Ultramid® Grades in Extrusion

The material of choice for demanding requirements in the packaging and extrusion field

BASF Plastics
key to your success

BASF
The Chemical Company

Good packaging product assortment. Ultramid® nylon provides “transparency”

Ultramid® – the clear choice

Ultramid® is BASF’s trade name for its line of polyamide (PA) products. BASF began manufacturing Ultramid® polyamides over 50 years ago. Today, BASF is one of the world’s largest producers of polyamides. Our line of nylon products includes Ultramid® B (nylon 6), Ultramid® C (nylon 6/66 copolymer) and Ultramid® A (nylon 66).

The Ultramid® nylon extrusion grades, available in a wide variety of viscosities and additive packages, are used in nearly all fields of packaging. Due to their outstanding properties, they have become indispensable to many applications.

Table 1: Melting temperatures of Ultramid® resins

Ultramid® nylon	Polyamide type	Melting temperatures (°C)	
B	PA 6	220	(428 °F)
C	PA 6/66	190-195	(374-383 °F)
A	PA 66	260	(500 °F)

Ultramid® nylon's strong crystalline cohesion is responsible for its high melting point and high thermal stability, as well as for its hardness, abrasion resistance and high gas and aroma barrier properties. The strong intermolecular bonding in the amorphous zones provide polyamides with high impact strength and elasticity and impart polyamide films with excellent thermoforming characteristics.

The semicrystalline nature of polyamides results in an excellent combination of properties and also makes them an important raw feedstock for packaging materials. For extrusion applications, Ultramid® nylon is the material of choice if those properties are required:

- oxygen barrier
- flavor and aroma barrier
- good mechanical properties
- high transparency
- thermoformability
- heat-resistance

Nomenclature

The Ultramid® nylon range consists of PA 6 grades, PA 66 grades and copolyamides, such as PA 6/66.

Ultramid® extrusion grades are designated by letters and digits which indicate chemical composition, viscosity and additives.

The letter (A, B, C) placed after the Ultramid® nylon product name identifies the type of polyamide:

PA 6 grades	Ultramid® B
PA 6/66 grades	Ultramid® C
PA 66 grades	Ultramid® A.

Viscosity class
The following numbers specify the viscosity class by Relative Viscosity in 96 %/23 °C sulphuric acid (i.e 33 for RV 3.3)

3 = easy flowing, low melt viscosity
32 = intermediate viscosity
33 = intermediate viscosity
36 = intermediate to high viscosity
40 = high viscosity
50 = very high viscosity

The melt index (MI), measured according to ISO 1133, decreases as the molecular weight rises and is a common measurement method for polyolefins. However, as polyamides are susceptible to melt-viscosity altering moisture absorbtion, this method is not commonly used.

Additives
L = lubricated
N = nucleated
XL = extra high lubricated
A = antiblocking agent
H = heat stabilized

Suffix
01 for cylindrical pellet shape
(no number = oval shape)

Example:
B40 LN (PA6, high viscosity, RV = 4,0 lubricated, nucleated)

Ultramid® nylon – more than just a high-tech product
Ultramid® nylon is engineered especially for your packaging application.

Moreover, BASF provides its customers the wide assortment of services that you expect from a leading supplier of engineering plastics, including:

- worldwide availability of Ultramid® nylon grades from manufacturing locations and sales offices throughout the world
- uniform product quality lot-to-lot through the consistent application of BASF's high quality standards which are identical all over the world
- certification in accordance with ISO 9001.

Most importantly, we offer our customers comprehensive technical support. Experienced technical service representatives specializing in extrusion processes respond quickly to your questions about materials and processing. Our laboratories are available to perform an extensive array of tests to analyze materials and help you in your product development. In addition, our plastics processing facilities give you access to film extrusion pilot lines that help us work together to optimize your manufacturing process.

Ultramid® nylon: It's obvious what's in the package, when you use Ultramid® nylon

Ultramid® nylon film properties and applications

Ultramid® nylons are especially well-suited for the packaging sector due to their high strength, outstanding thermoformability, high thermal stability, including resistance to sterilizing temperatures, and very good barrier properties towards gases, especially oxygen, flavors and aromas.

In multilayer constructions with polyethylenes (LDPE, LLDPE, EVA), high-quality flexible film may be produced for vacuum packaging of oxygen-sensitive foods such as ham, cheese, processed food and sausage. Vacuum packaging is one of Ultramid® nylon's main applications today.

