## 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

Distribution
LIMITED

ID/WG.137/33
18 September 1972

Original: ENGLISH

United Nations Industrial Development Organization

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

Bogotà, Colombia, 20 November - 1 December 1972

# DEVELOPMENTS IN BLOWN FILM EXTRUSION 1/

by

Jens Müller
DEMAG AKTIENGESELLSCHAFT
Darmstadt
Federal Republic of Germany

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

id.72-5860

Distribution
LIMITED

ID/WG.137/33 SUMMARY
18 September 1972

Original: ENGLISH

United Nations Industrial Development Organization

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

Bogotá, Colombia, 20 November - 1 December 1972

SUMMARY

# DEVELOPMENTS IN BLOWN FILM EXTRUSION 1/

by

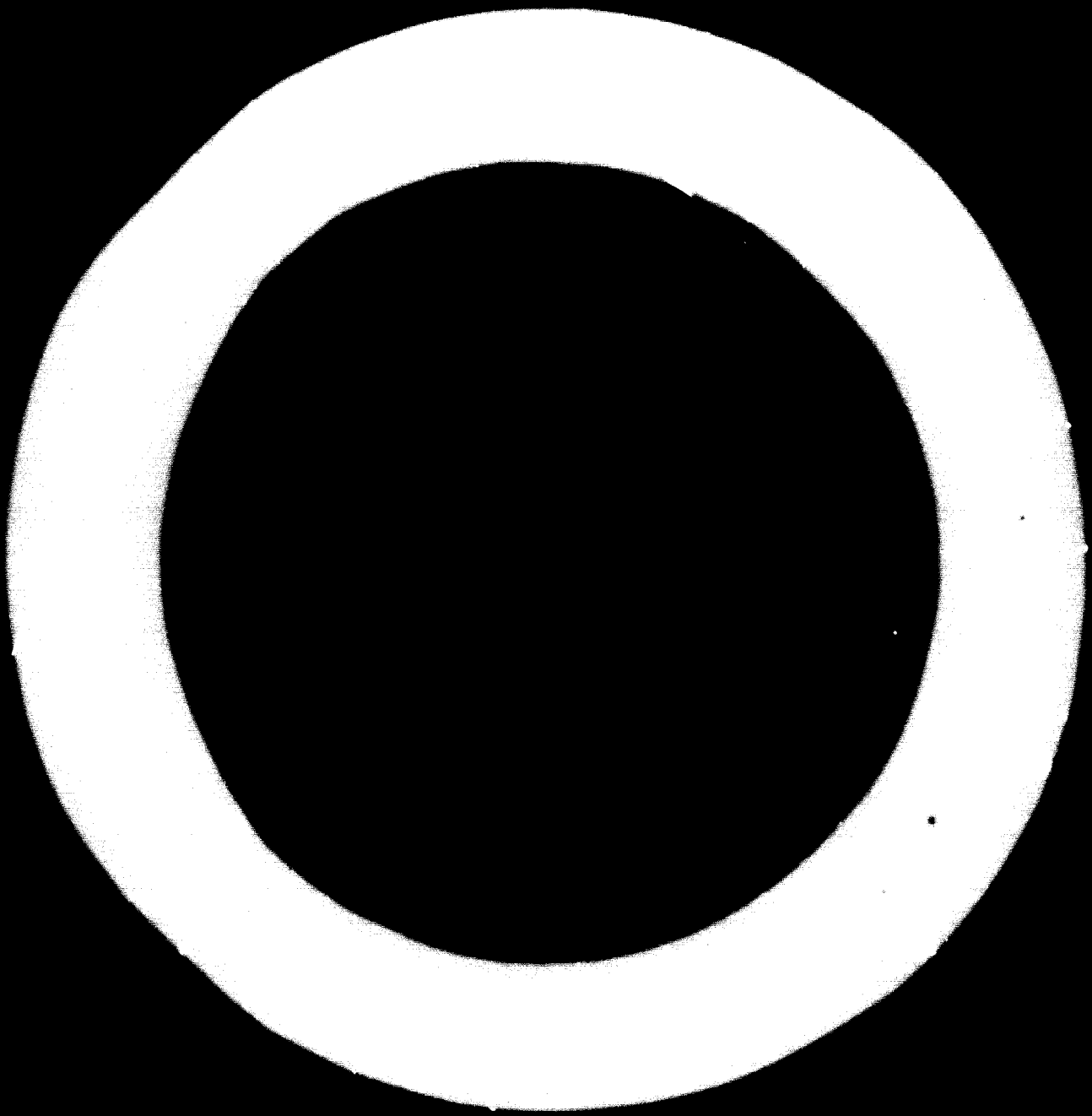
Jens Müller
DEMAG AKTIENGESELLSCHAFT
Darmstadt
Federal Republic of Germany

