

Designs Department
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POLYTETRAFLUORETHYLENE
PLASTIC BEARINGS

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POLYTETRAFLUOROETHYLENE PLASTIC BEARINGS

1. INTRODUCTION

- 1.1 ¹The properties of Polytetrafluoroethylene (P.T.F.E.) are quite outstanding and unique. The most important point being its very remarkable working temperature range, which is by far beyond the range of most other plastics, it remains flexible down to temperatures of -70 to -80°C and does not melt below 327°C (compared with 100 - 115°C for polythene). It has no tendency to embrittlement when kept at high temperatures for long periods and although the upper safe working temperature has not yet been determined, the material is expected to stand up more or less indefinitely at 250°C. In addition, its electrical properties are equivalent or better than those of polythene, and its chemical resistance is excellent, the only reagent which has been found to attack it, even up to temperatures of the order of 400°C, being molten sodium. However, the material is difficult to process, see attached appendix, but machining of the material from a sintered billet was effected without difficulty using conventional methods.
- 1.2 A superficial investigation, using P.T.F.E. as a turntable bearing material, has produced very promising results. The material being relatively elastic, permits an interference (without clearance) fit bearing assembly, and having the characteristic greasy surface of polythene, constituten an excellent substitute for conventional mineral oil lubrication.
- 1.3 It was noted that, as the recommended maximum working temperature of P.T.F.E., was approximately (280 °C?) it should produce a bearing material of sufficient acceptable white metal which has a melting point range of 185 - 250 °C.

2. TEST CONDITIONS

- 2.1 In order to obtain a relatively comparison with a known bearing the plastic elasticised alloy adopted for the TD/7 modifications to the was replaced by a light alloy shaft retained two P.T.F.E. bushes housed in splined housing in order to obtain good radial strata distribution.
- 2.2 The standard shaft used in conjunction with the TD/7 modification bearing was utilised, no attempt being made to select for minimum ovality or high surface finish.
- 2.3 The P.T.F.E. bushes were pressed into the splined housing, the shaft holes being bored in line and reamed to given an interference fit with the shaft of .006" (bush holes .006" smaller than the shaft).
- 2.4 Due to the fact that only small sizes of P.T.F.E. billets were available at the commencement of the investigation, no attempt was made to determine the thrust capacity of the material, purely radial load characteristics being sought. In fact, the thrust load was taken by a felt washer during the tests, as it was considered that the thrust exerted by the load of a standard turntable was above the fair area loading obtained when using restricted outside diameter due merely to availability considerations.
- 2.5 The complete bearing assembly replaced a physically similar steel to zinc based alloy bearing on an available TD/7 modified 201 P Garrard motor; a standard Garrard turntable being the load.

¹ P.T.F.E INFORMATION

3. RESULTS

- 3.1 The complete motor assembly as described in paragraphs 2.1 to 2.5 inclusive was run entirely without oil lubrication and has to date completed satisfactorily 1000 hours at 78 r.p.m., 14 hours at 1500 r.p.m.² 6 hours at 3000 r.p.m.², and 3 hours at 5000 r.p.m.²
- 3.2 After the above runs were completed, an interference fit remained between the shaft and the bearing material, it being estimated that the actual interference present was in the order of .001 - .002", it being appreciated that accurate dimensional analysis of a plastic of elastic character is difficult to accomplish without special optical equipment.
- 3.3 Figure 1 shows typical initial reduction of friction moment with time, the original high value existing at the commencement of each run, after the material has cooled and settled down to conform to shaft ovality.
- 3.4 Shaft wear proved to be minute, only a higher value of surface finish being apparent.
- 3.5 The P.T.F.E. holes were highly polished and in good condition, particles of dirt being trapped within the material and very probably responsible for shaft polishing by presenting a very fine lap surface. All traces of dirt were removable by cleaning with carbon tetrachloride.

4. CONCLUSION

- 4.1 Bearings manufactured from P.T.F.E. have the following advantages:-
 - a. Minimum running clearance.
 - b. Conventional lubrication unnecessary.
 - c. Bearings can be situated in inaccessible positions.
 - d. Minimum backlash on controls.
 - e. Excellent electrical properties combined with mechanical advantages.
 - f. Smooth running.
 - g. Quiet operation.
 - h. Long Life.
- 4.2 The use of P.T.F.E. for machine slides would show certain advantages.

