effects via the screw axles is of particular importance by reason of the small distance of axles. We found the following solution: The back-pressure of the left screw is absorbed by an axial taper roller bearing. The back-pressure of the right screw is absorbed by axial tandem bearings whose supporting rings distribute the pressure elastically to the axial cylinder roller bearing. Both back-pressure bearings are supported by a plate being bolted with the reduction gear. The cylinder is also connected with the plate via two tie rods so that the distribution- and reduction gear is not exposed to any strain from the injection pressure.

The triple tandem bearing installed one after another for the support of the right screw is described in figure 5. Like the multi collar thrust bearings (slide bearings) used years ago the total load is absorbed in equal parts in several phases. The problem is that the distances of the particular phases must have absolutely the same size, otherwise the bearing with the smallest distance would have to bear a larger load part. The sliding disks of the bearings are stiff parts and are manufactured with highest precision and assorted to sets. In the same manner the roller bearings are handled. Nevertheless there arise little differences in dimensions by installing them one after another. In order to eliminate these differences in the multi-stage height the supporting rings 1-4 are not stiff but elastic. By this elastic effect the difference in the distribution of load can be kept within 1o %.

The durability of the back-pressure bearings for the KM D 12o with regard to an injection pressure of 35o kg/cm^2 and a screw speed of 24 rpm amounts to 26.ooo hours. In this value the degree of uniformity of 1o % is just considered.

Naturally the back-pressure produced during the manufacturing process is automatically measured and controlled. The tie rods are subject to elongation according to the injection pression during the production. This value (for KM D 12o is fox example o,1 mm for 1o tons) is remitted to an inductive effective adometer. Via an amplifier of the measured quantity the value of the back-pressure is indicated on an instrument. When exceeding an injection pressure of approximately 35o kp/cm^2 a signal installation is acted. In case an injection pressure of approximately 65o kp/cm^2 is reached the driving motor is cut-off automatically.

5. Centralized lubricating system

The electric gear pump is mounted on the base frame and supplies lubricating oil to the reduction- and distribution gear. The pump draws off the oil from the casing of the reduction gear and transports the oil via a current meter and a filter in the heat regenerator. The current meter is adjusted to a minimum flow of 5 l/min. to 35° E. This aggregate sets in action a safety installation if this value is not reached.

The cooled oil is transported to the reduction gear in a central supply line. There the oil is transported in conduits to the meshings and to those lubricating points the injected oil does not reach.

The distribution gear has two connections for lubricating oil where butterfly valves are inserted to regulate the flow. In the distribution gear the oil level adjusts to the height of the holes in the backing plate serving for the immersion lubrification of the meshing and of the bearing.

6. Screws and screw cooling

The screws are rotating in opposite directions, seen from above they diverge. The connection of distribution gear and screws is effected by clutch sleeves that are equipped with a ratchet of a ratchet whee taking over the guarantee for the exact position of the screws. For the adaption of the equal radial clearance in both directions there are provided disks for adjustment at the ends of the screws. The screws are equipped with an oil temperation especially effective in the output zone. In the hole of each screw there is installed an oil feeding tube by which fresh oil is introduced via an oil feeding device. The oil penetrates at the screw tips, is conducted via a heat regenerator and flows back to the heating-cooling unit between the oil feeding tube and the screw hole via the oil feeding device.

At the occasion of the dismounting of the screws, the oil feeding device remains on the driving shaft. The oil connecting holes are arranged at the top and when the screws pass through the cylinder holes no oil can drop out. The screws are manufactured either of nitrided steel or of case hardened steel with a surface hardness of 700HV. Metering and degasifying zone are hard chromed.

The screw geometry developped by us is based on the following reflections:

Reouirements: 1. High output capacity with optimum plastification.

2. Maximum material protection during the plasticizing process.

This was reached with:

1. Great depth of thread of the screws, bringing high transporting capacity at a low screw speed.
2. Mathematically calculated combination of compression-, mashing- and mixing zones.
3. Prolongation of the rest period of the material during the plasticizing process in the cylinder by a standard lay-out of screws and cylinder to 22o D-length.

With our standard screws there can be reached relatively the same high output capacities in a relatively large PVC formulation range.

7. Cylinder and cylinder tempering

The tie rods of the distribution gear are bolted with an intermediate support taking up the cylinder. The intermediate piece is eouipped with a material filling hole and supports the dosing device. In order to avoid the transfer of heat we have inserted a water cooled ring. The cylinder is manufactured of nitrided steel and takes up the two screws in a twin hole. The anterior part of the cylinder is supported from the base frame and permits a free longitudinal displacement to compensate the thermal expansion. A connection of the tool is effected with a two-part tension ring wedge closing device in a way that the cylinder takes up the tool in a center and the position is fixed with a bolt.

In his length the cylinder is subdivided in 5 zones. Each zone is eouipped with a resistance heating device and a resistance thermometer. The zones 3,4 and 5 are developped as heating-cooling zones so that in helical notches oil tubes are inserted. A magnetic valve is coordinated to each cooling cycle being controlled by a regulator.

Between zone 3 and 4 there are inserted degasifying holes in the cylinder making possible the connection with the vacuum line via a degasifying crest. Through inspection glasses the degasifying process can be observed.

