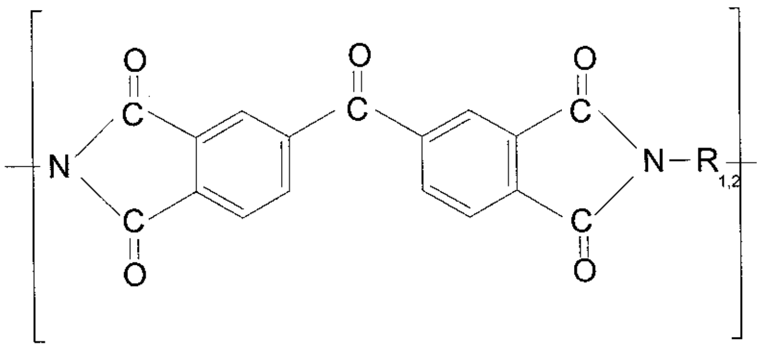
P84® Polyimide

POLYIMIDE-MOULDING POWDER



HP Polymer GmbH
A-4860 Lenzing - Austria

03/1997

P84 - Polyimide Moulding Powder

Content: 100% Polyimide Powder and Blends with Fillers
Color: Neat resin - yellow
Bulk density: Depending on particle size 150 to 350 g/litre

Mechanical properties:

	UNIT	**100% P84**	**100 % HT**
Density	g/cm^3	1,34	1,35
Hardnes SHORE D:		88	89
Tensile strength:	$N/mm^2/psi$	140/20300	
Elongation at break:	%	9	
Tensile modulus:	$N/mm^2/kpsi$	4000/580	
Flexural strength:	$N/mm^2/psi$	205/29750	175/25300
Elongation	%	7	5
Compressive strength:	$N/mm^2/psi$		
10% deformation		450/65000	540/78300
IZOD notched:	J/m	37	60
Deformation under load			
14 N/mm^2(2000 psi)/24 hrs	%	0,1	
Linear coeff. of			
thermal expansion:	10-6.1/K	50	

Thermal properties:

Glass transistion temp. Tg	°C	330	365
Heat deflection temp. HDT			
ISO R75/ASTM D648 - 1,85 N/mm^2	°C	317	368
LOI (Limiting oxygen index)	% O2	>44	

Others:

Water absorption ASTM D570:			
	%	0,62	
	%	0,92	
Equilibrium 50% RH	%	1,7	

Processing:

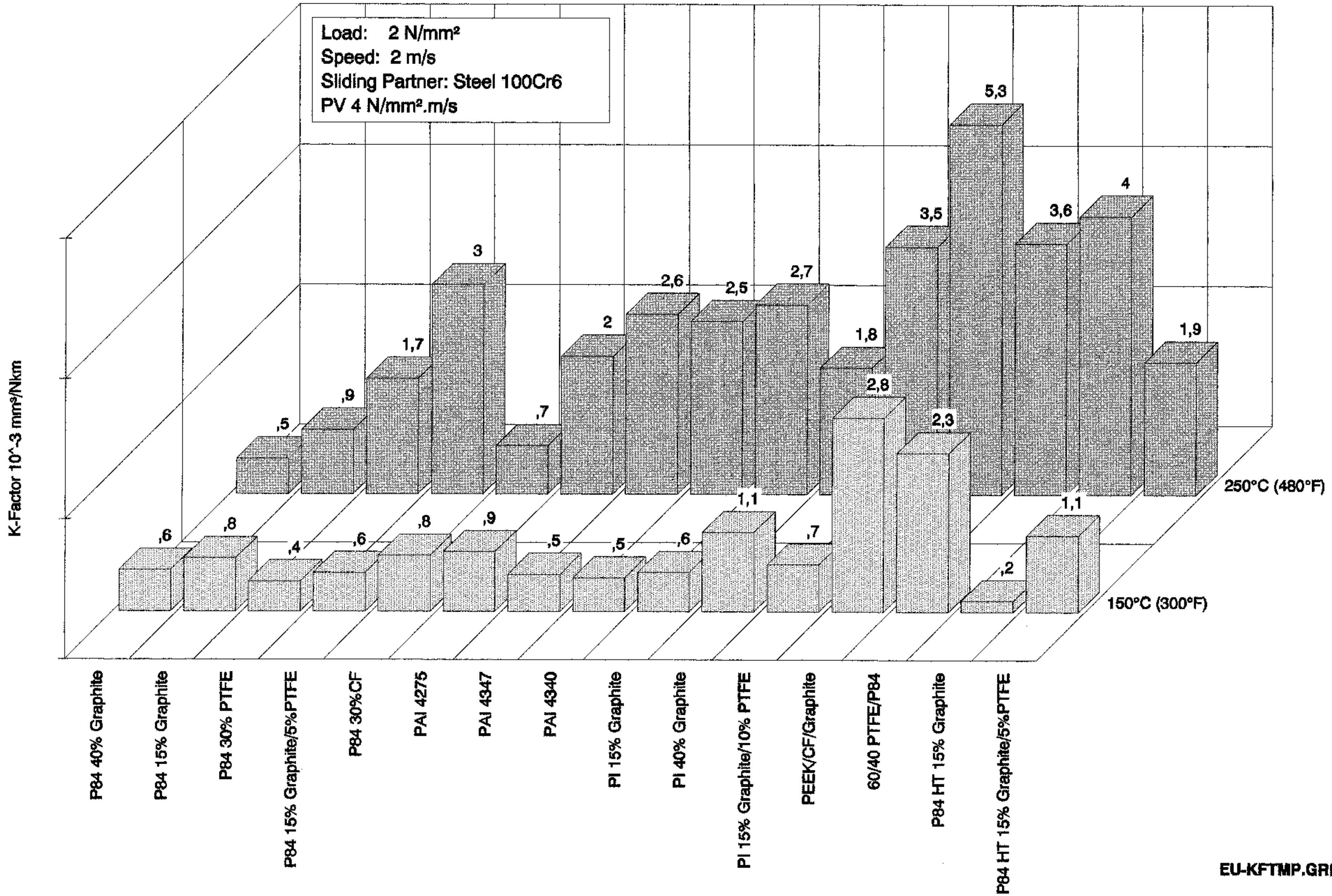
Hot Compression Moulding/Hot Coining

Temperature	°C/°F	340/645	365/690
Pressure	$kg/cm^2/psi$	350/5100	350/5100

Properties	Test Method	Units	100% P84	P84 15G	P84 15G/5P	P84 40G	P84 30 PTFE	P84 20 CF	100% P84 HT	P84 HT 15G
Density	ASTM D792	g/cm³	1,34	1,41	1,48	1,56	1,51	1,4	1,35	1,42
Water absorption	ASTM D570									
- after 24h, 23°C		%	0,62	0,65	0,53	0,87	0,49	0,98	1,86	1,55
- after 48h,50°C		%	0,92	1,44	1,14	1,73	1,2	1,47	3,31	2,61
Thermal conductivity at 40°C		W/m.K	0,22	0,53	0,53					
Coefficient of linear thermal	ASTM D696	1/K.10E-6	50	38	42	31	54	11	49	32
expansion (23-300°C)										
Max. service temperature in air		°C	280	280	280	280	270	280	300	300
short period peaks		°C	330	330	330	330	330	330	350	350
HDT index (1,85 N/mm²)	ASTM D638 M	°C	317	>315	>315	>315	>315	>315	368	>370
Flamability UL 94 (1,5 mm)			V-0							
Dielectric Str. @ 0,5/1,0/2,0 mm	ASTM D 149	kV/mm	45 / 30 / 20							
Tensile strength	ASTM D638 M									
- at 23°C		N/mm²	140	90	89	65	80	93	116	88
- at 250°C		N/mm²	50	30	28	33	48	41	62	45
Elongation at break	ASTM D638 M									
- at 23°C		%	9	3,5	3,5	2,2	4	7,5	9	8,2
- at 250°C		%	7,5	3,7	3,2	3	5,7	2,6	7,1	3,5
Flexural strength	ASTM D790									
- at 23°C		N/mm²	205	134	131	100	110	180	174	127
- at 250°C		N/mm²	78	48	60	43	30	60	116	85
Flexural modulus	ASTM D790									
- at 23°C		N/mm²	4000	4000	3000	4000		7100	4000	4200
Compressive strength	ASTM D695		700	400	185			360	510	290
- stress at 10% strain		N/mm²	240	220	190	130*	250			
- 0.1% offset yield stress		N/mm²	177	147	145	110	130			
IZOD impact strength notched	ASTM D256A	J/m	37	26	25	18	31	33	50	
Rockwell hardness at 23°C	ASTM D785	M-scale	120	115	110	111	93	123	125	116
Wear rate PV 4 N/mm².m/s	DIN 31680	μm/s	9,08x10E-3	1,8x10E-3	2x10E-3	1,2x10E-3	1,8x10E-3	3,6x10E-3		1,44x10E-3
Dynamic coeff.of friction	DIN 31680									
- PV 2 N/mm².m/s				0,29	0,28	0,35	0,35	0,38		0,32
- PV 4 N/mm².m/s				0,38	0,34	0,3	0,35	0,35		0,28
Static coeff.of friction	DIN 31680									
- PV 4N/mm².m/s				0,28	0,18	0,28	0,35	0,5		0,32