Films are used in different sizes and shapes: Heavy duty and garbage bags, shopping bags, shrinkable film for small packages, shrink hoods for pallets, C A film and HD film with paperlike features;

To reach the demand of a most efficient production of films, DEMAG designed a special screw geometry. By increasing the compression ratio (7:1) the energy is transfered from drive energy into heat by shearing in the region of the transition zone.

A 100% melt is the result at the end of the transition zone. This is obtained largely independent of the output. Since the high pressure drop at the end of the transition zone (compared with a 3-stage-screw) and the hight shear rate is effective

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



only for a very short period the material will not be damaged. In the metering zone the 100% plasticized material needs no further heat. The barrel is cooled with air and needs no intensive water cooling contrary to a 3-stage-screw. This is the reason why we save 15% of the energy consumption compared with the 3-stage-screw. This screw geometry offers advantages:

- high output
- low melt temperatures
- extremly good homogenity

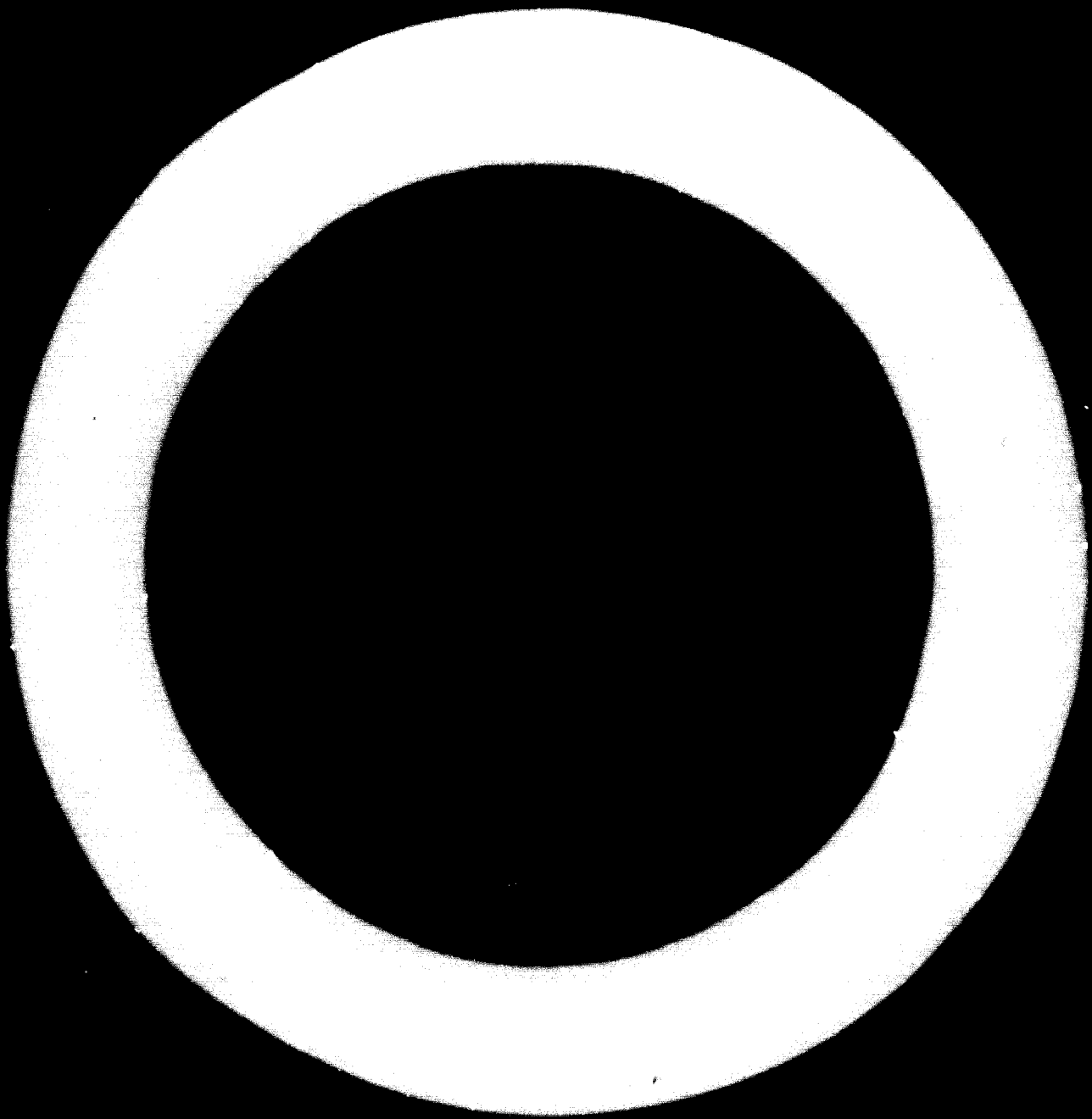
Extrusions lines for shrink films

Due to the homogenized melt and low melt temperature a high output can be achieved. The shrink values can be customade. The tolerances are 6 to 8%.

Paperlike film

Paperlike film of high molecular high density polyethylene is produced on the new designed DEMAG blow film line which consists of a 60mm extruder and a die with a diameter of 100mm to 200mm. The know-how is concentrated on material/composition and surface of die parts. Here as well it is the screw which guarantees good plasticized and homogenized material plus high output. Depending on resin and size the output will be between 40-80 kg/h. The film thickness is between 10 m to 100 m. Paperlike film substitutes

- paper wrap
- tissue paper
- bags of different sizes
- grease resistant paper
- labels



Todays films are produced in many different ways on extrusion lines.

Perhaps we think of bags of different sizes and shapes, heavy-duty and garbage-bags, shopping bags (in Europe), shrinkable film for small packages, shrink hoods for pallets, C&A film and recently we think of HD-PE film with paperlike features.

The efficiency of an extrusion line for production of films is judged by:

- the highest possible output,
- the quality of film regarding:
  - homogenity, which should be possibly good,
  - tolerances which should be very low,

and the operating safety and simple handling.

Assuming that all modern mechanical knowledge is realized in our extruders, which grants a reliable operation and simple handling, we may say, that process engineering of

- the unit screw/barrel
- die
- cooling ring,

decides about efficiency of an extrusion line.

The screw geometry has to be designed as follows:
- the melt be conveyed without surging
- the output has to be as high as possible
- the melt temperature has to be as low as possible
- the thermal and optical homogenity of the melt should be optimal.

The blown film die should be designed in such a way, that:
- the melt flow is symetrically formed from strand into a circular symetric tube
- differences in tension, which exists in the melt due to the screw process, are reduced by relaxation
- the spider marks are not visible and measurable
- the die gap geometry is machined precisely (small tolerances)
- the geometry of the gap can easily be changed, if necessary.

The cooling ring should be constructed in such a way, that:
- the cooling air conducted into the ring evenly and additionally equalized in the cooling ring,
- the cooling air is blown into the bubble at a constant speed around the circumference of the gap,
- speed and blowing direction of cooling air may be varied.

Screw design

Now I would like to show you how DEMAG has improved the screw geometry regarding above mentioned criteria.

Our developments started with the well-known 3-stage-screw with a long-metering section, which even still today is spread widely. The homogenizing qualities of screws of this type were improved during the last years by using shear parts shortly before the end of the screw.

This screw has two grave disadvantages:

- at high outputs, that means high screw speeds, an increase in melt temperature arises in the 15 D long metering section because of high shear rate and is even intensified at the mixing part.
  Only by intensive cooling it is possible to reduce this increase in temperature partially.
- At larger output quantities the melt transition is moved to the end of the screw. An additional increase in output can only be obtained by lengthening the screw. This will lead to 3o - 35 D screws, as well krown by all of us.