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² High speed runs carried out without turntable load

APPENDIX

P.T.F.E. Details by Imperial Chemical Industries Ltd

As a result of the very poor flow properties of the molten polymer, a novel technique of fabrication has had to be built up. The guiding principle has been never to attempt to alter the shape of the polymer to any great extent after it has been melted, but to perform the cold material and melt or sinter it in the approximate shape in which it is ultimately required. Fortunately, provided that the polymer is prepared in the right state of subdivision, it is reasonably amenable to cold pressing and quite strong, handleable performs can be prepared. These can subsequently be baked or sintered at temperatures up to 400 °C, when the individual fine particles weld together while the shape of the original cold pressed perform is retained unaffected. The process is closely parallel to that used in powder metallurgy. In some cases the cold pressed performs are baked open to the air in an oven, and in others they are baked in moulds under pressure. It is usually permissible to alter the dimensions or shape of the original preform by pressing in the molten state, up to a maximum of 50%. Any greater change of dimensions gives rise to tearing and disintegrating of the pressed article.

Extrusion is difficult, but again, by application of the principle of melting the polymer, after it has been preformed into the state in which it is ultimately required, some encouraging preliminary results have been obtained.

Details of the mechanical, thermal, chemical, optical and electrical properties are tabulated below:

A.	Mechanical	Value	Remarks
1.	Tensile strength	2000 - 4000 psi	Influenced by degree of orientation, e.g. values up to 15000 psi on special films
2	Elongation	300 - 400% at 1"/min. no load crosshead speed	Affected by method of fabrication
3	Impact strength- Izod -57 °C 25 °C 77 °C	2 ft lbs/in. of notch 4 ft lbs/in. of notch 6 ft lbs/in. of notch	ASTM D-256-41-T
4	Flexural strength	2000 psi (without breaking)	ASTM D-650-42-T
5	Shore hardness	55-70	'Scleroscope" reading (magnifier hammer)
6	Stiffness	60,000 psi	ASTM D-747-43T
7	Compressive strength	0.1% deformation at 1700 psi	At no-load cross-head speed of 0.05"/min. ASTM D-621-43
8	Compressive creep at 50 ° 1200 psi 1200 psi 1200 -psi	4-8% in 24 hours 4-8% in 85 hours 50% in 24 hours	Modified ASTM D-621-43 ASTM D-621-43
9	Density at 25 °C	2.1-2.3 g/cc.	
10	Flexibility	Pliable in thin sheets	Films do not crack on flexing at -75 °C
11	Dimensional stability	Excellent	No change on ageing
12	Machining qualities	Good	Easily machined or punched by conventional methods

B	Thermal	Value	Remarks
1	Melting Point	No true melting point	Subject to cold flow under load but form stable with no load at least 300 °C
2	Solid phase transition	327 °C	Disorientation and disappearance of crystallinity above this temperature with sharp drop in strength
3	Decomposition temperature	Above 400 °C	
4	Maximum service temperature	200 - 300 °C	Slow embrittlement at 300 °C
5	Conductivity	6×10^{-4} cals / cm ² / sec/ °C/cm	Cenco-Fitch apparatus 0.18" thickness of specimen
6	Expansion coefficient (cubical)	15×10^{-5} / cm ³ / °C 24×10^{-5} / cm ³ / °C 70×10^{-5} / cm ³ / °C	(20 - 100 °C) (100 - 250 °C) (250 - 300 °C)
7	Infrared transmission	Clear 2.7 - 7.5 mm	Test piece 10 mls thick
8	Burning rate	Non-flammable	
9	Heat distortion	61 °C at 264 psi) 98 °C at 132 psi) 130 °C at 66 psi)	Modified ASTM D-648 Flexibility test of deformation of bar under load, and hence unreliable as true guide to heat distortion for poly TFE.
10	Brittleness temp.	Below - 60 °C	ASTM D-746-43-T

C	Chemical	Value	Remarks
1	Solubility	Nil	Completely resistant to all organic solvents
2	Chemical resistance	Excellent	Not affected by corrosive agents
3	Light stability	Excellent	No detectable change in outdoor exposure for one year
4	Reaction with metals		No reaction with metal of construction in the service temperature range (some attack by molten sodium)
5	Oxidation		Not attacked by oxygen up to 300 °C
6	Water absorption	0.00	ASTM D-57042, not wet by water
7	Moisture permeability measured on 3 mil tape	Better than polythene and roughly equivalent to Saran	ASTM D-697 - 42T

D	Optical	Value	Remarks
1	Index of refraction	1.35 ± 0.05	
2	Capacity		Opaque in thick sections translucent in thin sheets
3	Colour		Essentially light
4	Appearance		Smooth, waxy