Ultramid® nylon films' good thermoformability guarantees particularly well-shaped vacuum packing with good contact clarity and outstanding appearance as well as good cost efficiency.

Ultramid® nylon is well suited for the production of biaxially oriented (BOPA) film which provides high stiffness, puncture resistance, barrier and transparency.

Nylon sausage casing is characterized by a high oxygen barrier as well as good printing properties and gage consistency.

Due to their special property profiles Ultramid® nylon based mono- or multilayer constructions may also be used in industrial applications such as release films for sheet molding compound (SMC), prepregs or roof underfelt sheeting.

The selection of the suitable Ultramid® nylon grade is determined by film

Table 2: Standard properties of Ultramid® nylon films (film thicknesses 20 - 100 µm)

			B36 LN cast film 25 µm	C33 LN01 blown film 25 µm	B33 L BOPA film 15 µm
Melting temperature	DSC	°C	219	196	219
Density		g/cm³	1.128	1.12	1.129
Tensile modulus	MD	MPa	1.600	1.400	
Tensile modulus	TD	MPa			
Stress at break	MD	MPa	85	80	260
Stress at break	TD	MPa	80	80	250
Elongation at break	MD	%	380	450	95
Elongation at break	TD	%	400	450	100
Oxygen Transmission Rate	23 °C/50 % rh	cm³/m²d bar	18	21	25
CO_2 Transmission rate	23 °C/0 % rh	cm³/m²d bar	160	180	200
Water Vapor Transmission Rate	23 °C/85 % rh	g/m²d	40	50	80

property requirement, the processing method to be applied and, in the case of coextruded films, on the viscosities of the other polymers involved. Ultramid® B36 LN is typically combined with PE-LD or PE-LLD of 3.0-4.0 g/10min melt index, whereas Ultramid® B40 L or B40 LN is coextruded in combination with PE of 0.8-1.0g/10 min melt index.

Typical values for the properties of film made from Ultramid® nylon are provided in table 2.

Fundamentals, screw geometry and processing temperatures

Barrier or three-section screws having an length of 24 to 28 D and a constant pitch of 1 D are generally considered to be suited for processing of Ultramid® nylon (cf. Table 3).

Table 3: Guide values for screw geometry (extrusion)

Length of sections		
Total length	L	20-28 D
Feed section	L_E	8-9 D
Transition section	$L_Ü$	4-6 D
Metering section	L_A	8-13 D[1)]

1) with shear section, length 1-2 D

The compression ratio should be between 3:1 and 3.5:1 (Fig. 2). The flight depth depends on the screw diameter D and on the melt viscosity.

Barrier screws are used especially for constant output. More gentle fusion and transport at constant speed are possible in a narrow output range.

The screw clearance (radial clearance between the screw and barrel) should be 0.1 to 0.2 mm to minimize leakage.

For screws having diameters above 90 - 150 mm, shear sections located at 22 - 25 D are recommended.

Screen packs having a mesh count of 400 to 3,600/cm² are usually recommended for the required backpressure and good melt homogeneity.

Processing temperature of Ultramid® A grades is typically in the range of 270 to 290 °C, 240 to 270 °C for Ultramid® B and 210 to 260 °C for Ultramid® C. Suitably powered heater bands and drives (e.g. 10 kW heater power and 60 kW drive power for an extruder having a screw diameter of 60 mm) with precise controllers for screw barrels, adapters and dies are required. Lubricants and nucleation agents have no significant effect on the resultant melt temperature.