8. Degasifying of the cylinder

To avoid enclosures in form of blister in the extruded product - essentially influencing the quality of the product- it is necessary to abstract all volatile components from the plastic material in the first plasticizing phase. For this purpose a vacuum is produced in a certain part of the cylinder. The degasifying system conceived of Krauss-Maffei functions as follows:

From a squirrel-cage induction motor the water-ring vacuum-pump is driven via an elastic shaft coupling. On the suction side of the pump a ball check valve is installed that prevents the penetration of water in the suction pipe when the pump is cut-off. From the ball check valve a hose pipe leads to a proportioning container and from there to the degasifying crest of the cylinder. In the proportioning container a filter is installed having the task to separate powder eventually carried along. The discharge can be easily effected by removing the cover of plexiglass. In the water supply-pipe a magnetic valve is inserted interrupting the water supply when the pump is cut-off. The vacuum pump has a separate drain pipe.

9. Command- and control instruments

The very difficult processibility of PVC from powder - chemical decomposition during the plasticising process at over-heating and the formation of muriatic acid attacking screw, cylinder and tool - makes necessary that the extruder is equipped with comprehensive command- and control instruments.

Some examples:

revolution counter for motor and screws

torque counter for the control of the motor load

revolution counter for the take-off units
thermometer and automatic regulation instruments for the heating- and cooling-zones
manometer for the vacuum zone
manometer for the calibration of pipes and profiles.
eventually measuring instruments for the control of mass pressure and mass temperature.

These measuring- and command instruments should be as far as necessary connected with security installations starting action in case maximum values are exceeded and in case of performance failures (for example deficiency of a temperature regulating instrument).

As security installations don't fully eliminate the risk, in the extruders of Krauss-Maffei safety fuses were installed that interrupt the machine in order to avoid damages to the machine when the measured values further increase or decrease.

Some examples:

Main driving motor: warning at 95 % load
cut-off at 110 % load.

Separate ventilator of the main driving motor:
cut-off of the main driving motor at deficiency of the separate ventilator.

Air-filter of the main driving motor:
cut-off of the main driving motor at dirty air-filter.

Dosing device: cut-off of the main driving motor at deficiency of the dosing device.

Back-pressure: warning when an injection pressure of approximately 350 atü is reached. Cut-off of the main driving motor in case an injection pressure of approximately 650 atü is reached.

Centralized lubricating system:
warning when the oil flow decreases below

5.1 min. When the flow is again under the control value after 5 minutes the main driving motor is cut-off.

Vacuum system: warning at deficiency of the pump motor.

Cylinder cooling: warning at deficiency of the pump motor.

IV. EFFICIENCY OF TWIN SCREW EXTRUDERS

The technical concept of the Krauss-Maffei extruders was just explained. It is followed by a critical consideration of the machine price:

The manufacturer is accustomed to expect from an extruder with a certain screw diameter a certain output capacity. These reflections certainly do not inform extensively but they are sufficient for the rough estimation of the technical standard of an extruder manufacturer. Comparing different types of extruders it has to be observed that for the comparison only the same construction principles, that means single-stage machines with cylindric screws, can be referred to.

In figure 1 we have plotted over the screw diameters of different types of extruders the obtainable output capacity (Pb stabilized pressure pipe). From the diagram you can see that in spite of the same screw diameter there exist considerable differences in the output capacity. Refer to a screw diameter of 9o mm, Krauss-Maffei achieves an output capacity of 275 kg/h with such a machine, the manufacturer D obtains only approximately 2oo kg/h and the manufacturer A approximately 175 kg/h. Take as a starting point the KM D 9o and look for output capacities of extruders with equivalent screw diameters produced by other manufacturers and you will state that D needs a screw diameter of approximately 1o5 mm and A nearly 12o mm. If high output capacities are obtained with a small processing unit, a high market value is given and in such a case the constructing engineer has available the means to be spent for durability and working safety.

To find a decision for an investment purpose there is frequently established a rentability calculation forwarded mainly as a "kilo-calculation" with reference to the price of the product. An essential cost factor in this calculation constitutes the initial costs of the extruder respectively the yearly redemption rate. At the end of the calculation the extruder is again of special importance as the total costs are divided by the hourly output rate in order to get the costs per kilo of the product. In case somebody wants to test the rentability of the extruder as a single machine, this is expressed by stating the relation of the investment costs to the hourly output capacity. The lower this value, the higher an extruder must be evaluated. Besides this form of evaluation there is a range of further factors especially required by the technician of the interested firms that are important for the purchase decision.

In figure 7 we have described the investment costs per kilo output in a bar graph. The investment costs refer to extruders ready for service with control cabinet and heating-cooling unit. We have again included in our observations the screw diameters as the investment cost factor is not independent of that.

From the diagram you can see that there exist differences in the investment costs of 17o-3oo $/kg for extruders with screw diameters of 6o to 13o mm. Furthermore it could be stated that immediately adjoining screw diameters (85 Ø and 86 Ø) show the same high difference in the investment costs. From the purely technical view there is no explanation and therefore we cannot analyse this special case more detailed.

The manufacturer A shows in the outcome of the investment costs a typical figure. For average screw diameters of 85 mm for example there exist favourable investment costs of 17o $/kg increasing with a greater screw diameter of 12o mm to 225 $/kg. It is generally known that processing problems arise with extruders of large pipe diameters. The machines don't achieve the output capacity they are due to bring. Although the price of the machine is relatively favourable compared with smaller types, the investment costs are increasing because in many cases it is not possible to increase the output capacity. In the last time the point of the most favourable investment costs moves more and more to machines with a screw diameter of 100 to 110 mm. That the extruder with a screw diameter of 60 mm shows an investment cost factor of 245 $ kg is clear, as the production costs are higher compared with a greater machine and some construction groups as electrical equipment, vacuum pump, cylinder cooling equipment, screw tempering equipment, etc. are taken over in almost the same execution. Nevertheless it must be mentioned that the smaller extruder of manufacturer A is exclusively **favourable** concerning investment costs.