E	Electrical	Value	Remarks
1	Power factor 60 cycles to 80 x 10 ⁶ cycles	Less than 0.0002	At 22.5 °C
2	Dielectric constant	2.0	At 22.5 °C over the above frequency
3	Dielectric strength	1000 - 2000 volts / mil	5 - 2 mil thicknesses ASTM D-149 0 40T
4	Volume resistivity	10 ¹⁶ ohm-cm	At 50% and 100% RH ASTM D- 257 - 38
5	Surface resistivity	3.5 x 10 ⁷ megohms	At 50% RH ASTM D- 257 - 38
6	Surface area resistance	Over 100 secs	Does not track, depolymeris under high energy spark ASTM D-495 - 42
7	Corona resistance	good	

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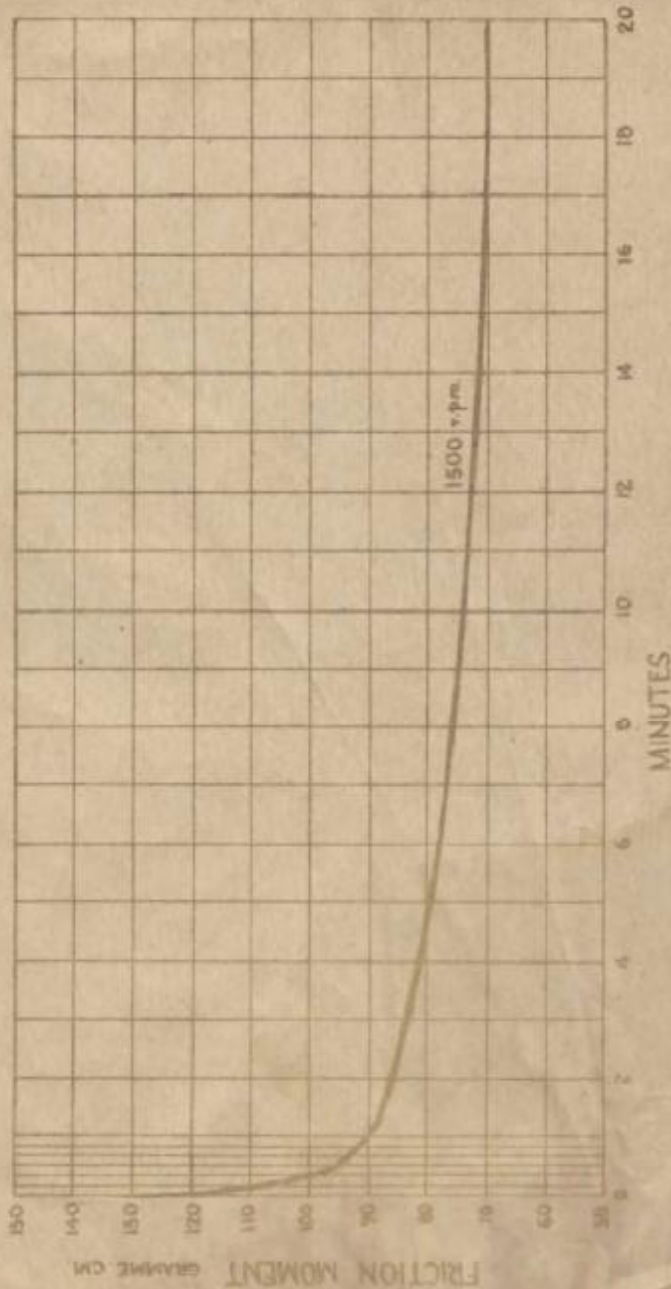


FIG. 1.

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P.T.F.E. (POLYTETRAFLUOROETHYLENE)
PLASTIC BEARINGS.


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DESIGNS DEPARTMENT
REPORT NO. 1.4 (47) 00/0

POLYTETRAFLUOROETHYLENE
PLASTIC BEARINGS

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POLYTETRAFLUOROETHYLENE FLUORO BRIDGES

1. INTRODUCTION

1.1 The properties of Polytetrafluoroethylene (T.F.E.) are quite outstanding and unique. The most important point being its very remarkably melting temperature range, which is by far beyond the range of most other plastics, it remains flexible down to temperatures of -75 to -80°C and does not melt below 327°C (compared with 100 - 125°C for polythene). It has an tendency to crystallize which starts at high temperatures for long periods, and although the upper safe working temperature has not yet been determined, the material is reported to stand up well to tests indefinitely at 250°C. In addition, its electrical properties are equivalent or better than those of polythene, and its chemical resistance is excellent, the only weakness which has been found is attack by acids at temperatures of the order of 400°C, being soluble in them. However, the material is difficult to process, one attempt at extrusion has resulted in the material being severely distorted and cracked without difficulty being experienced in other methods.