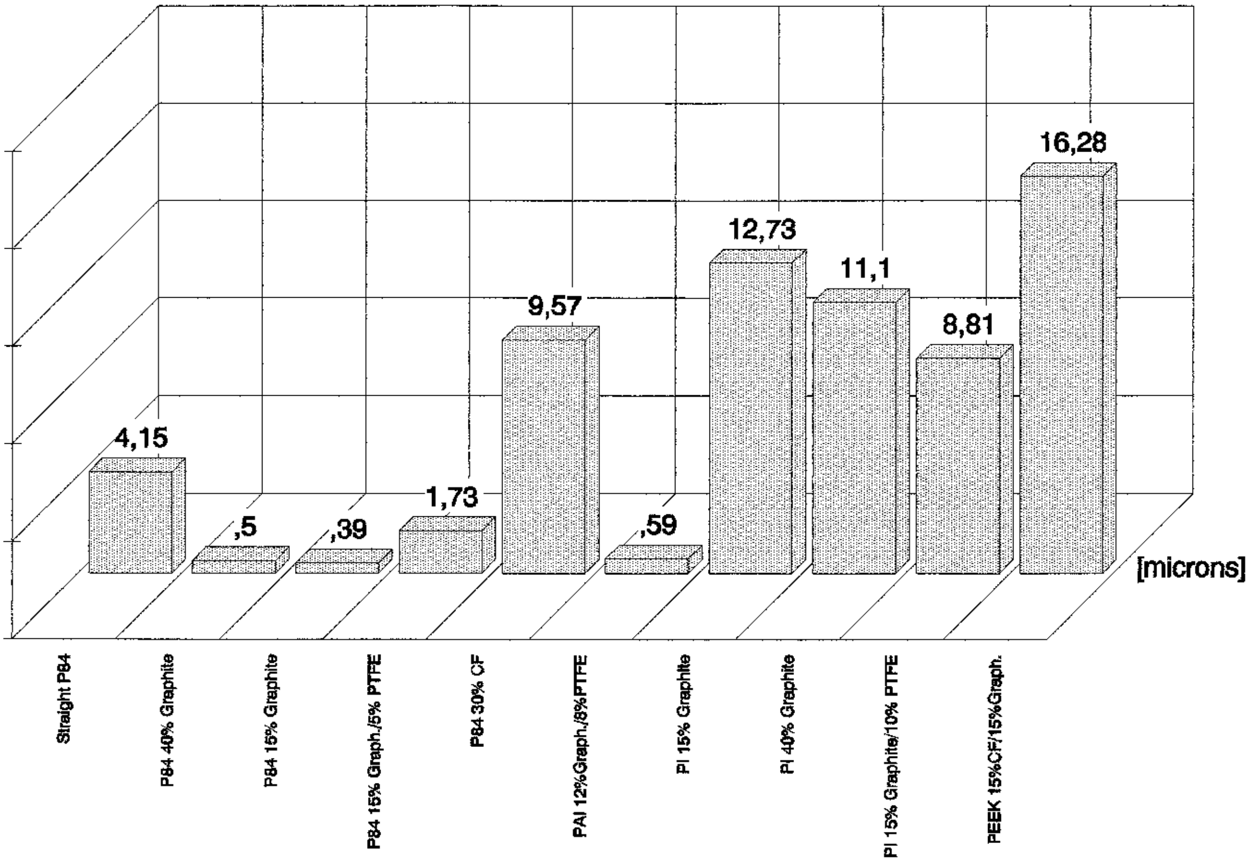
* at 5% deformation (break)

K-Factors at Elevated Temperatures and US-PV 100.000

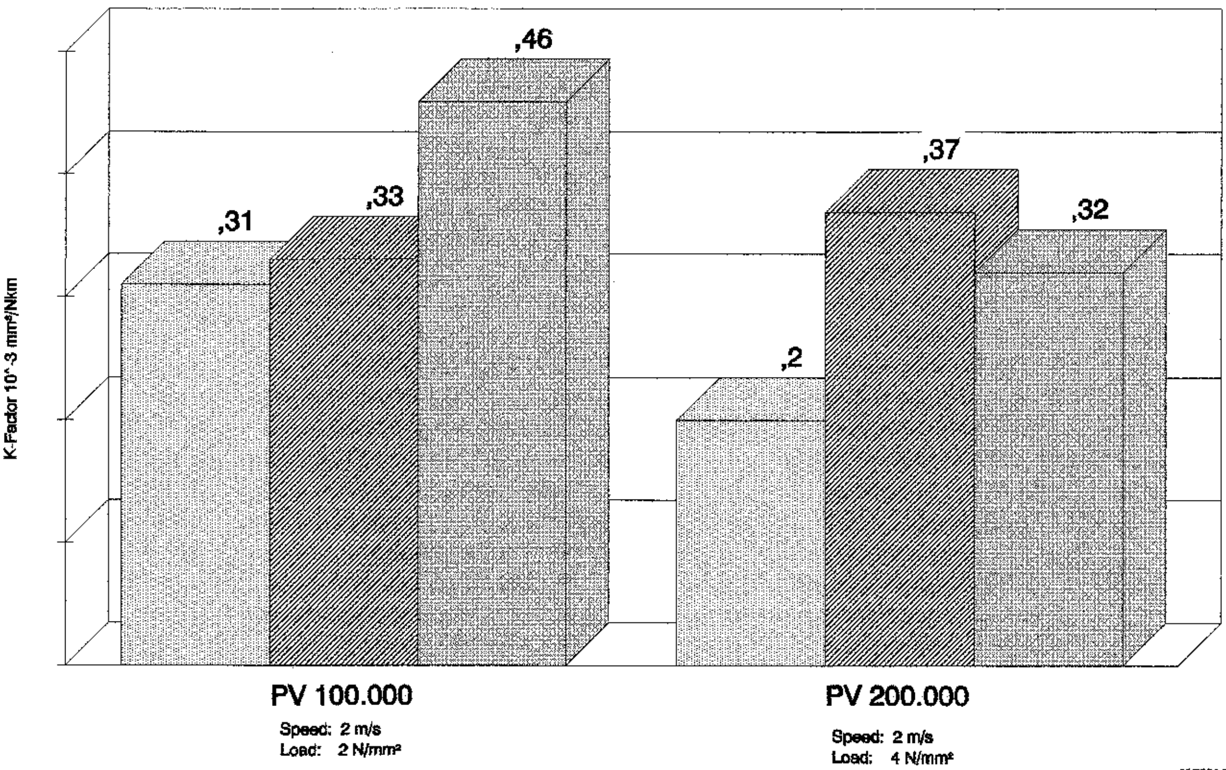


EU-KFTMP.GRF

Abrasion of Sliding Counterpart over 16 hrs against Steel 100 Cr6 (Bearing Grade)