Manufacturer D shows an investment cost curve constantly decreasing with an increasing screw diameter. Certainly D has an extruder type of 160 mm screw diameter in the production programme, not considered in our table that has higher investment costs than the medium size machine. There is a similar situation to A but for all types the investment costs are higher.

For the extruder types KM D 90 and KM D 120 Krauss-Maffei has a constant investment cost factor of 178 $/kg. The KM D 90 is approximately on the same level of investment costs than A 85 ø and a machine with conical screws. On the other hand the investment costs of E 80 ø and D 86 ø are essentially higher. The KM D 120 is on the same level as D 130 ø but has, compared with A 120 ø and E 125 ø, more favourable investment costs being 47 $/kg respectively 31 $/kg lower.

The investment costs for the planned extruder KM D 50 K will of course be higher than 178 $/kg. When we succeed to be on the same level than A 60 ø we have achieved our development task.

As it is just known we are also occupied with the project of a large extruder having an output capacity of approximately 700 kg/h. The object of the desired investment costs is 178 $/kg, the same value as for the types KM D 90 and 120.

Although we are in a very favourable position with our investment costs compared to the values of other manufacturers we warn to attribute to much importance to this evaluation. Important facts like machinery equipment, mechanic working reliability, costs for reparation and service, chemical engineering production security, large field of formula application, etc. should also be taken into consideration.

Finally I want to say that we were trying to create machines of high efficiency putting on the first places durability and production security in a high extent. We know that a newcomer penetrating in the market has to comply with the requirements to a special extent and in every respect.

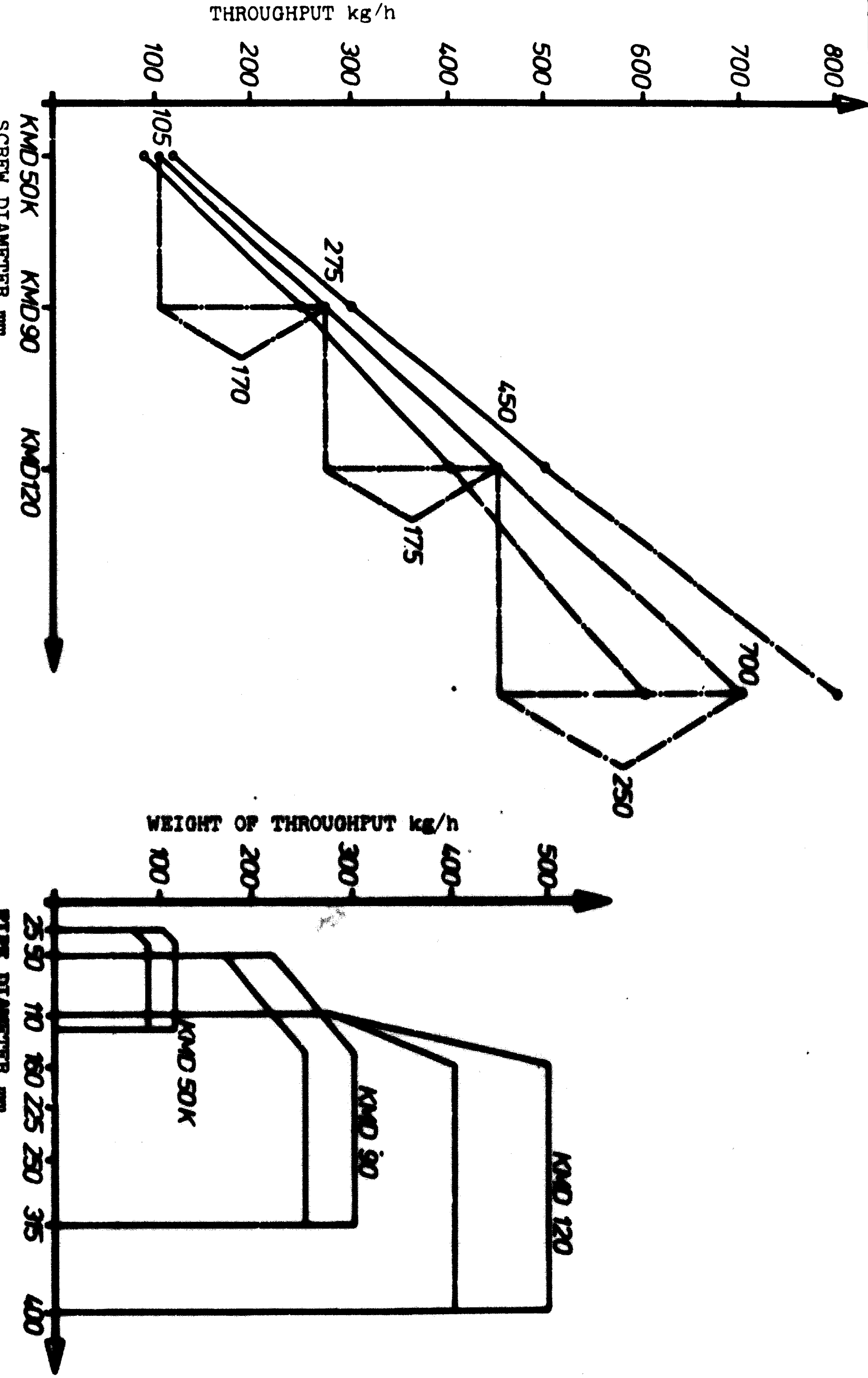

THROUGHPUT kg/h
100
200
300
400
500
600
700
800
SCREW DIAMETER mm
KMD 50K
KMD 90
KMD 120
105
275
450
700
170
175
250
WEIGHT OF THROUGHPUT kg/h
100
200
300
400
500
25
50
110
160
225
250
315
400
KMD 50K
KMD 90
KMD 120

