Designs Department
Report No 1.4. (49) (19 49/11)

# POLYTETRAFLUORETHYLENE
# PLASTIC BEARINGS


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2. Test Conditions

3. Results

4. Conclusion

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

Figure 1 DSKA 448

DESIGNS DEPARTMENT REPORT NO 1.4 (49)

POLYTETRAFLUOROETHYLENE PLASTIC BEARINGS

## 1. INTRODUCTION

1.1 [1]The 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$^{o}$C and does not melt below 327$^{o}$C (compared with 100 – 115$^{o}$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$^{o}$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$^{o}$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 $^{o}$C?) it should produce a bearing material of sufficient acceptable white metal which has a melting point range of 185 - 250 $^{o}$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

## 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 f 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<br>-57 °C<br>25 °C<br>77 °C | <br>2 ft lbs/in. of notch<br>4 ft lbs/in. of notch<br>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.<br>ASTM D-621-43 |
| 8 | Compressive creep at 50 °<br>1200 psi<br>1200 psi<br>1200 –psi | <br>4-8% in 24 hours<br>4-8% in 85 hours<br>50% in 24 hours | Modified ASTM<br>D-621-43<br>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 x $10^{-4}$ cals / $cm^2$ / sec/ °C/cm | Cenco-Fitch apparatus 0.18" thickness of specimen |
| 6 | Expansion coefficient (cubical) | 15 x $10^{-5}$ / $cm^3$/ °C<br>24 x $10^{-5}$ / $cm^3$/ °C<br>70 x $10^{-5}$ / $cm^3$/ °C | ( 20 – 100 °C)<br>(100 – 250 °C)<br>(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 )<br>98 °C at 132 psi )<br>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<br>60 cycles to 80 x $10^6$ cycles | Less than 0.0002 | At 22.5 $^oC$ |
| 2 | Dielectric constant | 2.0 | At 22.5 $^oC$ over the above frequency |
| 3 | Dielectric strength | 1000 – 2000 volts / mil | 5 – 2 mil thicknesses<br>ASTM D-149 0 40T |
| 4 | Volume resistivity | $10^{16 \text{ ohm-cm}}$ | At 50% and 100% RH<br>ASTM D- 257 – 38 |
| 5 | Surface resistivity | 3.5 x $10^7$ megohms | At 50% RH<br>ASTM D- 257 – 38 |
| 6 | Surface area resistance | Over 100 secs | Does not track, deploymeris under high energy spark<br>ASTM D-495 – 42 |
| 7 | Corona resistance | good | |

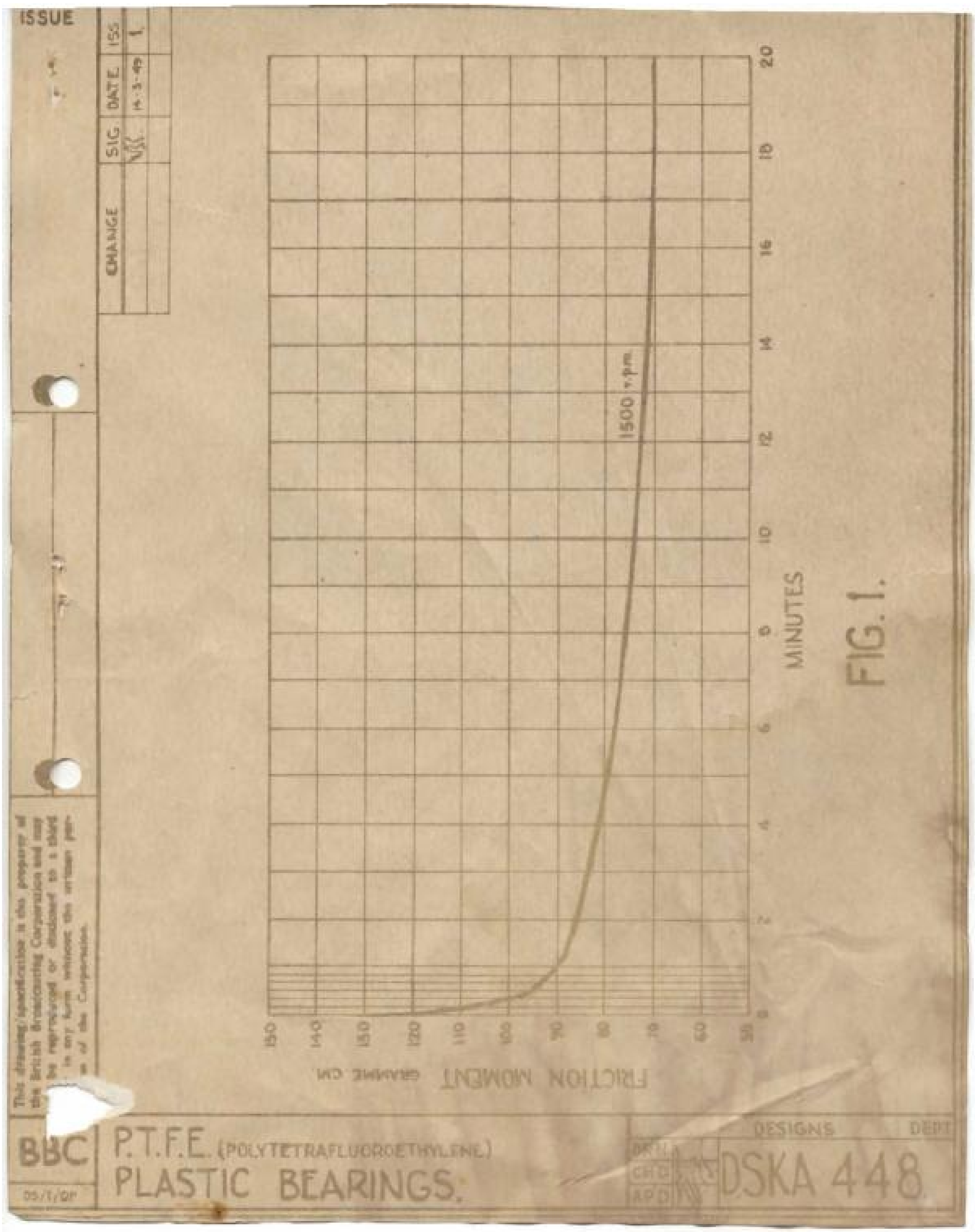
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FIG. 1.
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P.T.F.E. (POLYTETRAFLUOROETHYLENE)
PLASTIC BEARINGS.
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DESIGNS DEPARTMENT
REPORT NO. 1.4 (45) [illegible]