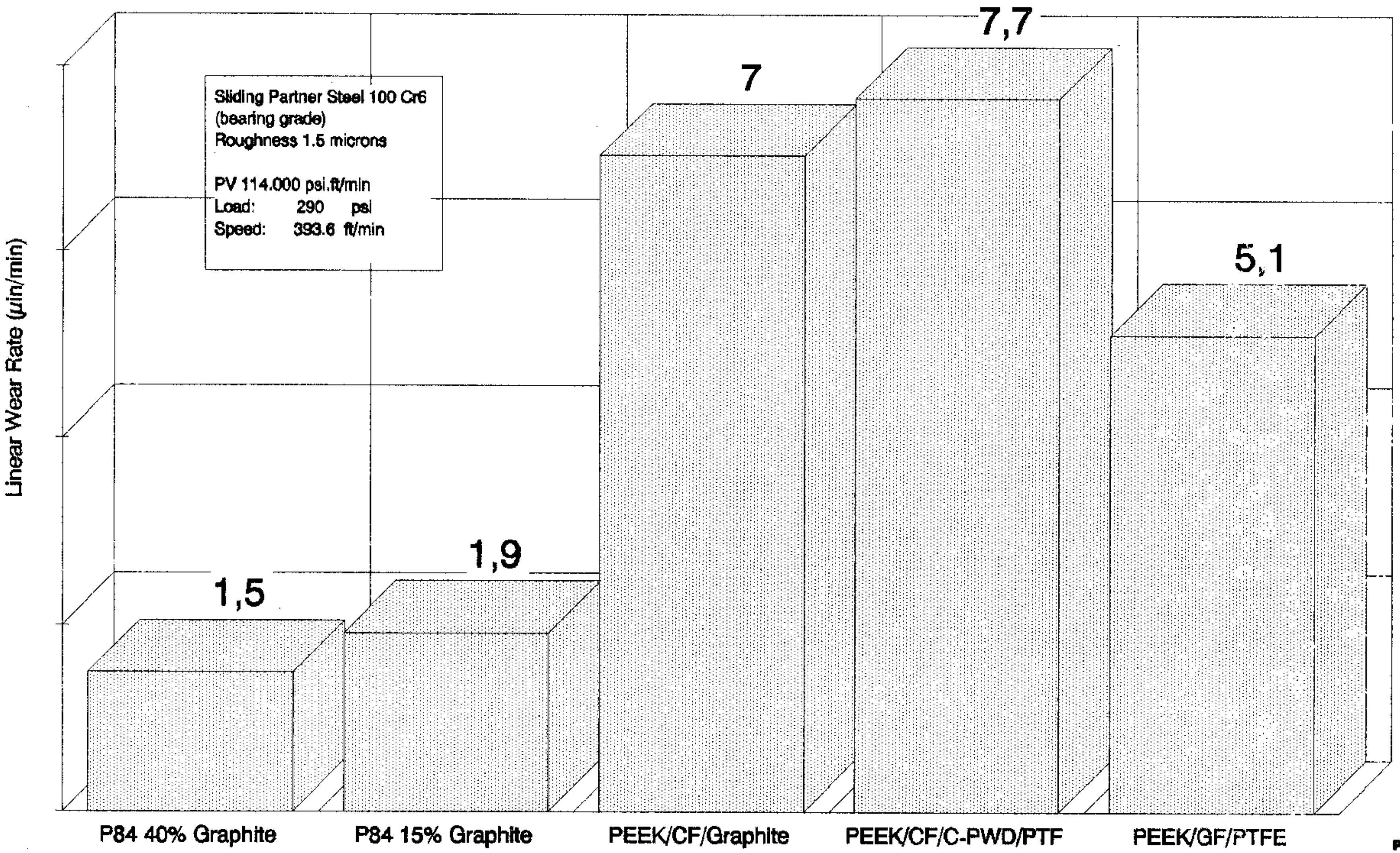


P84 Polyimide Formulations for Tribological Applications



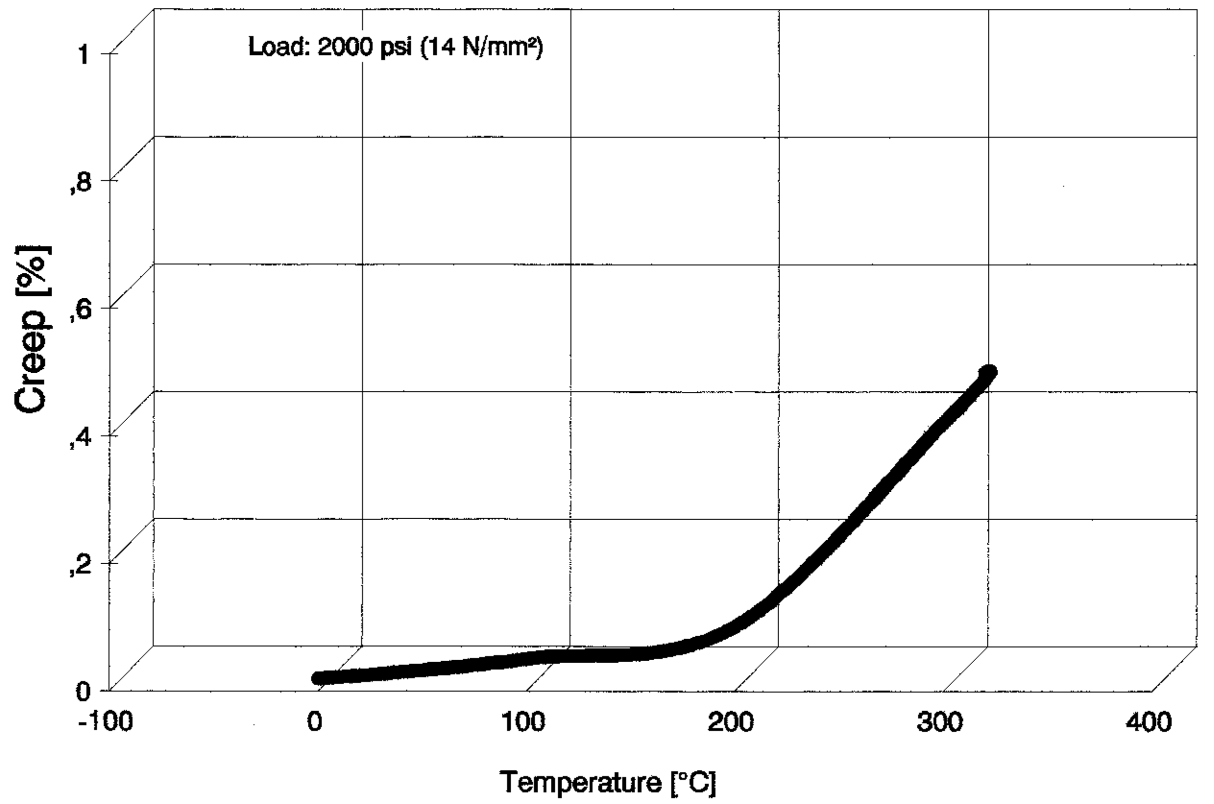
HCMABRAS.GRF

Linear Wear at 150°C/302°F and US-PV 100.000

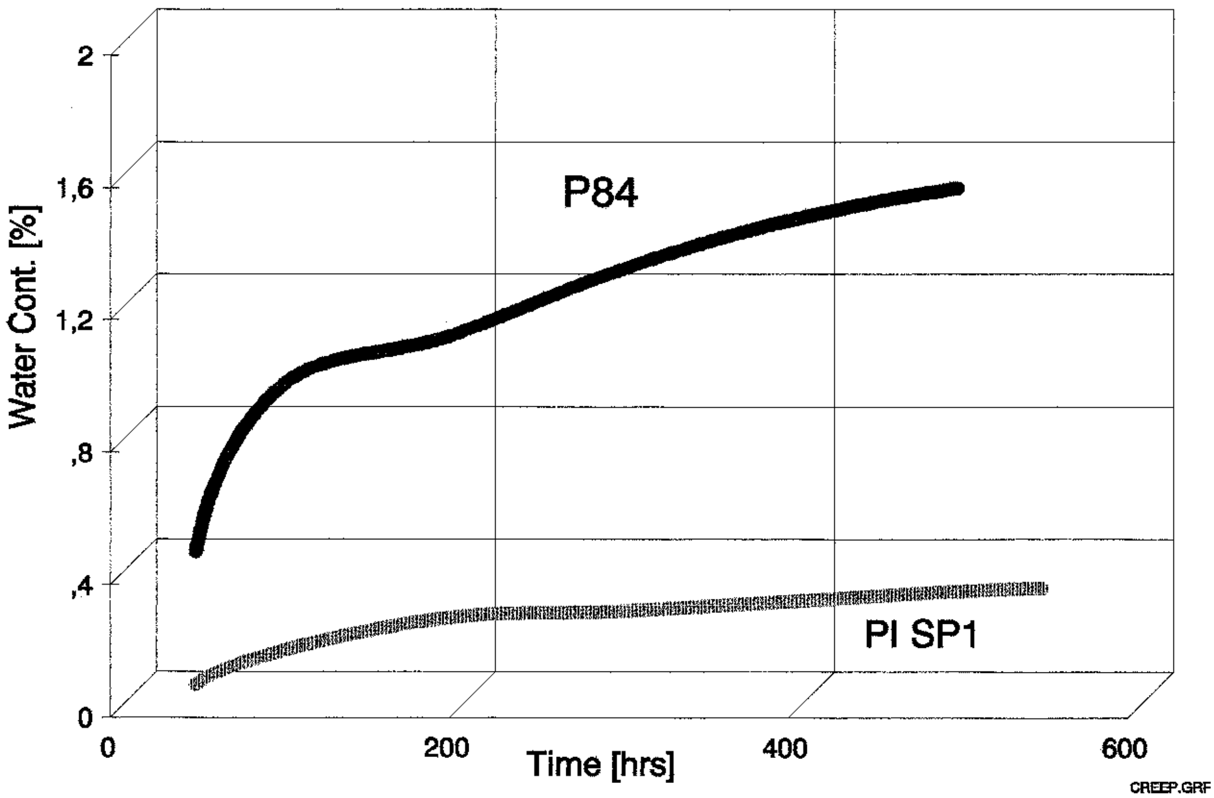


PEEKP84.GRF

Creep under Load of Straight P84

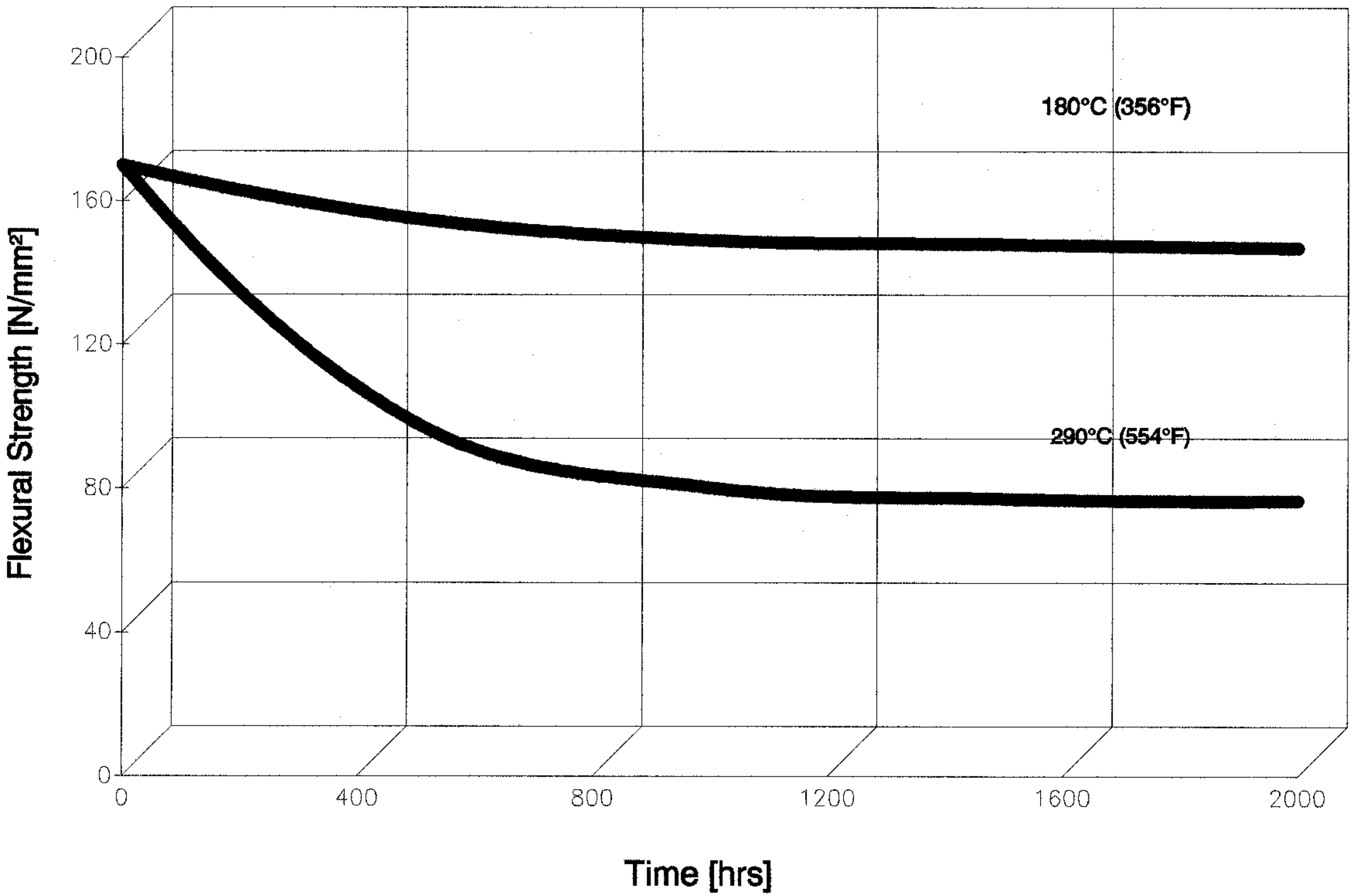


Water Absorption of PI Shapes at 20°C (68°F) and 65% Rel. Humidity



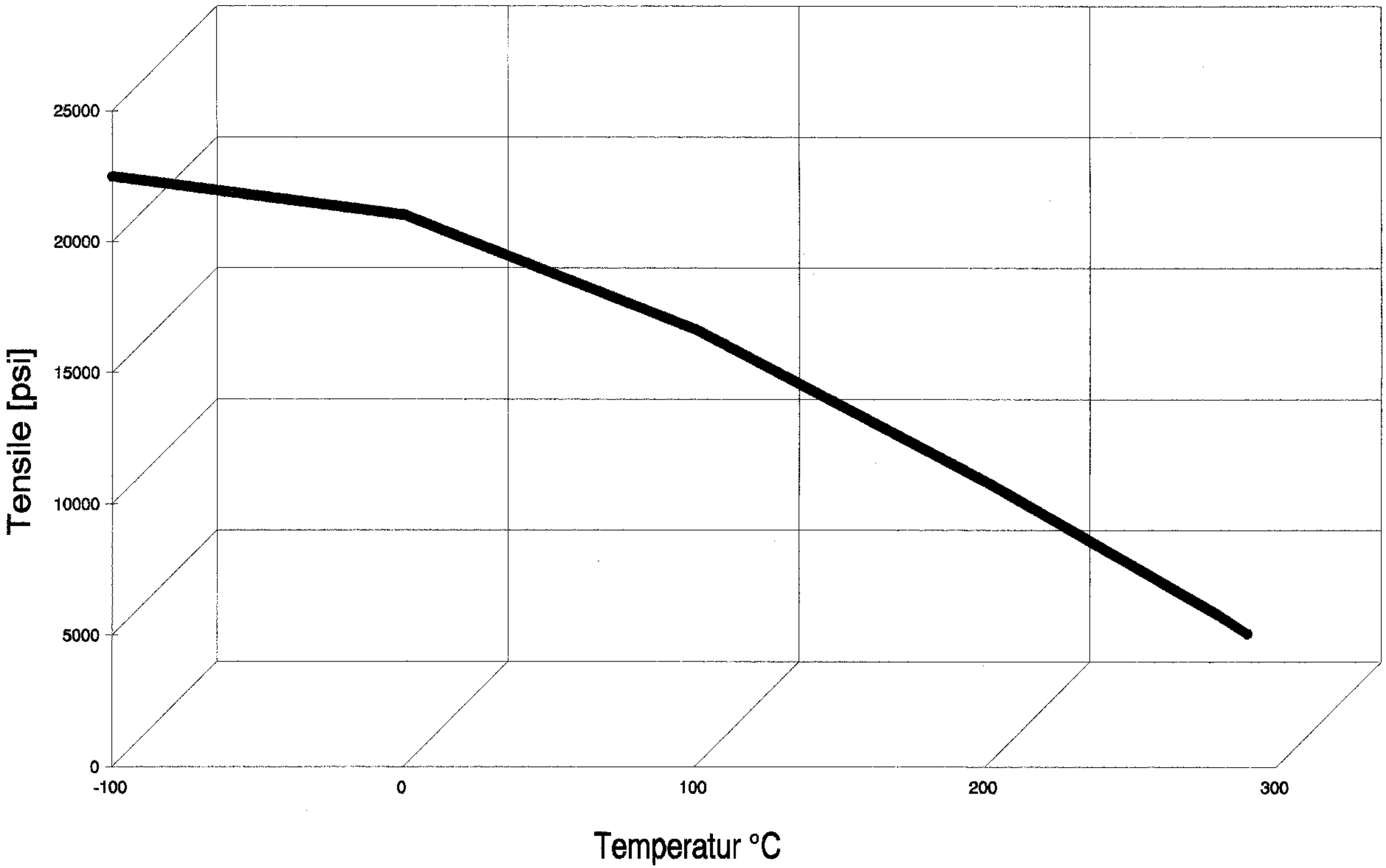
CREEP.GRF