Here we started our development. By increasing the compression ratio from 4:1 to 6 and even 7:1 the transformation of energy from drive energy into heat by shearing in the region of the transition zone is intensified. In the transition zone the resin is transferred from a solid to a plastic state.

The result is a 1oo% melt at the end of the transition zone. This is obtained largely independent of the output. Due to the substantially higher pressure drop at the end of the transition zone (compared with a 3-stage-screw) the quality of the mixture is distinctly improved. The reason is the particle destructing effect of the pressure drop.

This has an advantageous result on the homogeneous mixing of master batch into the melt.

As the high pressure drop in connection with the high shear rate is effective only for a very short period the material will not be demaged.
What does now happen in the metering zone?

As the granulate is plasticized to a 100% at the end of the compression zone, it is not necessary to add energy in this section. For this reason we have distinclty enlarged the depth of the thread in this area, so that the ratio of the depth feeding section to metering section is 1,5 - 2:1. The result is that at first the pressure drops, increasing later again to the required tool pressure at the end of the screw. Furthermore the melt temperature increases only slightly due to the low effective shearing rate.
When using these screws it is sufficient to cool the barrel with air, contrary to a 3-stage-screw which requires an intensive water cooling. This is also the explanation for the low energy consumption when using the DEMAG step screw - as we call it - compared with the 3-stage-screw. We save approximately 15%.

In the 12 D metering section the material is homogenized and mixed to an optimum. Due to the lower demand in regard of pressure drop and shear rate, the relaxation process can already start in the melt.

With extremely difficult mixing problems, which have not yet occured, it is theoretically and practically possible to install a mixing part for an intensive mixing into the metering section. Paractical results for complicated mixing operations were already achieved.

Summarizing I may say that - due to the mentioned measures - it is possible to offer a screw geometry which guertantees:

- high output at
- low melt temperatures and
- extremely good homogenity.

## The blown film die

In the beginning I have indicated some requirements which we have materialized by the following design features:

- the dies are bottom fed.
- in long manifolds the melt has enough time to relax
- spider marks are eliminated by a breaker plate, not only visibly but also measurably. For highmolecular weight high density polyethylene, polypropylene and polyamide, a spiral mandrel instead of a breaker plate is used.
- the die gap is machined to an extreme concentricity and surface finish and in addition chrome-plated. This results in small tolerances.
- the geometry of the die gap (which is gap and land) can be varied easily by exchanging the mandrel insert. Herewith an optimum adaptation in regard of strength and elongation in machine and transverse direction, penetrating strength, tear strength, shrink way and tension in machine and transverse direction is achieved.

## The cooling ring

The demands on the cooling ring are realized as follows:

- the cooling ring is fed in machine direction at 6 to 9 positions according to size. The housing is constructed with a great volume, so that at low air speeds a uniform air distribution can be obtained. This is supported by a triple deflection inside the housing.
- the air leaves the cooling ring gap with uniform speed around the circumference.
- to achieve the optimum speed and blowing directions for different resins, film thickness and bubble shape

(especially at high blow up ratios of 4 to 6:1 as used for shrink film and biaxal orientated paperlike film) the air ring gap can be adjusted and the blowing direction can be varied by changing the cooling ring lips.

## Extrusion lines for shrink film and paperlike film

In the following I shall discuss the consequences of this development work on the efficiency of shrink-film-lines for the production of pallet shrink film and of the recently developped line for high molecular weight high density polyethylene.

## Shrink film

Shrink film for pallet hoods is nowadays produced on 12o mm and 15o mm extruders. According to the film dimension a die with 35o mm to 4oo mm diameter is used.

To achieve, for example, a film with 2,5 m lay flat width, the bubble is blown up with a ratio of 3.5 to 4,5 to 1. This results in a biaxial orientation of the film. Film thickness normally used is 1oo µm to 2oo µm. The best possible shrink values are 5o% in machine and 5o% in transverse direction. By suitable modulation of the melt flow in the region of the die gap and the cooling in the region of the bubble expansion the shrink values can be decreased from 5o/5o% to 35/35%.

These above mentioned shrink values correspond with shrink tensions and can also be decreased from 2.5 to 1,8 - to - 1,o to 1.5 g per square mm.