FIGURE 1

TORQUE VALUES OF TWIN SCREW EXTRUDERS

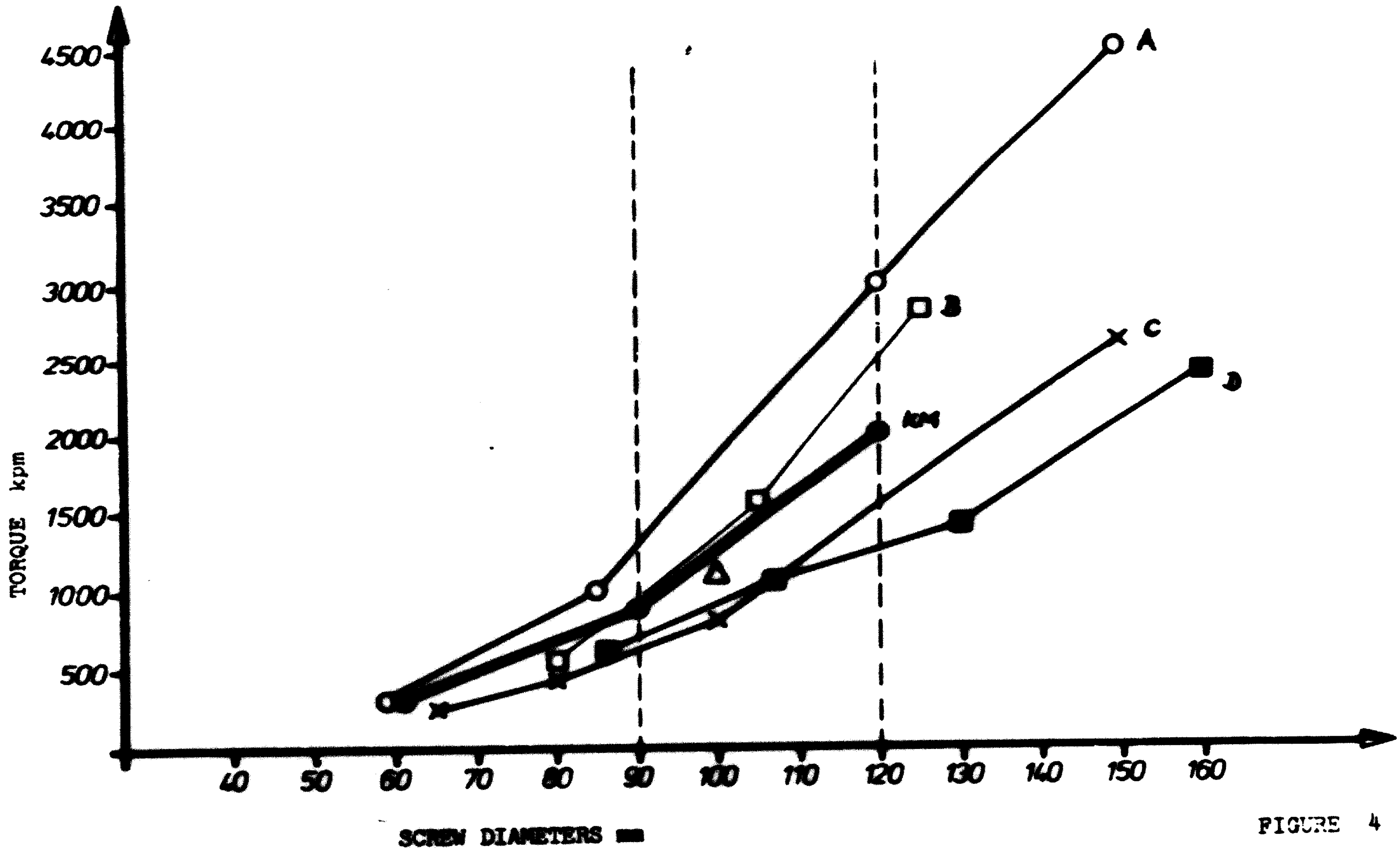
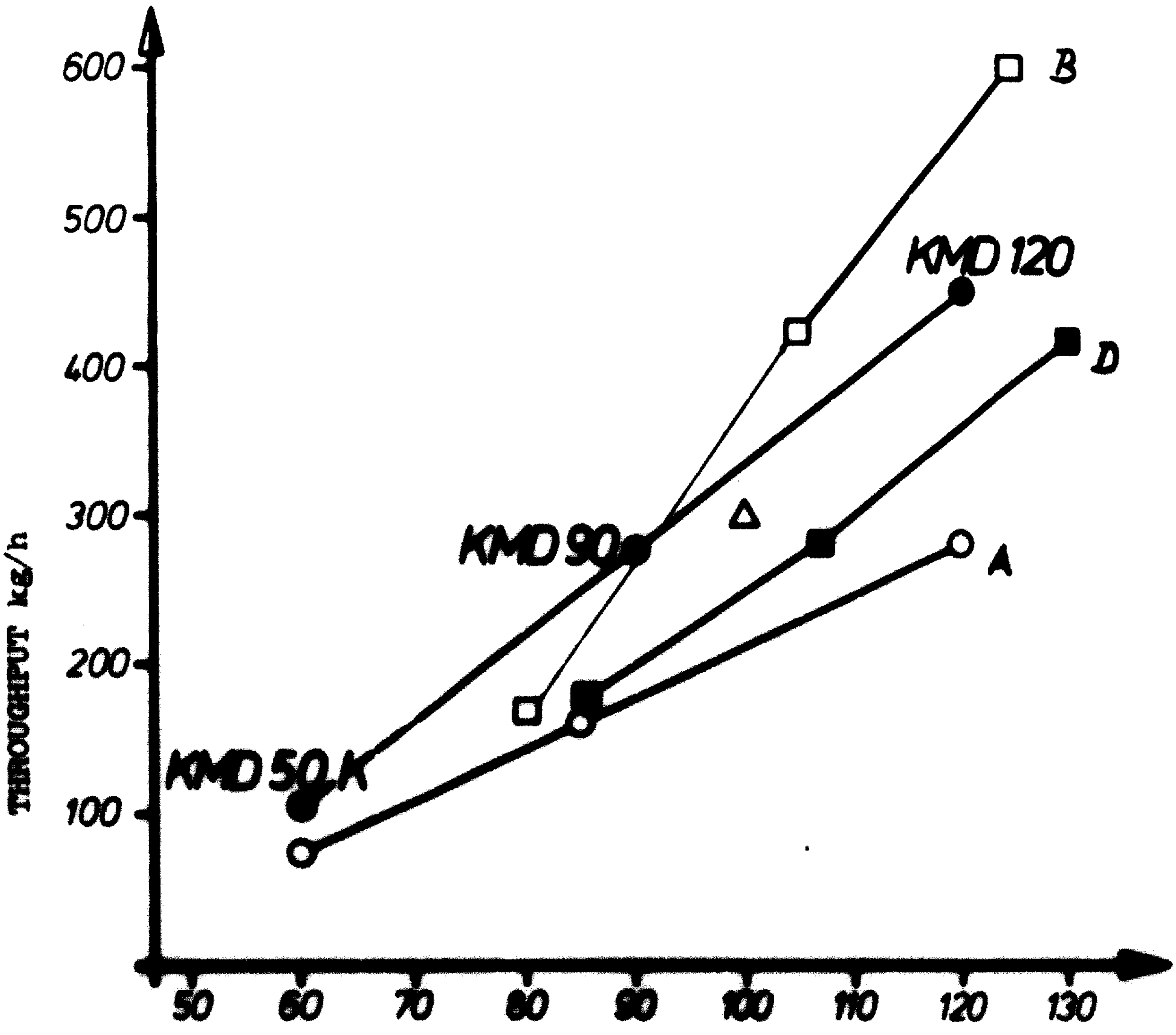