Retention of Flex Strength under Exposure to Elevated Temperatures

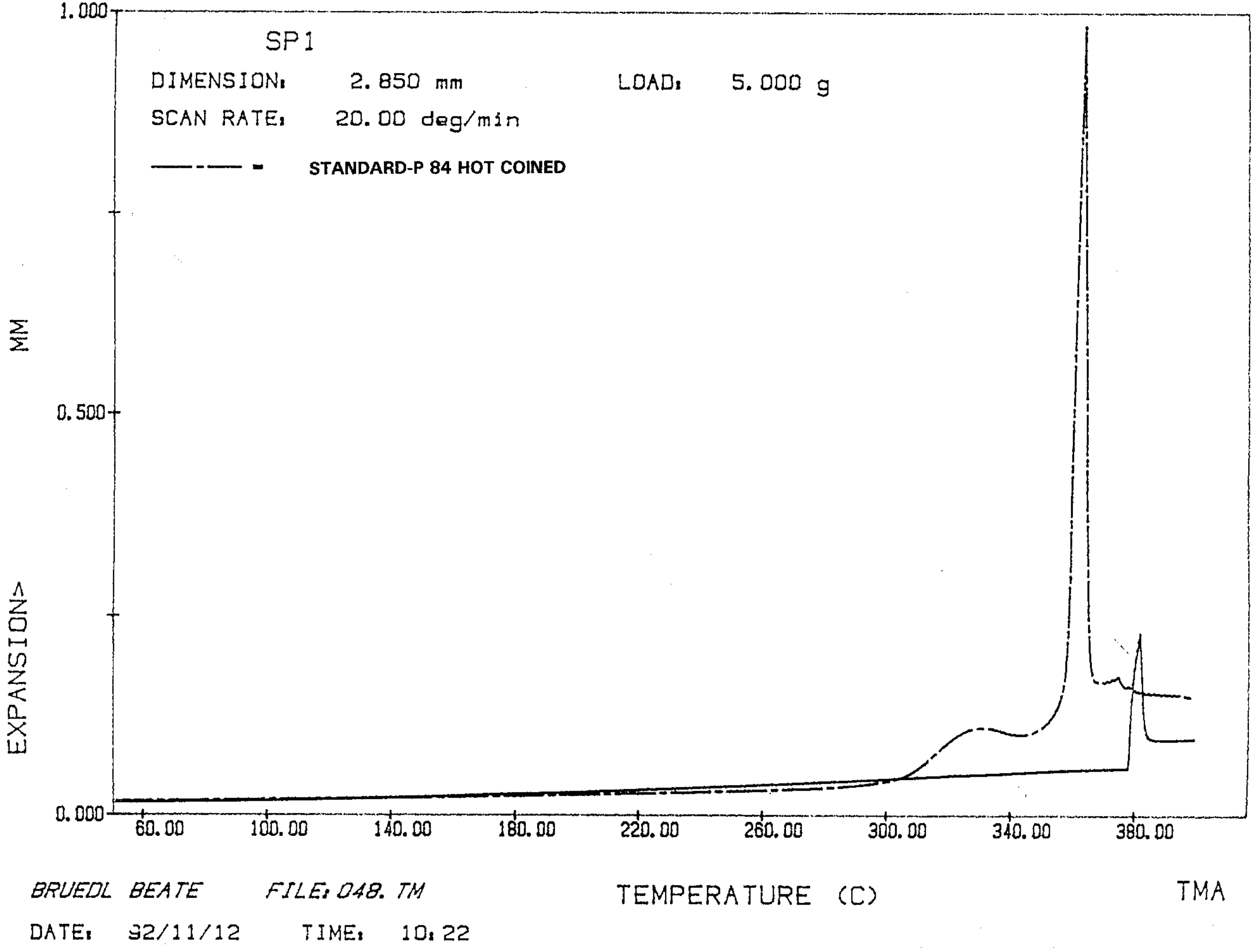


flexlmeu.grf

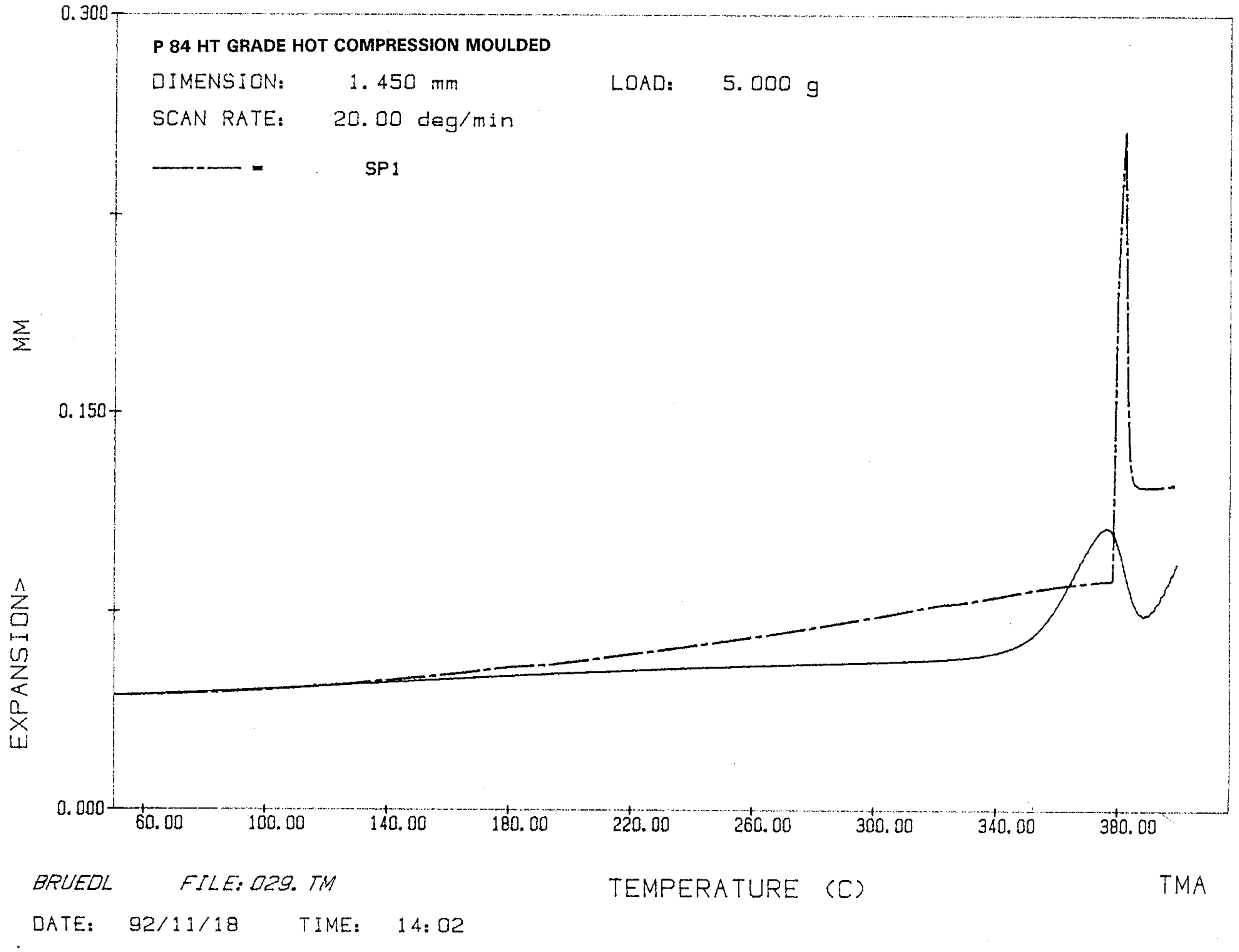
Retention of Tensile over Temperature



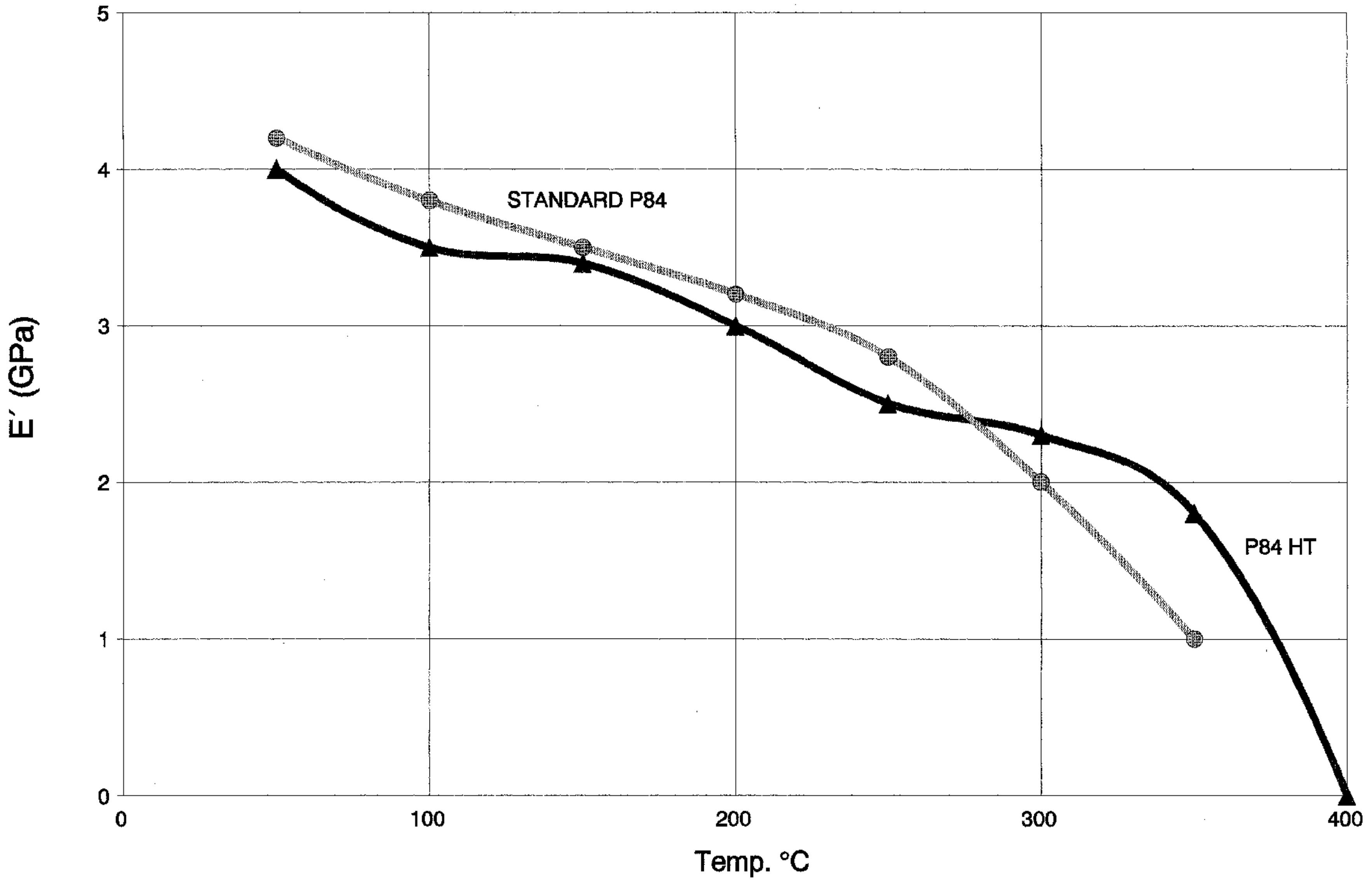
tenpzugus.grf



SP1
DIMENSION: 2.850 mm
LOAD: 5.000 g
SCAN RATE: 20.00 deg/min
STANDARD-P 84 HOT COINED
1.000
0.500
0.000
MM
EXPANSION>
60.00
100.00
140.00
180.00
220.00
260.00
300.00
340.00
380.00
TEMPERATURE (C)
TMA
BRUEDL BEATE
FILE: 048. TM
DATE: 92/11/12
TIME: 10:22


P 84 HT GRADE HOT COMPRESSION MOULDED
DIMENSION: 1.450 mm
LOAD: 5.000 g
SCAN RATE: 20.00 deg/min
SP1
0.300
0.150
0.000
MM
EXPANSION>
60.00
100.00
140.00
180.00
220.00
260.00
300.00
340.00
380.00
TEMPERATURE (C)
TMA
BRUEDL
FILE: 029. TM
DATE: 92/11/18
TIME: 14:02

DMA CURVES of P84 RESINS



HT-dma.grf

Hot-Compression-Moulding

As an example the production of a 8 inch diameter 2 inch high billet.