Films with these properties are sold very successfully in Western Germany at the moment.

In this market alone approximately 6o ooo metric tons of film are produced.

The influence of melt temperature, die tolerance, die gap geometry and cooling technique were discussed already. Shrink values can be custom-made with existing know-how.

With our 15o mm extruder and 4oo mm die we achieve outputs of

| | | |
|---|---|---|
| 45o kg/h | at | 1oo µm |
| 375 kg/h | at | 125 µm |
| 35o kg/h | at | 15o µm |
| 3oo kg/h | at | 2oo µm |

The thickness tolerances are in the region of ± 6 to ± 8%.

The attainable shrink values (way/tension) are:

from 45/49% to 35/37% and
from 2.3/2.1 g/mm$^2$ to 1.2/1.5 g/mm$^2$

With a 12o mm extruder the output will be appr. 28o kg/h.

These outputs can only be achieved because the extruder delivers a homogenized melt at lower melt temperature (at melt index $MFI_2$ = o.1 - o.3 g/1o min. 18o °C against 25o°C with a normal three stage screw), which flows evenly in the die and has narrow tolerances. By intensive and uniform cooling an intensive cooling and at the same time supporting of the big bubble is obtained so that a safe production can be guaranteed.

Paperlike film

Paperlike film out of high molecular high density polyethylene is produced on the recently developped DEMAG blown film line which consists of a extruder and dies with diameter of 1oo mm to 2oo mm.

The nip roll stand can be height adjusted, the winders for winding two single webs are driven directly by DC drives.

With the screw discussed already the high molecular HD-PE is extremely good plasticized and homogenized. The die incorporates as a special feature a spiral mandrel which is designed according to rheological principles and therefore eliminating spider marks.

The attainable film tolerances are:

at 10 µm ± 15%
at 20 µm ± 10%
at 40 µm ± 7,5 %
at 100 µm ± 5%

The output depends on resin and die size and will be between 40 and 80 kg/h.

Melt fracture can be avoided by developped know-how in material/ composition and surface of die parts.

To obtain a biaxial equally orientated fila the extruder bubble is blown up at a ratio of 4 to 6/1. Only an extremely uniform cooling can result in a calm bubble and safe lay flat operation.