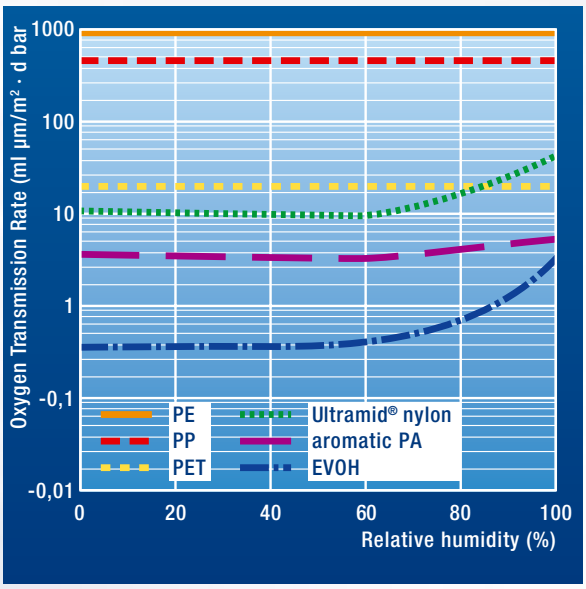


Fig. 1: Barrier properties of polyamide films

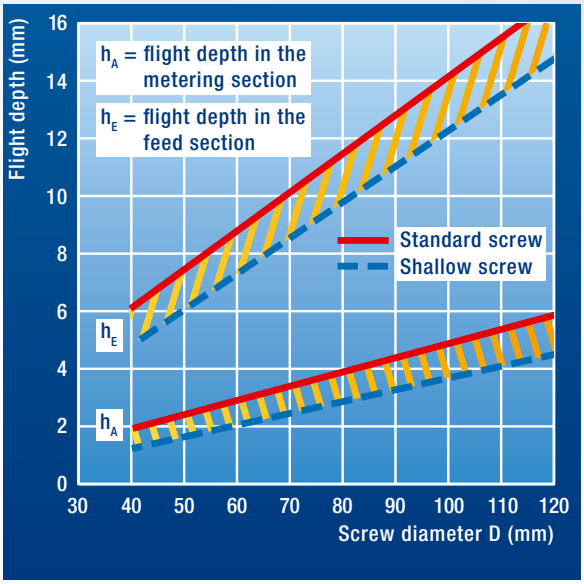


Fig. 2: Screw flight depths for three-section screws in extrusion machines

Processing techniques for manufacturing film
Flat film (cast film) and tubular film (blown film), which are used primarily for packaging food, may be extruded from Ultramid® B, C and A grades of medium to high viscosity, usually in the form of a multilayer film containing polyethylene.

Blown film
Multilayer blown film from Ultramid® B or C resins, polyolefins and suitable adhesive materials may be coextruded utilizing commercially available equipment as used for manufacturing of polyethylene blown film. Especially in the case of a non-symmetric layer structure (e.g. PE/tie/PA/Ultramid® C), copolyamides are preferred to produce highly thermoformable and flexible multilayer film with high transparency and low curl. The curl may be further reduced by humidification of the film by a hot-water bath. Monolayer blown film may also be produced using Ultramid® B grades or Ultramid® A44.

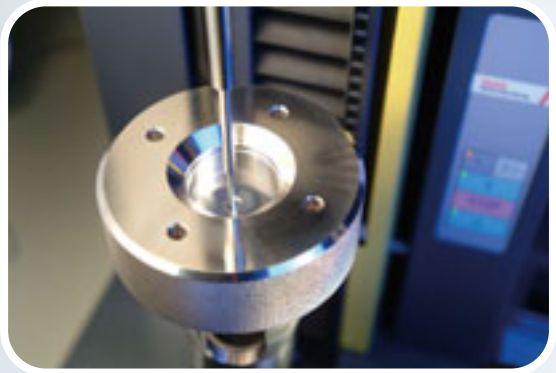
The die gap should be approx. 1.0 - 1.2 mm (multilayer film) or 0.5 mm (monolayer film). The extruded film is cooled with air, a take-off speed of more than 30 m/min (100 ft/min) is achievable. Typical blow-up ratio (die diameter/tube diameter) lies in the range of 1:3.0.

The tube should be collapsed as close as possible to the solidification zone (frost line) so that the film is laid flat while still warm and flexible.

Downward extrusion into a cold-water (6-20°C) cooling bath with outside or in/outside water cooling is also possible. In this case, line speed up to 150 m/min is feasible. Typical thickness of tubular film made from Ultramid® nylons is 20 to 180 µm. Table 4 contains an example of tubular film extrusion processing parameters.

Cast film
Cast film (flat film) is mainly extruded from Ultramid® B nylon grades. It is normally drawn to a thickness of 20 to 200 µm (1 to 8 mils) from T- or coathanger dies of up to 2,000 mm (6.5 ft) wide. The die gap should be approx. 10 - 12 mm (multilayer film), line speed of 120 m/min is possible. For efficient production, extruders having screws of 60 - 150 mm (2.5 - 6.0 in.) in diameter (25 to 28 D in length) are recommended.