POLYTETRAFLUOROETHYLENE
PLASTIC BEARINGS

Work carried out by:
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[illegible]

[illegible]
Head of Designs Department

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[illegible] DEPARTMENT REPORT NO. [illegible]

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1. INTRODUCTION

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1.2 A superficial investigation, using P.T.F.E. as a possible bearing material, has produced very promising results. [illegible]

1.3 [illegible]

2. [illegible]

2.1 [illegible]

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 give 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 felt 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.

3. <u>RESULTS</u>

3.1 The complete motor assembly as described in paragraphs 2.1 to 2.5 inclusive was run entirely without all lubrication and has to date completed satisfactorily 1,000 hours at 78 r.p.m., 14 hours at 1,500 r.p.m.*, 6 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 actual interference present was in the order of .001 - .002", it being appreciated that accurate dimensional analysis of a plastic or elastic character is difficult to accomplish without special optical equipment.

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4. CONCLUSION

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

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(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.

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## APPENDIX

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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 preform 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 preforms 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 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 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 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. |

| A. Mechanical | Value | Remarks |
|---|---|---|
| 3. Impact strength-Izod | | ASTM D-256-41-T |
| -37°C<br>25°C<br>77°C | 2 ft.lbs/in. of notch<br>4 "<br>6 " | |
| 4. Flexural strength | 2000 p.s.i. (without breaking) | ASTM D-650-42-T |
| 5. Shore hardness | 55-70 | "Scleroscope" reading (magnifier hammer) |
| 6. Stiffness | 60,000 p.s.i. | ASTM D-747-43T |
| 7. Compressive strength | 0.1% deformation at 1700 p.s.i. | at no-load cross-head speed of 0.05"/min. ASTM D-695-42T |
| 8. Compressive creep at 50° | | modified ASTM D-621-43<br>ASTM D-621-43 |
| 1200 p.s.i.<br>1200 p.s.i.<br>4000 p.s.i. | 4-8% in 24 hrs.<br>4-5% in 24 hrs.<br>50% in 24 hrs. | |
| 9. Density at 25°C | 2.1-2.3 g/cc. | |
| 10. Flexibility | pliable in thin sheets | Films do not crack on flexing at -30°C. |
| 11. Dimensional stability | Excellent | no change on ageing |
| 12. Machining qualities | good | easily machined or punched by conventional methods |