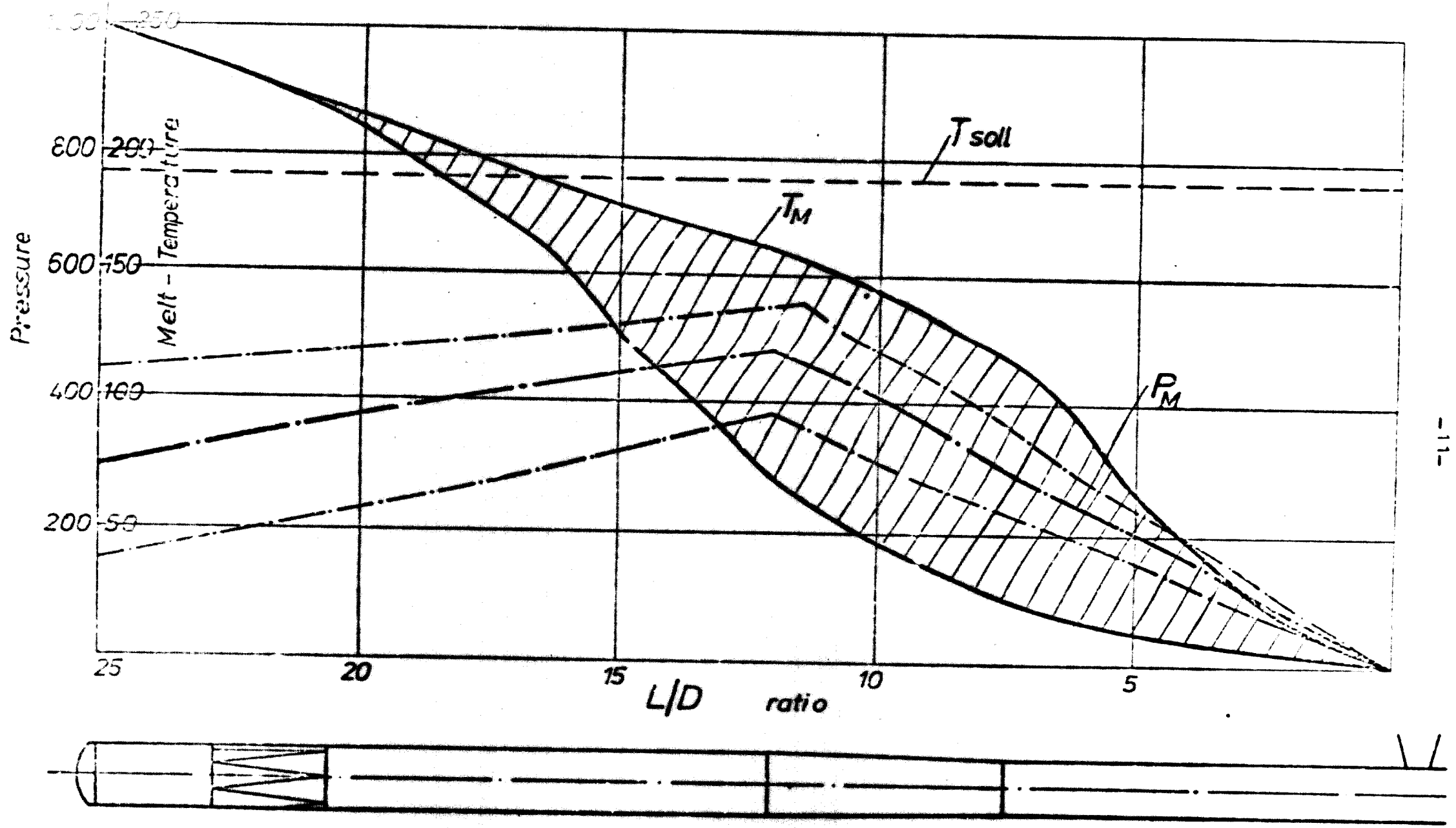
The laying flat is effected in the best possible temperature range herewith avoiding wrinkles (this is possible by means of a height adjusted nip roll stand).