Film properties and quality (i. e. tolerances, dimensional stability, machinability and transparency as well as thermoformability), are highly determined by the processing conditions. The chill - roll temperature should be set to 20 - 40°C for thermoforming film of high transparency or 80 - 120°C for film of high dimensioned stability.



Oriented PA film
Biaxially oriented (BOPA) film may be manufactured from Ultramid® B resins by rapid cooling of film and subsequent simultaneous or sequential stretching in machine and transverse direction. Cast (tenter frame) or blown (double bubble) technology may be applied. Stretch ratio will usually be between 2.7 and 3.2 (both machine and transverse direction).

Artificial sausage casing may be manufactured from Ultramid® nylon as both conventional as well as biaxially oriented shrinkable blown film.

PA 66 (Ultramid® A44) is primarily used for unoriented film, while PA 6 (Ultramid® B40 L) is highly suited for oriented, shrinkable film. Biaxially oriented casing is frequently coextruded with polyolefins in order to achieve the required water vapor barrier in a multilayer film application.

For processing examples, refer to table 4.

Vacuum packaging

Sausage casing

Blown film

Quality control

Cast film

Table 4: Examples of film extrusion processing parameters for Ultramid® nylon

Product	Unit	B36 LN	C33 01	B32 B33 L
Production process		cast film	blown film	BOPA film
Film type		multilayer film PE/PA	multilayer film PE/PA	PA/PA/PA film
Film width	mm	1800	900	4200
Film thickness (total/PA)	µm	120/30	90/15	15
Screw diameter	mm	90	60	175
L/D		28	28	28
Screw sections	L/D	9/5/14	9/5/14	9/5/14
Flight depth lf/lm[1)]	mm	14/14.5	8/2.5	18/6
Heater temperatures				
Cylinder	°C	265	250	265
Adapter	°C	260	245	260
Die	°C	260	245	260
Melt temperature	°C	265	250	265
Melt pressure	bar	120	150	150
Screw speed	RPM	50	70	65
Output (total/PA)	kg/h	500/180	250/50	750
Die		T-die	circular die	T-die
Die width[2)]	mm	2000	300	4500
Die gap	mm	1.2	1.2	2
Blow-up ratio			2.2	
Cooling		chill-roll 30 °C air knive, vacuum box	air 12 °C IBC	chill-roll 12 °C electrostatic pinning
Stretching (MDO/TDO)				3.2/3.0 sequential or simultaneous
Winding speed	m/min	70	35	150

1) Flight depth in the feeding zone (lf) and the metering zone (lm)
2) w = die width, d = die diameter

Processing of monofilaments

The following Ultramid® grades are used for the production of stretched monofilaments such as industrial wires, fishing lines, tennis racket strings, weed trimmer lines, bristles and dolls' hair.

Ultramid® B27 E, a polyamide 6 of low viscosity, is optimally suited for blending with other Ultramid® grades for the production of monofilaments of diameters up to 0.7 mm. Applications include fishing lines, monofilaments for fishing nets, bristles and fine monofilaments for industrial fabrics.

Ultramid® B33 L, a polyamide 6 of intermediate viscosity, is the general-purpose grade for the production of fine and medium gage monofilaments for the fisheries sector and industrial applications such as filters, paper screening fabric and bristles. These monofilaments are stronger and more flexible than B27 E monofilaments.

Ultramid® B40 L is particularly suitable for manufacturing stretched monofilaments having medium and relatively thick diameters of up to 5 mm and for bristles.