1.2 A experimental investigation, using T.F.E. as a suitable bonding material, has produced very promising results. The material being particularly suitable for bonding to metal surfaces without the need for any special surface treatment, and having the usual electrical, physical and chemical properties of a plastic material.

1.3 It was noted that, in the experiments with the bonding of T.F.E. to metal surfaces, the material was found to be particularly suitable for bonding to metal surfaces which are difficult to bond to by other methods.

2. THE EXPERIMENT

2.1 An attempt was made to bond a piece of T.F.E. to a metal surface using the method described in the above mentioned report. The results of this experiment are given in the following table.

- 2.2 The standard shaft used in conjunction with the TD/7 anti-friction bearing was utilized, no attempt being made to select for minimum ovality or high surface finish.
- 2.3 The P.T.F.E bushes were pressed into the splined housing, the shaft holes being bored in line and reamed to give an interference fit with the shaft of .005" (bush holes .006" smaller than the shaft).
- 2.4 Due to the fact that only small sizes of P.T.F.E. Vilets were available at the commencement of the investigation, no attempt was made to determine the thrust capacity of the material, purely radial load characteristics being sought. In fact, the thrust load was taken by a felt washer during the tests, as it was considered that the thrust exerted by the load of a standard turntable was above the fair area loading obtained when using resubstituted outside diameter due merely to availability considerations.
- 2.5 The complete bearing assembly replaced a physically similar steel to zinc based alloy bearing as an available TD/7 bearing 201 F Garrard motor; a standard Garrard turntable being the load.

3. RESULTS

- 3.1 The complete motor assembly as described in paragraphs 2.1 to 2.5 inclusive was run entirely without oil lubrication and has to date completed satisfactorily 1,000 hours at 75 r.p.m., 24 hours at 1,500 r.p.m., 4 hours at 3,000 r.p.m., and 3 hours at 3,000 r.p.m.
- 3.2 After the above runs were completed, an interference fit remained between the shaft and the bearing material, it being estimated that the normal interference present was in the order of .001 - .002", it being appreciated that separate dimensional analysis of a plastic or ceramic character is difficult to accomplish without special optical equipment.
- 3.3 Figure 1 shows typical initial reduction of friction moment with time, the original high value existing at the commencement of each run, after the material has cooled and settled down to conform to shaft ovality.
- 3.4 Shaft wear proved to be minute, only a slight loss of surface finish being apparent.

*High speed runs carried out without turntable load.

3.3 The P.T.F.E. coils were highly polished and in good condition particles of dirt being trapped within the material and were probably responsible for shaft polishing by presenting a very fine lap surface. All traces of dirt were removable by cleaning with carbon tetrachloride.

4. CONCLUSION

4.1 Bearings manufactured from P.T.F.E. have the following advantages:-

- (a) Minimum running clearance.
- (b) Conventional lubrication unnecessary.
- (c) Bearings can be situated in inaccessible positions.
- (d) Minimum backlash on controls.
- (e) Excellent electrical properties combined with mechanical advantages.
- (f) Smooth running.
- (g) Quiet operation.
- (h) Long life.

4.2 The use of P.T.F.E. for machine slides would show certain advantages.

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APPENDIX

F.V.F.M. Details by Imperial Chemical Industries Ltd.

As a result of the very poor flow properties of the molten polymer, a novel technique of fabrication has had to be built up. The guiding principle has been never to attempt to alter the shape of the polymer to any great extent after it has been melted, but to prepare the cold material and melt or sinter it in the approximate shape in which it is ultimately required. Fortunately, provided that the polymer is prepared in the right state of subdivision, it is reasonably suitable to cold pressing and quite strong, handleable preforms can be prepared. These are subsequently be baked or sintered at temperatures up to 400°C, when the individual fine particles weld together while the shape of the original cold pressed preform is retained unaffected. The process is closely parallel to that used in powder metallurgy. In some cases the cold pressed preforms are baked open to the air in an oven, and in others they are baked in moulds under pressure. It is usually possible to alter the dimensions or shape of the original preform by pressing in the molten state, up to a maximum of 30%. Any greater change of dimensions gives rise to tearing and disintegrating of the pressed article.

Extrusion is difficult, but again, by application of the principle of melting the polymer, after it has been preformed into the state in which it is ultimately required, some encouraging preliminary results have been obtained.