Hot Compression Moulding means sintering the material at temperature above the Tg under a pressure of 5000 psi. Moulding temperature is 650°F.
The necessary equipment is a press which is able to maintain 100 metric tons over a 15 hour cycle and a top and bottom heated mould with heater-band.

The mould is shown in the attached drawing.

As a release agent silicon-oil-spray should be used.
Before filling the mould the powder has to be dried to eliminate the equilibrium moisture.
Drying can be done at 220°F over 2 hours (for a 4 lb loading).
At the filling step the mould should be preheated to 480°F and the powder should be transfered direct out of the oven into the mould.
The first compression up to 2500 psi should remove the air from the loading. After this step the heating starts with a ramp up to 570°F. At this temperature the first dwelltime with 1 hour is necessary. Then the full pressure is applied (5000 psi) and the ramp up to 650°F starts.
Reaching this temperature a dwelltime of 4 hours is needed to get uniform heat penetration.
At the end of this program a slow cooling ramp starts to reduce temperature within 4 hours down to 480°F under the full pressure.
After reaching this temperature the part should be released.

<u>Neat Resin:</u>

Base resin is P84 Powder -40 mesh HCM Grade.
Best mechanical and electrical properties. Good friction and wear behavior. High radiation stability.

<u>Graphite-Composite:</u>

Base resin P84 Powder -325 mesh HCM Grade. Filler 15% Graphite LONZA KS 5-44 (Particle Size 5 to 50 microns).
Excellent friction and wear properties high residual mechanical strength. Very smooth machined surfaces.

Graphite/PTFE Composite:

Base resin P84 Powder -325 mesh HCM Grade.
Filler 15% Graphite LONZA KS 5-44 and 5% PTFE Lubricant for example ICI FL1680.
Lower coefficient of froction than straight graphite formulations. Outstanding friction properties on rough sliding surfaces through PTFE-transfer to the oposite material.

PTFE Composite:

Base resin P84 Powder -325 mesh HCM blended with 30% PTFE Lubricant ICI FL1680.
Lowest coefficient of friction of all PI-Composites.

MoS2 Composite:

Base resin P84 Powder -325 mesh HCM, blended with 15% MoS_2.
For tribological applications in dry ambiente and vacuum.

Fillers/Reinforcement Materials:

Graphite:

LENZING AG tested most of available graphite types to choose the best material for P84.
We found following properties are important:

* Homogenius machined surface	-	fine particle size needed
* High wear resistance	-	good incorporation of the graphite in the matrix needed - surface morphology important
* Mech. properties	-	paricle size of filler should be roughly the same than of matrix-resin, matrix material must be on the filler-surface after blending.
* Blending	-	the function of blending time and filler-coating is very important. Masterbatches and Premixes are necessary.

PTFE:

To get a uniform matrix and best F&W properties the use of very fine PTFE particles is necessary. Also the melting point of the used material should be at the same level as the matrix materials Tg. In testing most of available Lubricants we choosed ICI´s FL 1680 as the best type to use in P84.

MoS2:

The lubrication of MoS2 is based on surface-smoothing through material transfer. In this respect it is very important to have very fine particles as a filler and the right percentage in composition.
To guarantee the highest purity to be able to process MoS2 at 650°F in combination with P84 Lenzing specyfied a special grade for P84.

Carbonfibre:

The use of carbonfibres in combination with P84 has following advantages:

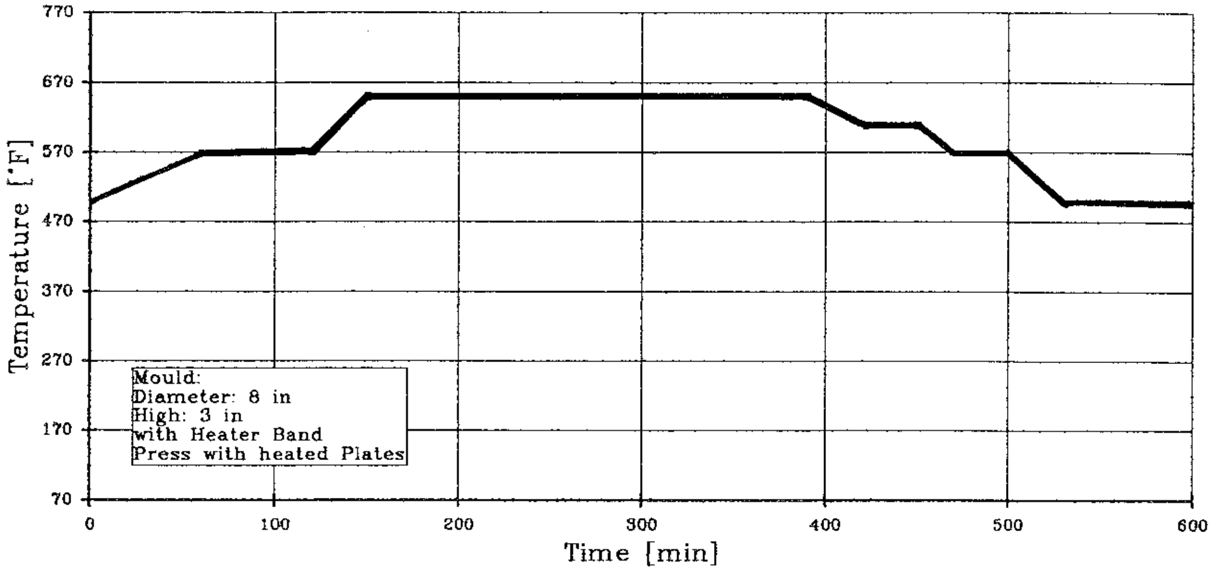
Due to the negative thermal expansion of carbon-fibres the coefficient of linear thermal expansion of P84 can be affected to the same level than metals.
As well as the thermal transmission of such composites is much better than under the use of graphite. So it is well known that the use on only 0.5% of carbonfibres in 3mm lenght double the heat transmission of plastics.
The use up to 30% CF increases the flexural modulus up to 1.400 Mpsi.

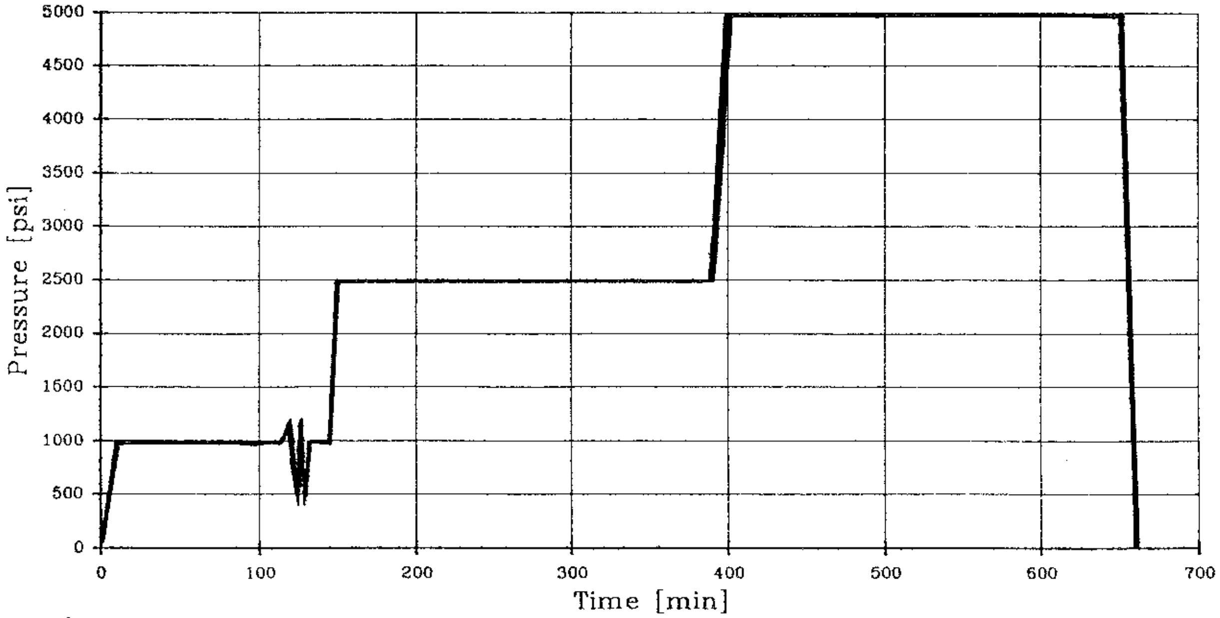
A disadvantage is the poor machinability of such materials as well as the reduction of elongation. It is not possible to improve tensile strength of P84 using reinforcement fibres.

Glass-Fibres/Balls:

The use of up to 50% by wt. of Glass is used to improve the HDT index of P84 in very temperature sensitive applications (for example welding apparatus or plasma guns - arc-resistance required).
The additon of some 5% PTFE to this composite improves machinability.