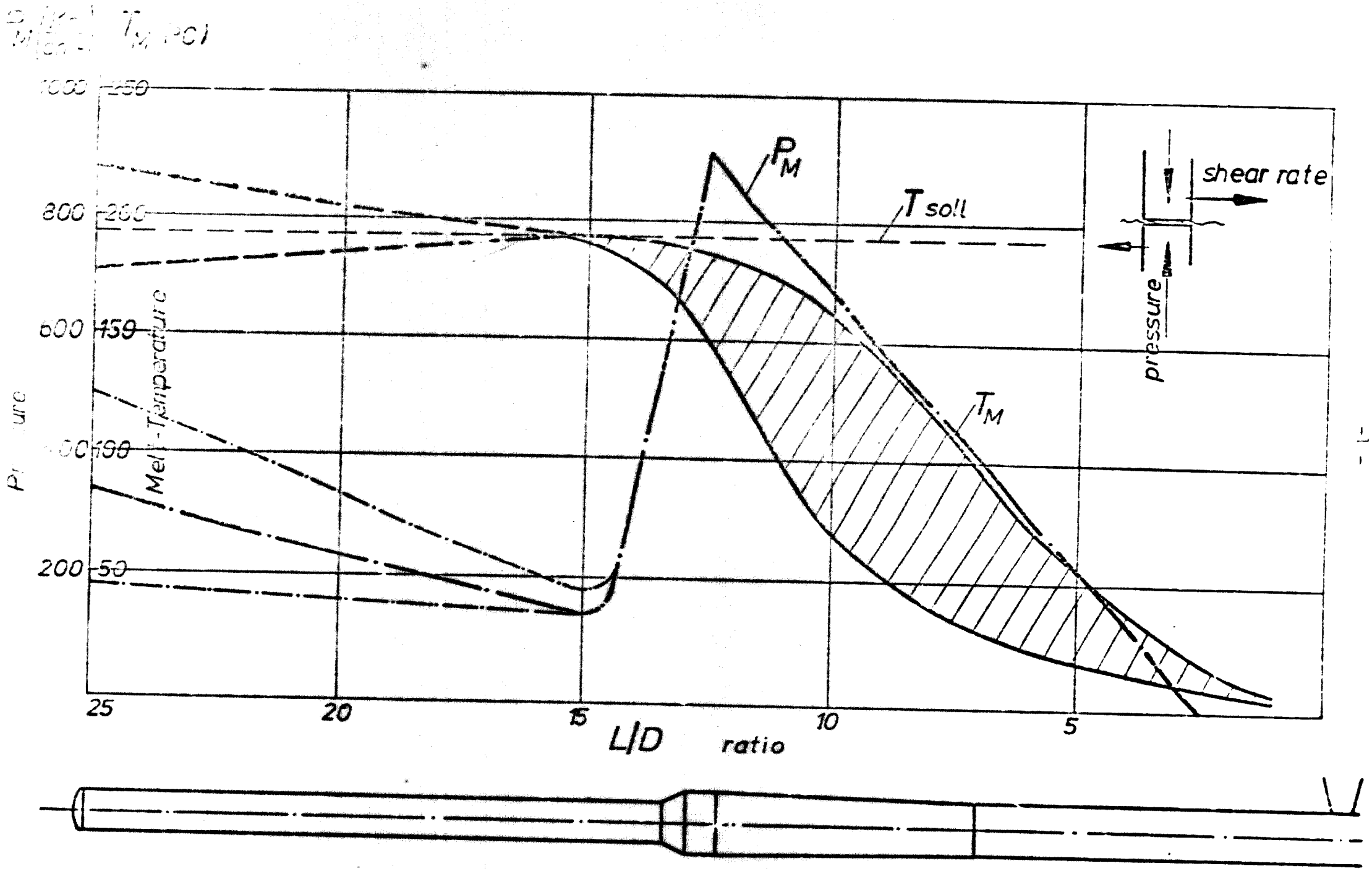
Then the lay flat film is trimmed and guided to the winder over tendency driven deflector rolls. Here the single web is wound wrinkle-free and without build-ups.
The application of this kind of film in areas where still paper is used promises a great arount of consumed polyethylene.

Just think of the substitution of

- paper wrap
- tissue paper
- bags of different sizes
- grease resistant paper and
- labels.

This shows you already, how attractive this field will be in future and which chanes in the market will arise.
Our company is ready for the future by up-to-date development and will help you with efficient lines to find the right start into this future.


Pressure
Melt - Temperature
800
600
400
200
250
200
150
100
50
T soll
$T_M$
$P_M$
25
20
15
10
5
L/D ratio


$T_M$ (°C)
1000
800
600
400
200
250
200
150
100
50
Pressure
Melt-Temperature
$P_M$
$T_{soll}$
$T_M$
shear rate
pressure
25
20
15
10
5
L/D ratio

APPENDIX

## I The Company: DEMAG Kunststofftechnik

DEMAG Kunststofftechnik is a subsidiary company of DEMAG AG in Duisburg which is one of the most important engineerung companies in Germany. DEMAG Kunststofftechnik combines three companies which are well known in the european plastics industry. It is Ankerwerk Nürnberg GmbH, Stübbe Maschinenfabrik GmbH, Kalldorf and DEMAG Extrusionstechnik, Darmstadt. In the beginning of this year the three companies joint together and built DEMAG Kunststofftechnik which now produces and sells machines for the plastics processing industry.

## II The Products of DEMAG Kunststofftechnik

The products of DEMAG Kunststofftechnik are:

1) ANKER injection moulding machines
2) STÜBBE injection moulding machines
3) DEMAG extrusionslines
4) Polyurethan plants

1) The range of ANKER injection moulding machines combines injection moulding machines for thermoplastics, thermosets and elastomers incl. models with vertical clamp units. Multicomponent machines for multicolor and sandwich-moulding.