Table 5: Monofilament processing

Ultramid®	Unit	B33 L	C40 XL	A34
Product		Monofilaments, bristles (general)	Monofilaments for fishing lines	Monofilaments, bristles (general)
Production technique		Extrusion, water quenched, stretched between rolls		
Dimensions[2]	mm	d = 0.30	0.30	0.51
Screw diameter D	mm	45	45	45
L/D		25	25	25
Flight depth h_E/h_A	mm	8.0/2.5	8.0/2.5	7.0/2.2
Screw sections[1]		6/7/12	6/7/12	9/4/12
Heater temperatures barrel adapter die	°C	 260/290/285/275 275 275	 270/280/275/270 265 265	 275/290/280/280 280 280
Melt tempereature	°C	275	265	280
Melt pressure	bar	120	32	42
Screw speed	min^{-1}	55	32	42
Type of die Dimensions	mm	Die x 30 1.40 2.0 d	Die x 20 3.0 d	Die x 10
Additional cooling		Waterbath 10-20 °C	Waterbath 35-40 °C	
Take-off/Stretching		7-roll set 7-roll/3-roll set Stretch ratio 1:4.0 Stretch temperature 210 °C	7-roll set 7-roll/3-roll set 1:5,7; 2-step 130 °C/230 °C	7-roll set 7-roll/3-roll set 1:4.5 200 °C
Take-off speed	m/min	25.0	20.0	20.0
Weight per unit length	g/m	0.0806 (stretched)	0.0806 (stretched)	0.232 (stretched)
Output	kg/h	16.8	10.3	10.8

1) Length of feed/compression/metering sections as multiple of screw diameter D.

2) s = thickness, d = diameter, b = width; for dimensions of roads and tubes see DIN 16980, 16983, 16982

Ultramid® A27 E and A34 are used for relatively stiff bristles and monofilaments. Ultramid® A34 is also used in blends with Ultramid® B33 L for making weed trimmer lines.

Ultramid® C33 and C40 XL are suitable for the manufacture of high-grade sports angling lines, hook monofilaments, long lines of up to 2.0 mm and tennis racket strings.

Extrusion lines for monofilaments and bristles mainly consist of a single-screw extruder, spinning pump (precision gear pump), spinneret (multiple die), waterbath for cooling, roll stretching units, hot-water stretching bath and/or hot-air stretching channels. The ratio of the peripheral speeds of the roll stretching units, usually seven-roll sets, corresponds to the stretching ratio which is preferably in the range of 1:4 to 1:6. Depending on the type of monofilament stretching, is done in one or more steps. The subsequent shrinkage or relaxation step comprises of a further hot-air channel and a set of three rolls which run at a lower peripheral speed depending on the required percentage shrinkage (e.g. 5 to 10 %).

Special methods involving particular know-how are occasionally used for the production of monofilaments or wires having large diameters (> 3 mm).

Table 5 provides examples of monofilament extrusion.

Other extrusion applications

Ultramid® provides high resistance to lubricants, engine fluids, hydraulic and radiator oils, aliphatic and aromatic hydrocarbons and many other solvents – even at elevated temperatures. Therefore **tubes** for central lubrication systems, fuel and oil pipes, pneumatic and hydraulic control lines and Bowden cables are produced utilizing high viscosity grades Ultramid® A44, B40 L, B50 L. **Corrugated tubes** for the automotive industry are made of Ultramid® B40 L or B50 L.

As the global leader in nylon for building **wire jacketing**, BASF Corporation knows what it takes to succeed in this industry. By replacing a large portion of the PVC insulation with a thin layer of durable, abuse-resistant Ultramid® nylon, performance increases while costs decrease. Our special grade of nylon not only provides a higher level of abrasion resistance, end-use temperature rating, and hydrocarbon resistance, but also reduces PVC consumption, overall cost and weight. Of course, as you would expect of a leader, we have the know-how to successfully process this product as well. Simply contact your BASF representative.

Post-processing of Ultramid®

Surface coating
Due to its outstanding resistance to most solvents, Ultramid® may be coated in one or several layers of various paints which adhere well and have no adverse effects on mechanical properties. One- or two-component paints with binders matched to the substrate are suitable.

Metallizing
Articles made from the various Ultramid® grades may be metallized in high vacuum following priming or by electroplating after suitable preliminary treatment. Excellent surface quality can be achieved.

Dyeing
Ultramid® may be colored in the dyebath using water dispersible, or water soluble dyes.