FIGURE 4

THROUGHPUT IN RELATION TO SCREW DIAMETERS



INVESTMENT COSTS PER kg TROUGHPUT

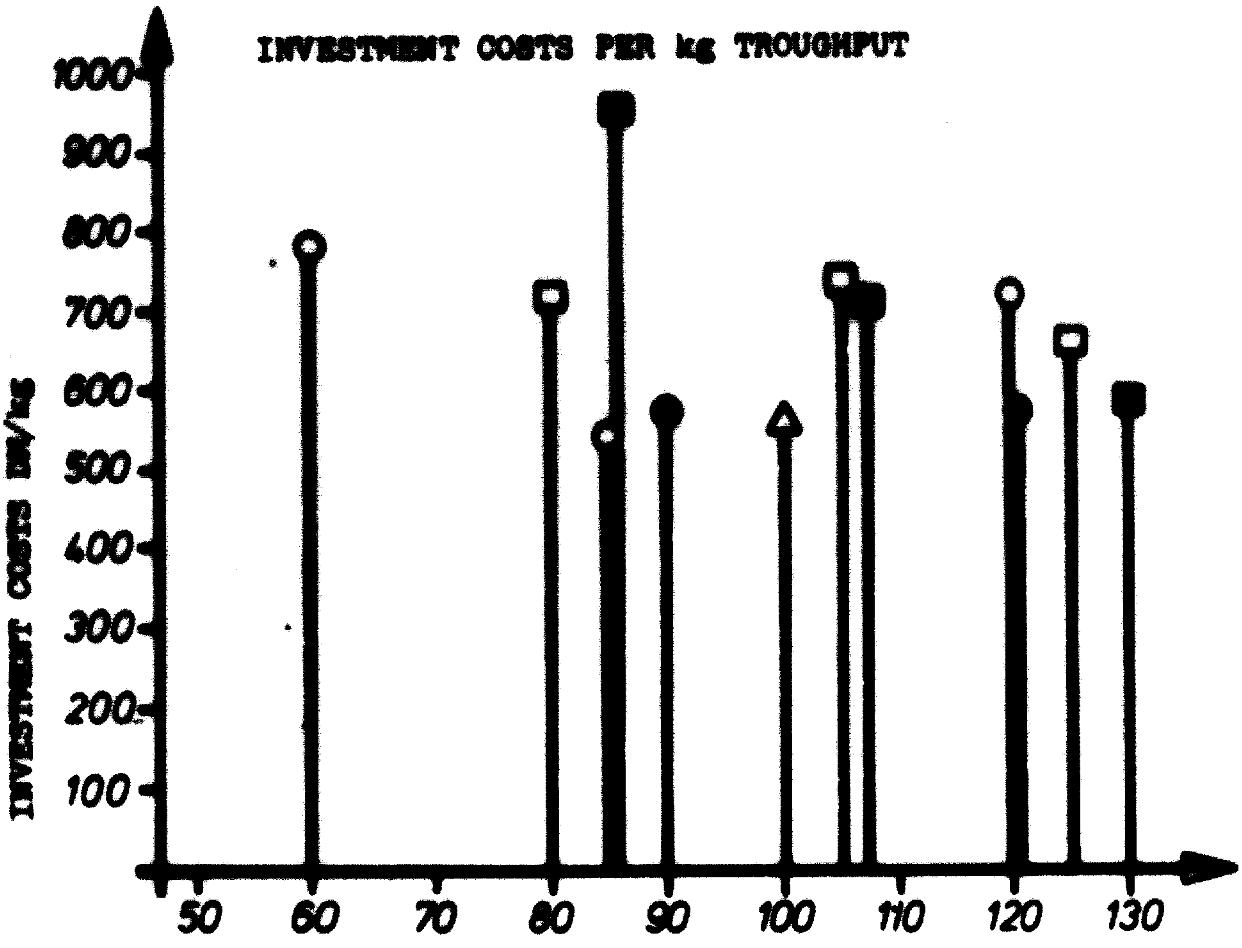
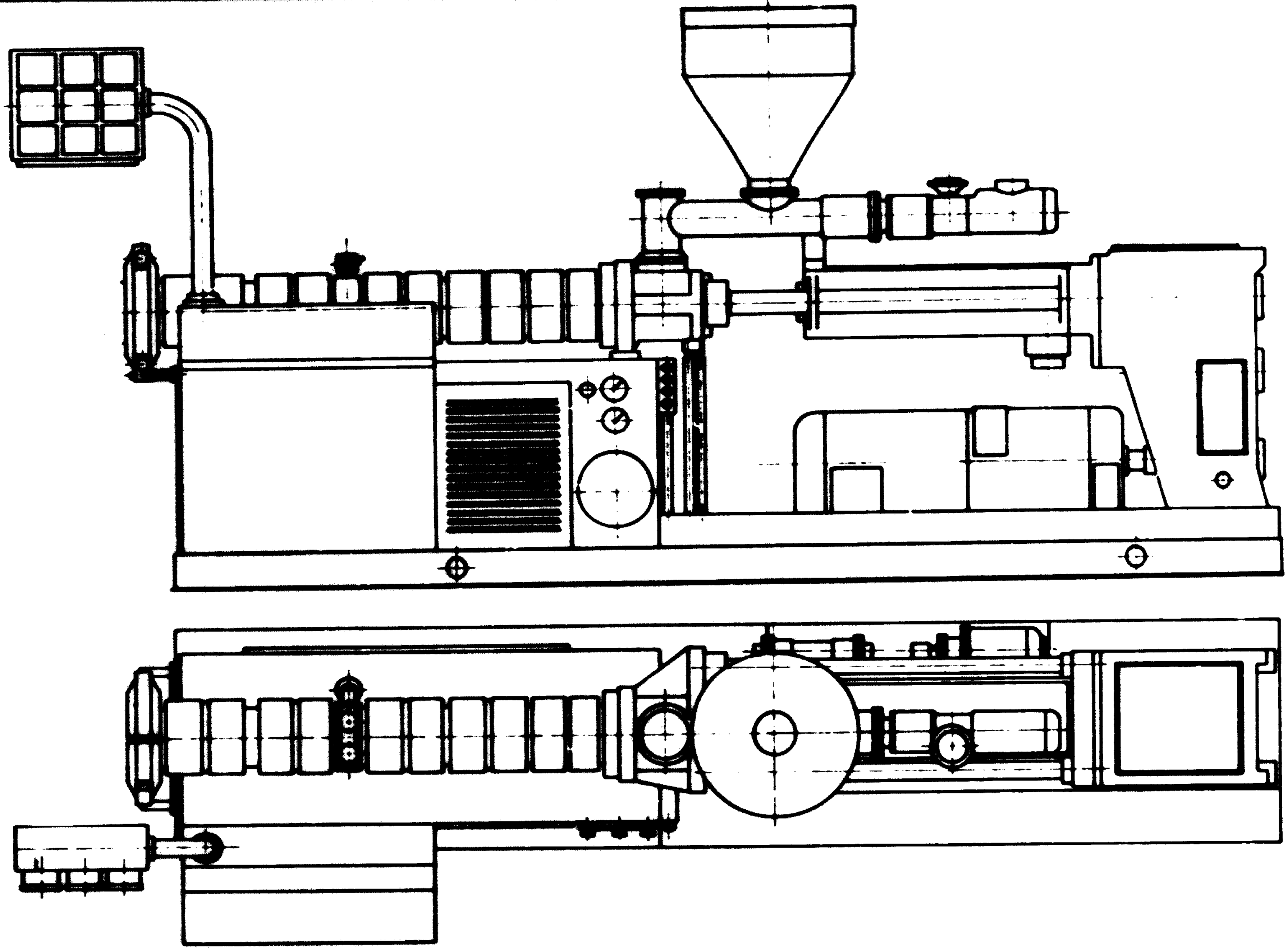
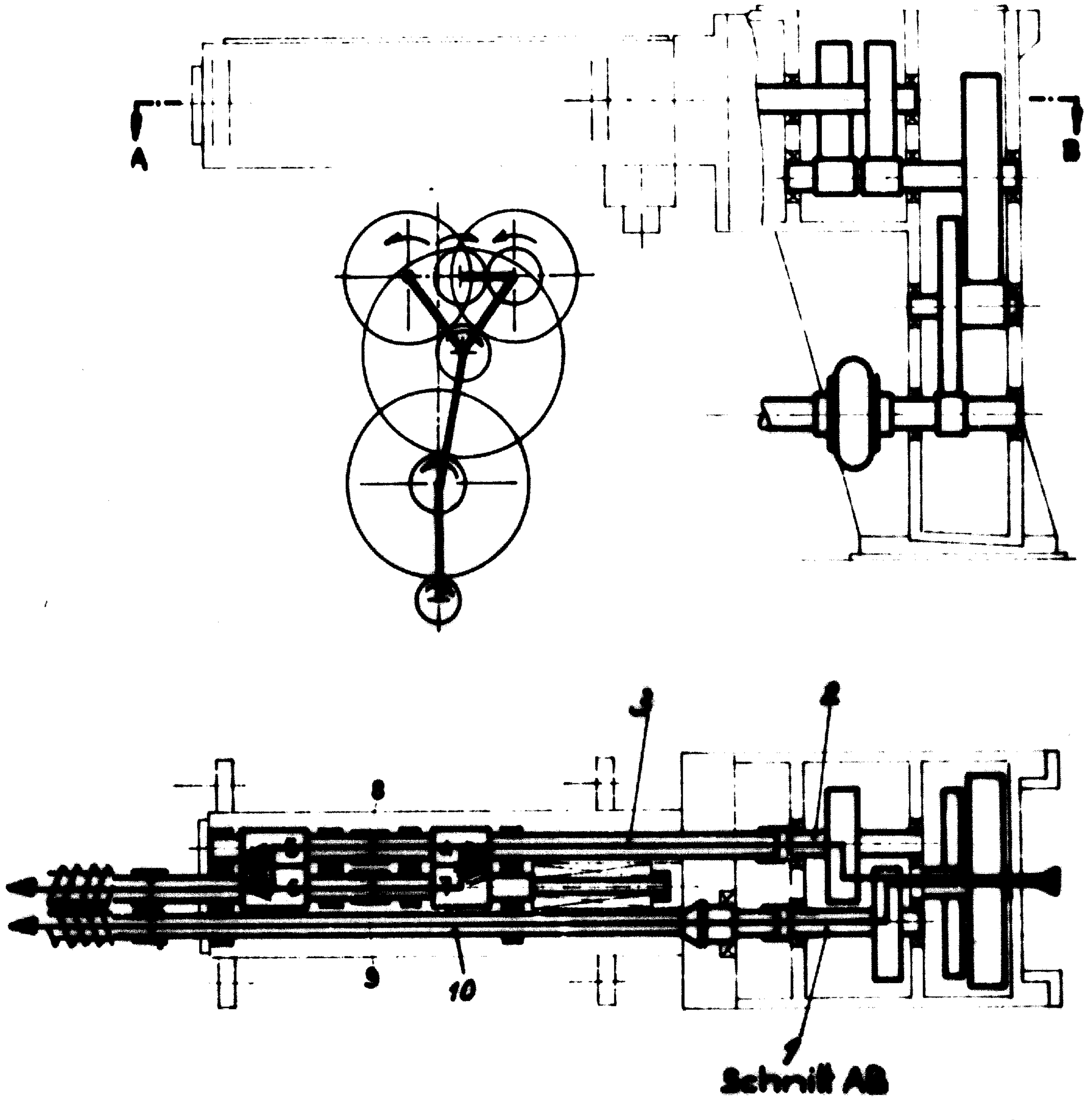