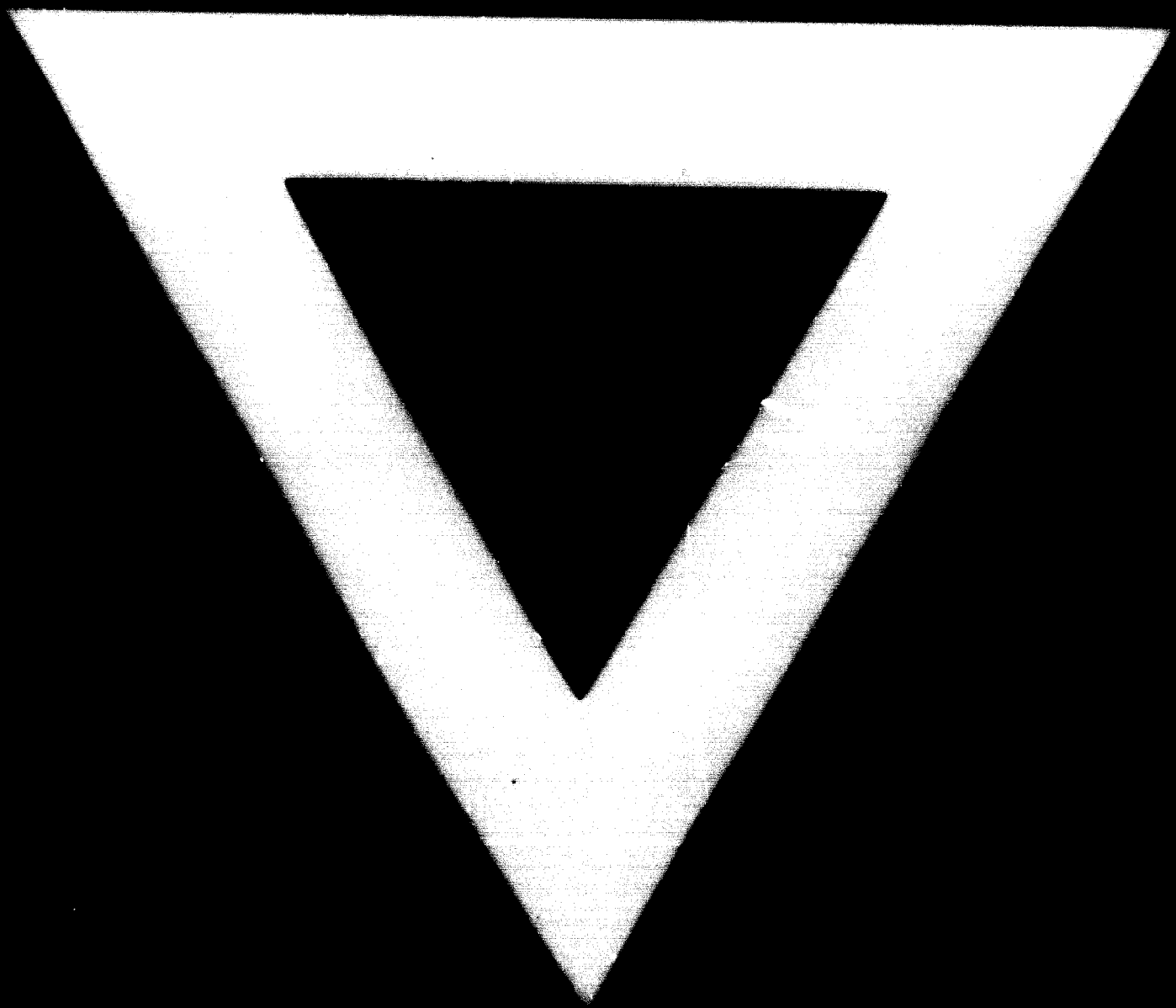
2) The STÜBBE injection moulding machines programme combines injection moulding machines with clamping forces from 3o ts to 65o ts. Beside standard injection moulding machines there are built machines for special purposes such as rotary table machines and machines with vertical clamp unit which can be equipped with a sliding table for insert moulds.

3) DEMAG Extrusionstechnik developes, manufactures and sales complete extrusionlines for the following products:
   - garbage films
   - heavy-duty bags
   - shopping bags
   - HD-PE film with paperlike features

- household films (flat film extrusion)

These plants include units for printing, welding and for the further manufacture to bags or sheets.

4) Polyurethan foaming plants for the production of rigid polyurethan components.



G . 8 . 74