Conditioning
Articles manufactured of Ultramid® resins will achieve their optimum toughness and final dimensions only after moisture absorption. Conditioning by exposing products to warm, humid air or steam, or passing through hot water, will ensure rapid humidity absorption to a level of 2.5-4% the equilibrium content in contact with air at average relative humidity. (cf. Fig. 3)

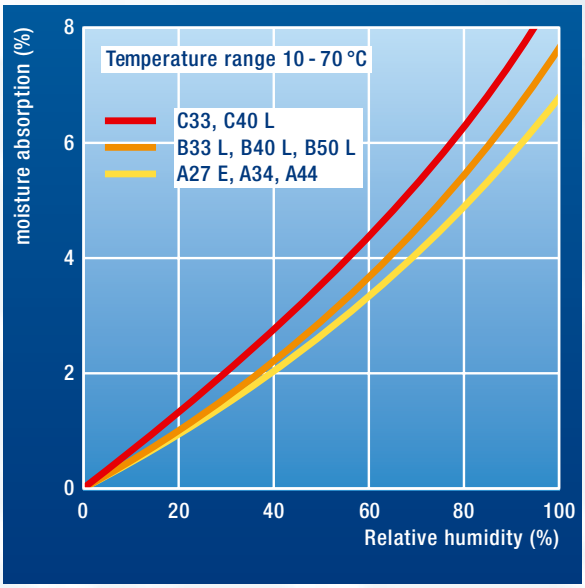


Fig. 3: Equilibrium moisture content of Ultramid® as a function of relative humidity in the temperature range 10-70 °C

Safety precautions during processing

Ultramid® resins will decompose, as all thermoplastic polymers, when exposed to excessive heat, e.g. when setting too high processing temperatures or when cleaning equipment by burning off. Besides Caprolactam smoke (in case of Ultramid® B and C), gaseous decomposition products, mainly ammonia and carbon monoxide may be formed, especially when the resin is heated to above 310°C. At temperatures above 350 °C, small quantities of pungent smelling vapors of aldehydes, amines and other nitrogenous decomposition products may also formed.

Generally, measures should be taken to ensure ventilation and venting of the work area, preferably by means of an extraction hood over extruder cylinder and die.

Food legislation

Certificates regarding the status of Ultramid Extrusion grades with respect to agency compliance can be obtained by contacting BASF.

Ultramid® nylon extrusion grades (Ultramid® B, C) fulfil the requirements of the European Directive 2002/72/EC dated 6th August 2002 related to “plastic materials and articles to come into contact with foodstuffs” and its amendments and the requirements of the Bedarfsgegenständeverordnung (German ordinance) in the revised version of 23.12.1997 (Monomers an other starting substances) including the 9th amendment of the ordinance of 07.04.2003 and the BfR (former BgVV/BGA) – Recommendation X. “Polyamid”, dated 01.06.98.

The following restrictions for Ultramid® B grades have to be ensured:

Caprolactam:
SML(T) = 15 mg/kg, together with its sodium salt expressed as caprolactam.

The following restrictions for Ultramid® C grades have to be ensured:

Caprolactam:
SML(T) = 15 mg/kg, together with its sodium salt expressed as caprolactam

Hexamethylenediamine:
SML = 2,4 mg/kg

The meaning of the used abbreviations are:

SML(T) = specific migration limit in food or in food simulant expressed as total of moiety of substance(s) indicated
SML = specific migration limit in food or in food simulant

Ultramid® B extrusion grades comply with the FDA Regulation 21 CFR 177.1500, “Nylon resins” Section (b) 6.1. Ultramid® C extrusion grades comply with the FDA Regulation 21 CFR 177.1500 “Nylon resins”, Section (b) 4.2 and should be used only for laminates complying with 21 CFR 177.1395.

Supply form and storage

Ultramid® is supplied predried and ready for processing in a variety of moisture proof containers, such as boxes, big bags (Asia) and bulk containers.

To ensure that the perfectly dry material delivered cannot absorb moisture from the air, the containers must be stored in dry rooms and always carefully sealed again after portions of material have been withdrawn. Ultramid® can be kept indefinitely in the undamaged bags. Containers stored in cold rooms should be allowed to equilibrate to normal temperature so that no condensation on the pellets may occur.

Note

The data contained in this publication are based on our current knowledge and experience. In view of the many factors that may affect processing and application of our product, these data do not relieve processors from carrying out their own investigations and tests; neither do these data imply any guarantee of certain properties, nor the suitability of the product for a specific purpose. Any descriptions, drawings, photographs, data, proportions, weights etc. given herein may change without prior information and do not constitute the agreed contractual quality of the product. It is the responsibility of the recipient of our products to ensure that any prosprietary rights and existing laws and legislation are observed. (August 2004)

Please consult your local Representative regarding product selection and availability in your area.

Do you have technical questions about Ultramid®?

We will be happy to assist you at our Extrusion Infopoint:

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