FIGURE 7



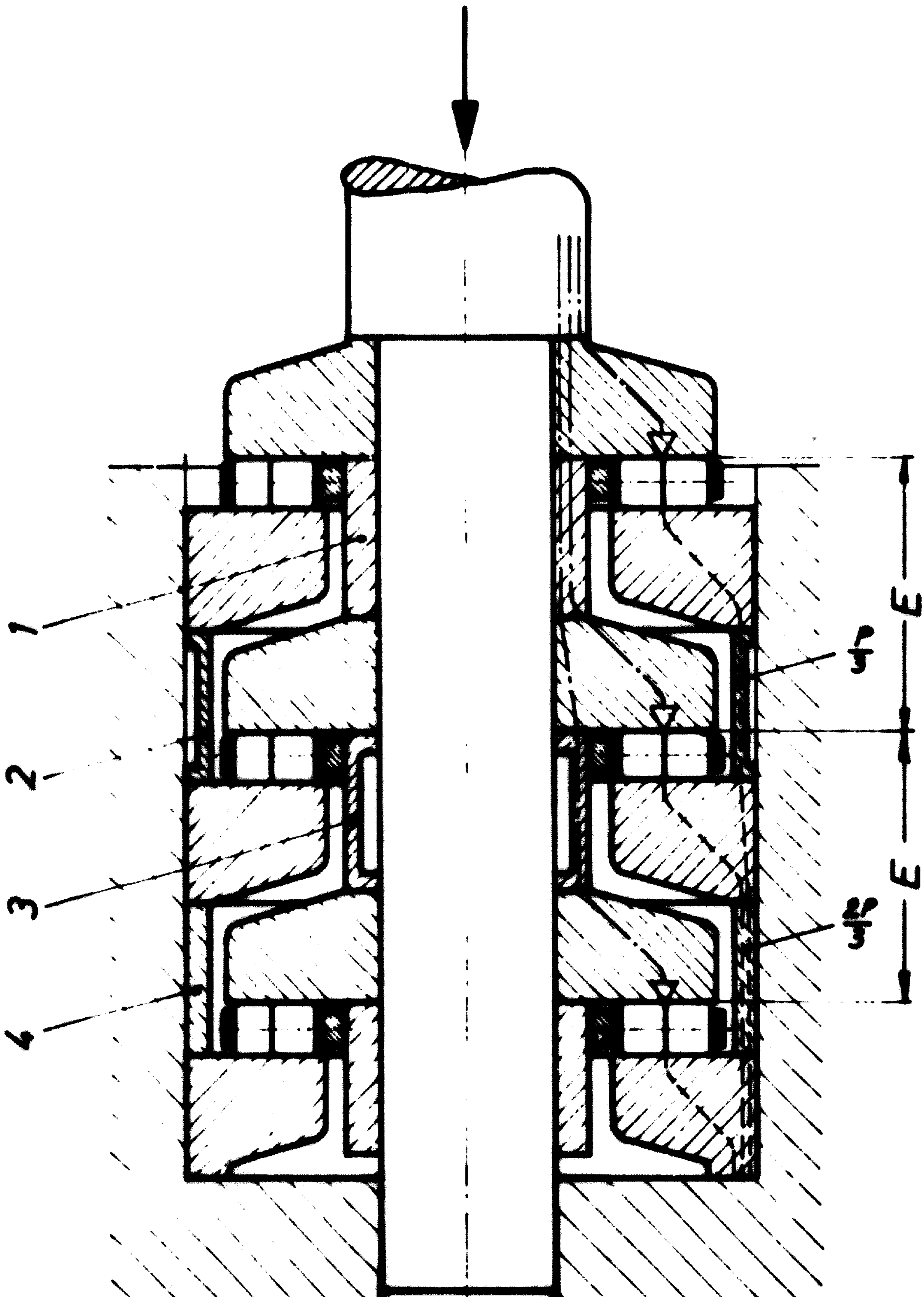
EXTRUDER TYPES KM D

FIGURE 2

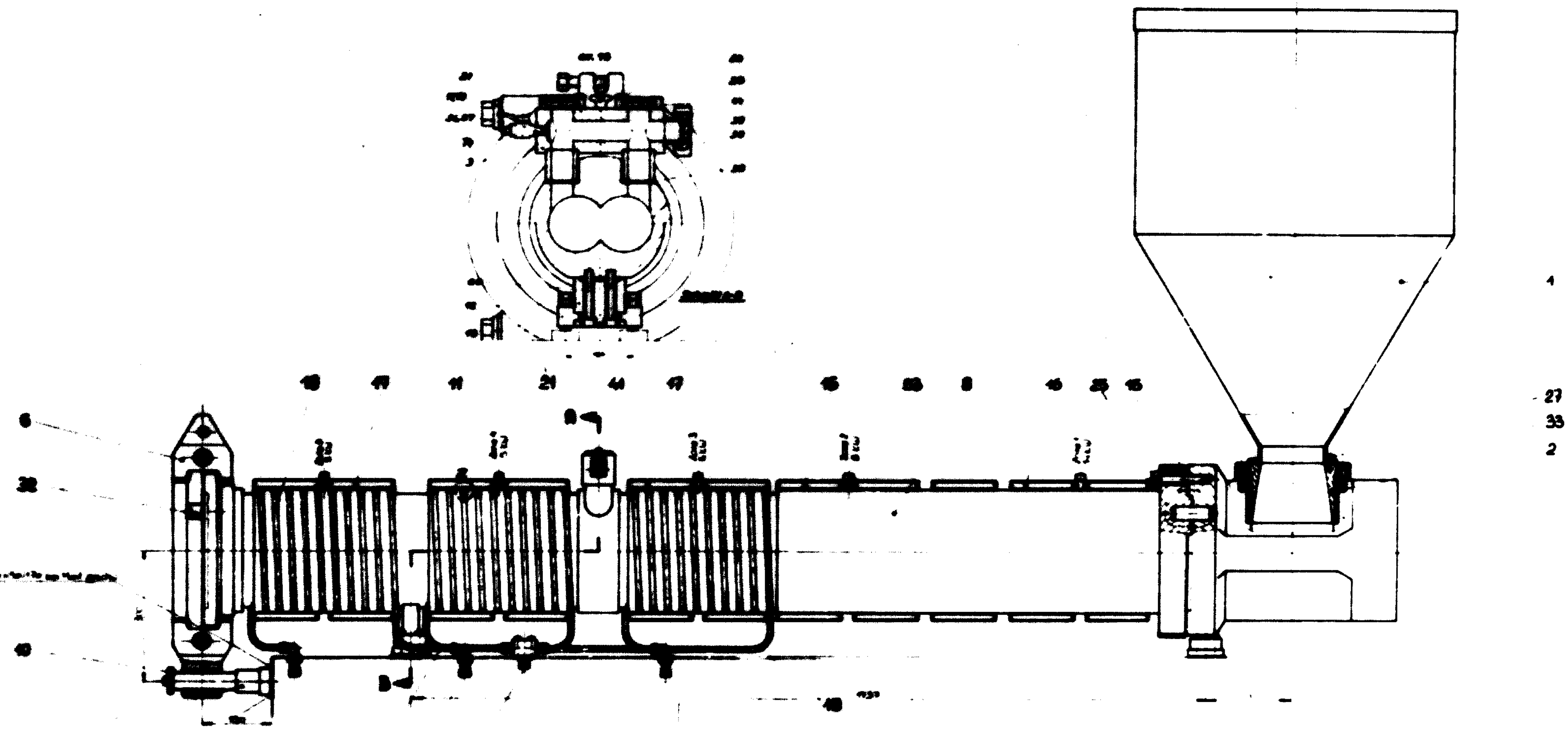


EXTRUDER DRIVING GEAR SCHEME

FIGURE 3



TANDEM BEARING FIGURE 5



CYLINDER

FIGURE 6

2. 8. 74