Moulding Cycle
Hot Compression Moulding of P84 Powder





Sintercy.drw

Hot Coining Process for P84 Powder

The process is used to make smaller stock shapes of P84 resins.
The diameters are limited by the handling possibilities of the moulds. It is common used up to OD´s of 8 to 10 inches

The used moulds have to be able to maintain pressures up to 10.000 psi at 400°C (750°F).
This indicates the use of high wall thicknesses and hot working steels to be used for the tools.
Sintering can be done in a simple air circulation furnace which can maintain temperatures up to 400°C (750°F).

The following steps will describe how to mould and sinter during this process.

1. The predried powder (100°C (212°F) over several hours) is filled into the mould and compacted for 5 mins with 350 kg/cm² (5000 psi), to get the air out.

2. The closed mould is placed in a preheated oven (350°C (662°F) and kept for several hours, depending on the size..
   After each full hour it has to be taken out and compacted again with 350 kg/cm² (5000 psi) for 5 mins. then placed again in the oven.

3. When the calculated end of the dwelltime is reached, the mould is placed in the press, loaded with 550 kg/cm² (8000 psi) and cooled to 250°C (480°F).
   At this temperature the part can be released.

The calculation for the sintering time (dwelltime) should be approx. 1.5 hours/in wall thickness.

Ram-Extrusion

Ram-Extrusion with P84 Powder is possible on equipments for UHMWPE or Duroplastics.
We recommend the use of -40 mesh HCM powder - because of best flow properties.
The addition of less than 1% PTFE granulate as a lubricant is necessary.
The processing temperatures are up to 670°F in steps of 20 to 30°F/heating-zone.
The coolant at the top of the extruder should be turned off.
A heated hopper is helpfull but dry-air-overflow in the material storage is sufficent.
The powder should be predried at 200°F and imediatly filled into the hopper. No storage on air should be done.
If a vibration feeder is used the feeding channel should be sealed with a polyethylene film to avoid any moisture contact of the powder.
The feeder should be positioned in a way that the material can be filled directly into the barrel after the piston has moved upwards. Never fill powder into the rotatig phone on top of the barrel.
Used brakes should be hydraulic or mechanical (see drawing) types because of needed high forces. The ram-force must be up to 10.000 psi where 50% of this is lost through friction in the tool.
Tools are cylindrical, no reduction of the diameter from top to bottom is needed.

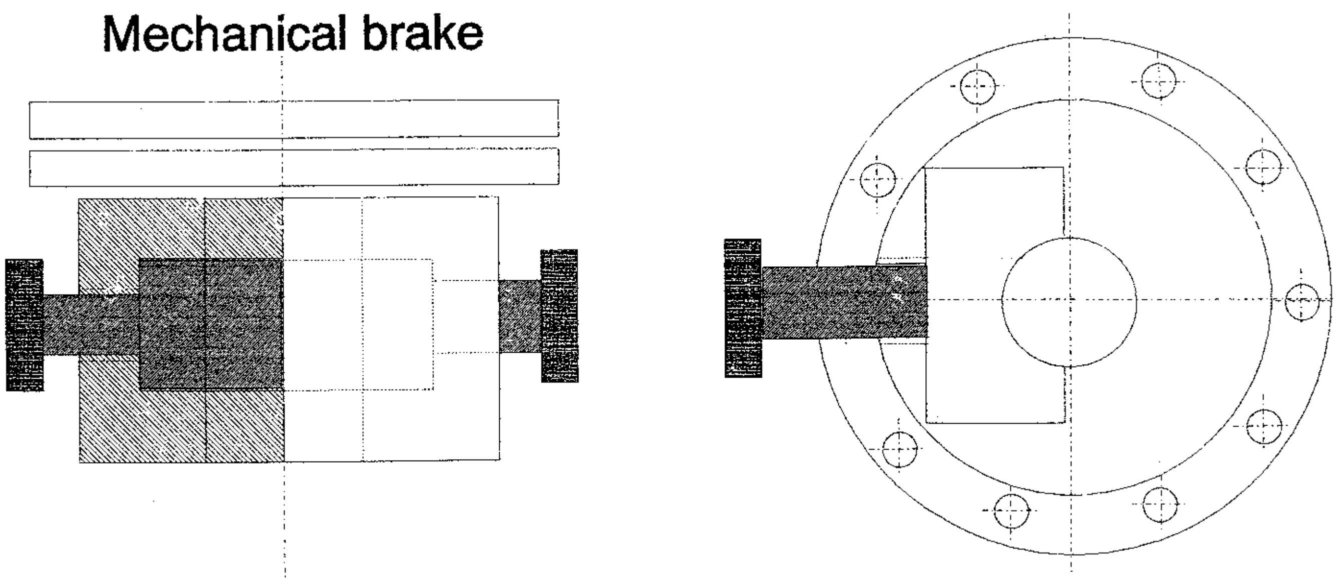
The extrusion of compounds with graphite is possible under the use of P84 coated filler (masterbatches). Also some PTFE as a lubricant is neccessary.

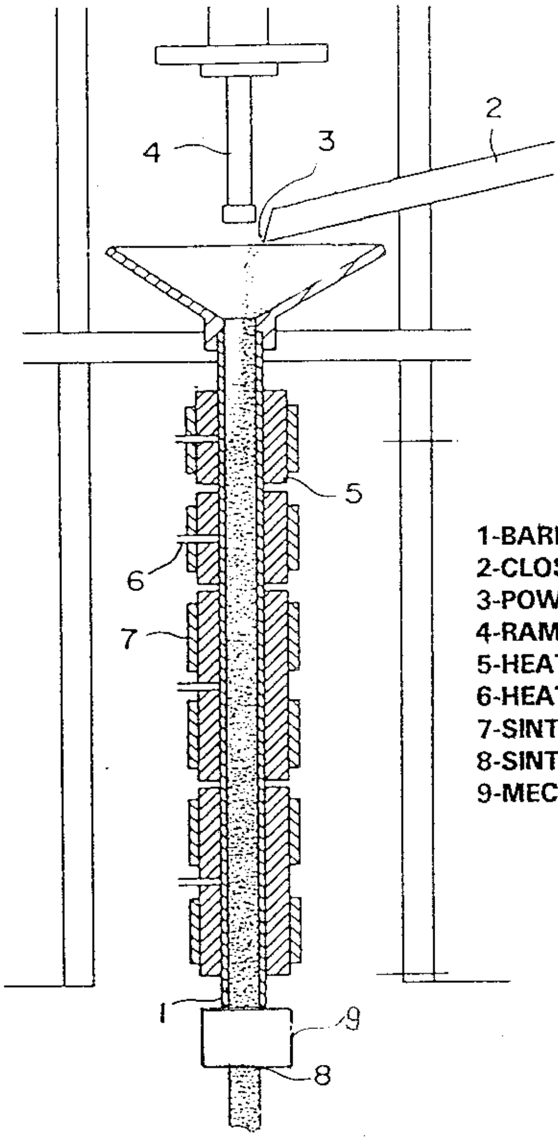
Extrusion speed at 1 inch diameter is approx. 4 to 5 feet/hour at a barrel length of 3 feet.

The temperatures on a barrel with 4 heaterbands are as follows:

Section 1:	340-350°C	644-662°F
Section 2:	360°C	680°F
Section 3:	360°C	680°F
Section 4:	350°C	662°F

Mechanical brake





1-BARREL
2-CLOSED FEEDER
3-POWDER
4-RAM
5-HEATER-BAND 1 - PRE-COMPACTION (640-660°F)
6-HEATER-BAND 2 - SINTERING (680°F)
7-SINTERING AND ANEALING SECTION
8-SINTERED ROD
9-MECHANICAL BRAKE

Direct Forming

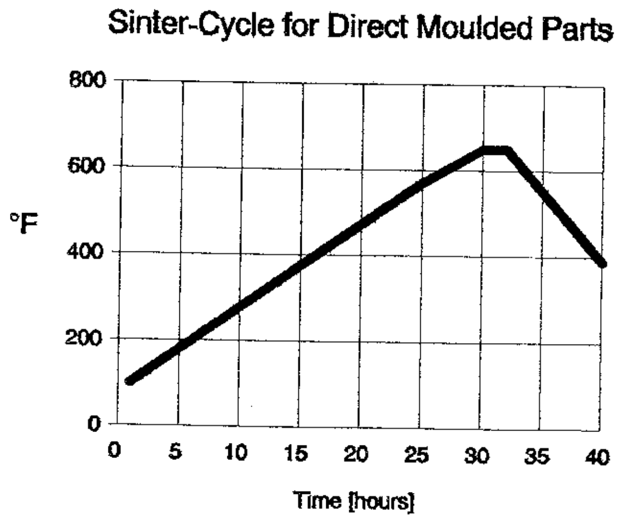
This method for moulding finished parts is possible if metal-moulding equipment is available. Changes in mould and feeder are neccessary.
The mould needs heater cartridges (see drawing) to be able to maintain temperatures up to 250°C (480°F). The feeder needs to be heated by oil or electrical heating to maintain temperatures above 200°C (400°F).