Details of the mechanical, thermal, chemical, optical and electrical properties are listed below:

<u>a. Mechanical</u>	<u>Value</u>	<u>Remarks</u>
1. Tensile strength	2000-4000 p.s.i.	Influenced by degree of orientation, e.g. values up to 15,000 p.s.i. on special films.
2. Elongation	300-400% at 1"/min. no load crosshead speed.	affected by method of fabrication.

<u>A. Mechanical</u>	<u>Value</u>	<u>Remarks</u>
1. Impact strength-Imod		ASTM D-256-41-T
-370C	2 ft.lbs./in. of notch	
210C	4 "	
770C	6 "	
4. Flexural strength	1000 p.s.i. (without breaking)	ASTM D-150-42-T
5. Shore hardness	55-70	Durometer reading (magnifier hammer)
6. Stiffness	60,000 p.s.i.	ASTM D-747-42T
7. Compressive strength	0.1: deformation at 1700 p.s.i.	at no-load cross-head speed of 0.05"/min. ASTM D-691-42T
8. Compressive creep at 25°C		modified ASTM D-691-42
1200 p.s.i.	4-5% in 24 hrs.	ASTM D-691-42
1800 p.s.i.	4-5% in 24 hrs.	
4000 p.s.i.	50% in 24 hrs.	
9. Density at 25°C	2.1-2.3 g/cm ³ .	
10. Flexibility	pliable in thin sheets.	Film do not crack on flexing at -199C.
11. Dimensional stability	Excellent	no change on aging.
12. Machining qualities	good	easily machined or finished by conventional methods
<u>B. Thermal</u>	<u>Value</u>	<u>Remarks</u>
1. Melting point	no true melting point	subject to soft flow under load but very stable with no loss at least 300°C.

<u>Physical</u>	<u>Value</u>	<u>Remarks</u>
1. Solid phase transition	NT°C	Disorientation and disappearance of crystallinity above this temperature with sharp drop in strength.
2. Decomposition temperature	above 400°C.	
3. Maximum service temperature	200-300°C.	also experiments at 300°C.
4. Conductivity	4×10^{-14} ohm/cm ² / 100°C/cm.	Compton-Pitch apparatus 0.125 thickness of specimen
5. Expansion coefficient (average)	$15 \times 10^{-5} / 100^\circ\text{C}$ $25 \times 10^{-5} / 100^\circ\text{C}$ $70 \times 10^{-5} / 100^\circ\text{C}$	(20-100°C) (100-250°C) (250-300°C)
6. Infra-red transmission	clear 2.1-7.5 microns	test piece 10 mils. thick
7. Burning rate	non-flammable	
8. Heat distortion	65°C at 250 p.s.i. 35°C at 150 p.s.i. 150°C at 50 p.s.i.	modified ASTM D-648 firmness test no deformation of bar under load and under thermal shock as true guide to heat distortion for poly 100.
9. Brittleness temp.	below -10°C.	ASTM D-746-43-6
<u>Chemical</u>	<u>Value</u>	<u>Remarks</u>
1. Solubility	nil	completely resistant to all organic solvents.
2. Chemical resistance	excellent	not affected by common corrosive agents

<u>D.</u>	<u>Chemical</u>	<u>Value</u>	<u>Remarks</u>
1.	light stability	excellent	no detectable change in outdoor exposure for one year
2.	Reaction with acids		no reaction with dilute of conc. nitric acid in the service temperature range when immersed by boiling solution
3.	Oxidation		not attacked by oxygen up to 300°C
4.	Water absorption	0.00	ASTM D-1542, not wet by water
5.	Moisture permeability measured on 5 mil tape	less than polythene and roughly equal to bakelite	ASTM D-375-48T
<u>E. Optical</u>			
<u>Value</u>			
1.	Index of refraction	1.33 ± 0.01	
2.	Opacity		opaque in this service temperature range in thin sheets
3.	Color		essentially light
4.	Appearance		smooth, gray
<u>F. Electrical</u>			
<u>Value</u>			
1.	Power Factor		
	at 25°C	less than 0.0001	at 32.5°C

<u>Properties</u>	<u>Values</u>	<u>Remarks</u>
1. Dielectric constant	2.0	at 32.5°C over the above frequency range
2. Dielectric strength	1000-2500 volts/mil	1.5 mil thicknesses ASTM D-149-40T
3. Volume resistivity	10^{16} ohm-cm	at 30°C and 100% RH ASTM D-425-40
4. Surface resistivity	5.1×10^7 ohms	at 30°C RH ASTM D-425-40
5. Surface res. under UV	over 100 ohms.	Some mil thick, irradiation under high energy source ASTM D-425-40
6. Impact resistance	good	