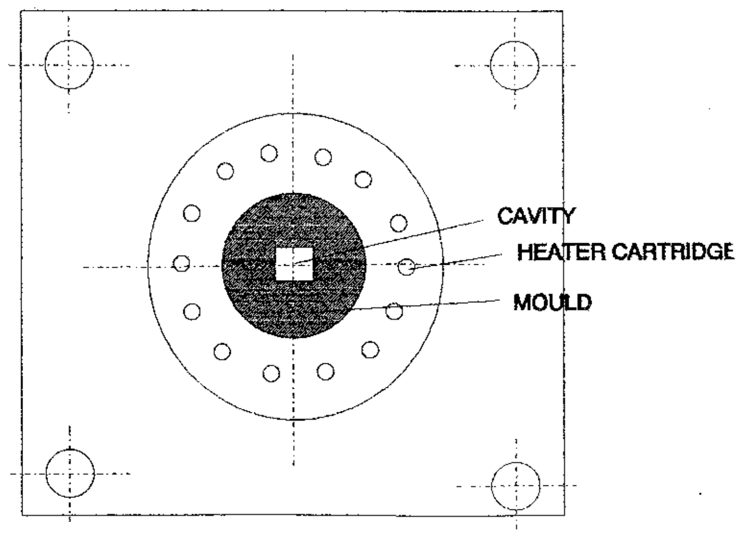
Moulding pressure is approx. 50.000 psi. Dwelltimes have to be calculated to 30 sec/10 gramms.

The addition of 0.5 to 1% PTFE (Lubricant type) as a release agent is neccessary.
LAG is offering finished blends ready for moulding.

Sintering has to be done in an oven with nitrogen or inert-gas flow following the temperature curve shown in this brochure.
The sintering causes dimension changes on the moulded parts. In moulding direction they are aprox. +10%, in cross direction -5%.
The obtained density in approx. 95% of the hot compression moulded articles. The mechanical properties are on the 80% level.

Available are finished formulations containig graphite, graphite/PTFE, glass/PTFE and molysulfide besides P84.





How to machine P84

P84 hot compression moulded or ram-extruded can easily machined into closly tolerances precision parts by using standard metal-working equipment.
It is recommended to use carbide tooling if a long tool life is particularly important.
High-speed steel can also be used for short runs on multiple-point tools.

When machining P84 the following rules should be adhered to:

* Use the maximum positive rake angle possible and sharp cutting edges

* Avoid high cutting pressures and subsequent overheating

* Use low feed rates

* Plastics have a higher thermal expansion than metals. Allow the workpiece to cool before finishing.

* Avoid deflection caused by the clamping pressure. It is recommended to use O.D. or I.D. collets. If a chuck is to be used, provide for soft jaws.
  A higher number of jaws helps distribute the holding force.
  Reduce the clamping pressure.

* Cooling of the workpiece with air, water or coolant.

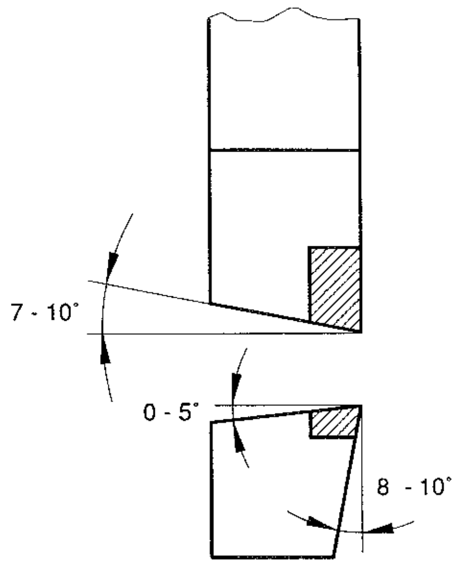
The cutting depth has no influence on the surface quality. In order to achieve very close tolerances, it is recommended to rough-turn the part and allow it to cool before finish turning. In case of threading, the depth of feed should be lower than 0.005 inch to prevent the threads from chipping. To avoid chattering deflection of long workpieces with small diameters, it is recommended to support them by means of moving collar.

	Cutting Speed feed/min	**Feed** in/R
Rough Turning	300 - 450	0.01 - 0.02
Finish Turning	450 - 550	0.002 - 0.006
Parting	240 - 300	0.002 - 0.003

Turning

P84 parts machine easily using standard turning equipment. It is recommended to use carbide-tipped tools.
For rough and finish turning operations use a cutting geometry similar to that used for aluminum, for turning on a numerically controlled lathe, use TIZIT H10T DCGT 11T 302 FN-27.
The nose radius of the cutting tip should be between 0.004 and 0.008 in to guarantee a good surface finish. It is important the cutting tip be level to the centre of the piece to be turned.
Sharp cutting edges allow high cutting speeds
Use low feed rates.

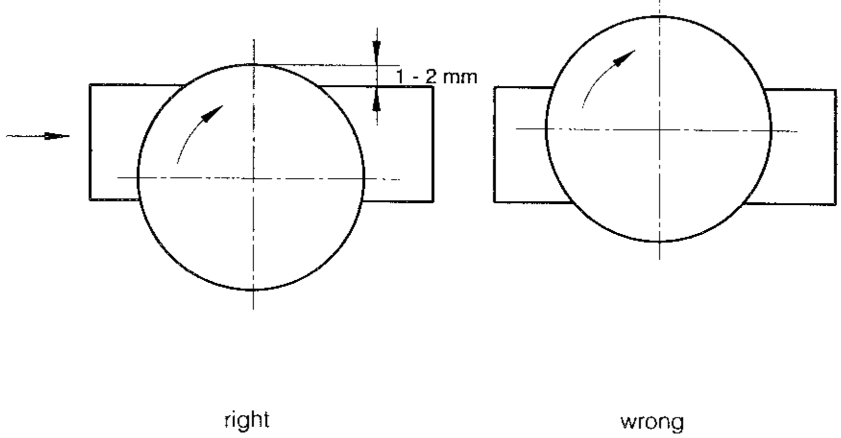
Lathe Tool



Milling

P84 parts can be machined with all standard HSS or carbid-tipped milling equipment. Multiple-point milling cutters are preferably used. To avoid edge chipping, we recommend the milling be performed from the outside of the block towards the center and use small exit angles. Cutting speed should be between 2.5 and 4 in/min and feed rates lower than 0.03 - 0.006 in. The lower the feed rate, the better the surface finish.
Lubricating or cooling is not required.

Conventional Milling



Drilling

HSS drills (point angle 90°) or carbide drills (point angle 90 - 120°) can be used to drill holes into P84 parts. If the drill diameter is more than 0.8 in, reduce the web thickness. Work at drilling speeds of 450 - 550 ft/min and feed rates lower than 0.004 in.
To avoid local heating in the worpiece, provide for good chip removal.

Parting

P84 materials can be cut with circular or band saws. 8 - 12 teeth/in should yield excellent results. If you use hard-metal tipped blades, tool life will be longer.
Saw speed for circular saws should be 80 - 120 in, for band saws 12 - 16 in.
If plates are to be cut with circular saws, adjust the blade height in such a way that the blade breakthrough is within 0.08 - 0.12 in to the surface to avoid edge chipping.

Grinding

P84 parts can be ground to close tolerances with surface grinders used for metal working. Round bars and tubes are ground on centerless grinders. Use double-coated tape to fix the material to the table and cool with water.
Table surface speed should be about 60 ft/min for rough grinding and 35 ft/min for finish grinding.

CHEMICAL RESISTANCE LIST FOR P84

LENZING HPP

Chemical	Recommendation (+) no reduction of properties , (o) suitable - loss of properties less 10%, (-) not suitable
Antifreeze-liquid	(+)
Brake Fluid	(+)
Diesel	(+)
Fuel (unleaded)	(+)
Hydraulic Fluid	(o)
Jet Petrol JP5	(+)
Jet Petrol JP4	(+)
Motor Oil	(+)
Thermal Conduction Oil	(+)
Skydrol 500B	(+)
Acetone	(+)
Freon TF	(+)
Ethylacetat	(+)
Isopropanol	(+)
Methylethylketone	(+)
Perchloroethylen	(+)
Benzene	(o)
Toluene	(+)
Xylene	(o)
Bleaching Agent (Clorox)	(o)
Dish Washing Detergent (Joy)	(+)
Deion. Water (100°C/212°F)	(-)
Coolant Liquid (120°C/248°F)	(-)

Chemical	Concentration	Temperature	Recommendation
			(+) no reduction of properties , (o) suitable – loss of properties less 10%, (–) not suitable
	(%)	(°C)	
Sulphuric Acid	1	55	(o)
	5	20	(+)
	5	95	(-)
	10	20	(o)
	20	20	(-)
	20	50	(-)
	70	20	(-)
Nitric Acid	10	20	(+)
	30	20	(-)
	30	50	(-)
Hydrochloric Acid	10	95	(-)
	20	50	(-)
	37	20	(-)
	37	20	(-)
Acetic Acid	100	20	(o)
Formic Acid	85	20	(-)
Benzoic Acid	sattiated	95	(o)
Benzoic Acid	sattiated	20	(o)
Oxalic Acid	sattiated	20	(+)
Sodium hydroxide	5	20	(-)
Ammonium hydroxide	5	20	(-)
Sodium hypochlorite	0,4	20	(+)
Sodium chlorite	0,5	20	(+)
Sodium chlorite	0,5	50	(+)
Sodium chlorate	0,5	20	(+)
Hydrogen peroxide	0,5	20	(+)