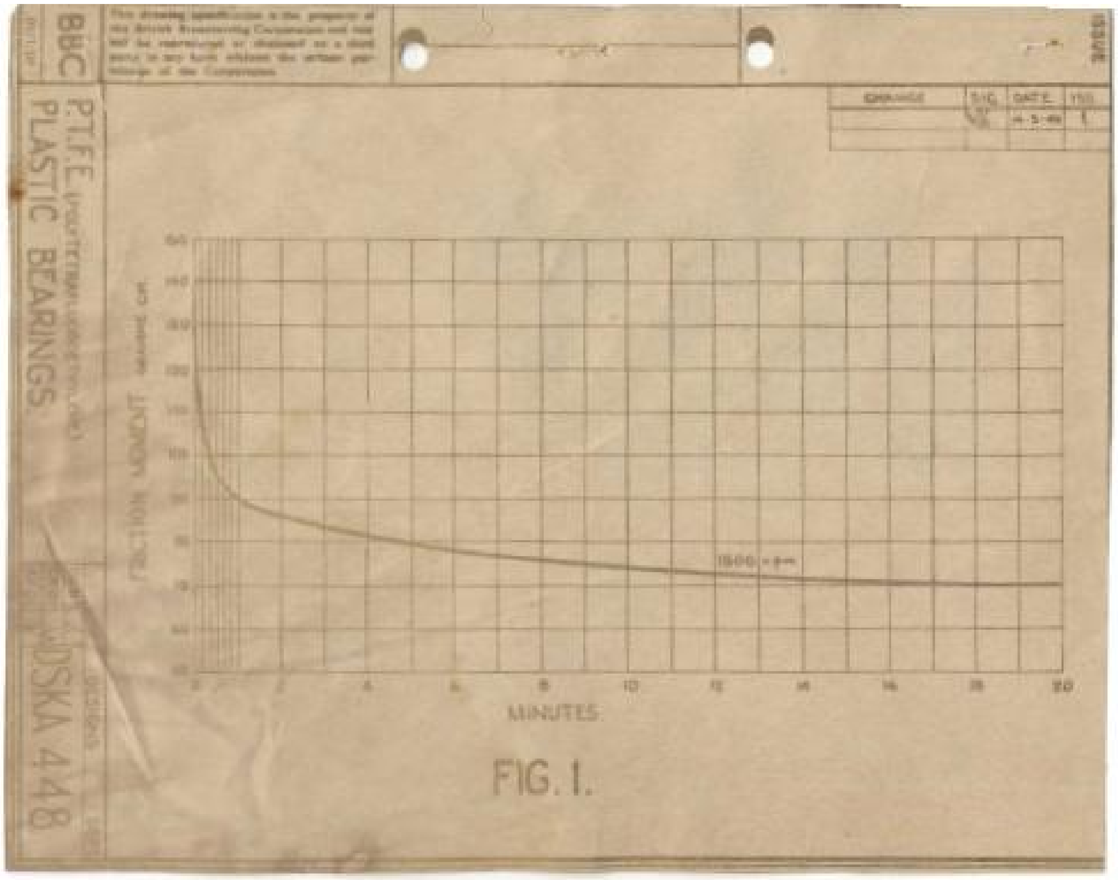
| B. Thermal | Value | Remarks |
|---|---|---|
| 1. Melting point | no true melting point | subject to cold flow under load but form stable with no load at least 300°C. |

| | B. Thermal | Value | Remarks |
|---|---|---|---|
| 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 | 250-300°C. | slow embrittlement at 300°C. |
| 5. | Conductivity | $6 \times 10^{-4}$ cals/cm²/sec/°C/cm. | Cenco-Fitch apparatus 0.125" thickness of specimen |
| 6. | Expansion coefficient (cubical) | $15 \times 10^{-5}$/cc³/°C.<br>$25 \times 10^{-5}$ "<br>$70 \times 10^{-5}$ " | (20-100°C)<br>(100-250°C)<br>(250-300°C) |
| 7. | Infra-red transmission | clear 2.7-7.5 mu. | test piece 10 mils. thick |
| 8. | Burning rate | non-flammable | |
| 9. | Heat distortion | 42°C at 264 p.s.i.)<br>58°C at 132 p.s.i.)<br>130°C at 66 p.s.i.) | modified ASTM D-648 flexibility test of deformation of bar under load, and takes shrinkage as true guide to heat distortion for poly TFE. |
| 10. | Brittleness temp. | below -80°C. | ASTM D-746-44T |

| | C. Chemical | Value | Remarks |
|---|---|---|---|
| 1. | Solubility | nil | completely resistant to all organic solvents. |
| 2. | Chemical resistance | excellent | not affected by common corrosive agents |

| | | |
|---|---|---|
| C. Chemical | Value | Remarks |
| 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-570-42, 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 ± 0.03 | |
| 2. Opacity | | 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 $30 \times 10^6$ cycles | less than 0.0002 | at 22.5°C. |

| E. Electrical | Value | Remarks |
|---|---|---|
| 2. Dielectric constant | 2.8 | at 22.5°C over the above frequency range |
| 3. Dielectric strength | 1000-2000 volts/mil | 1-8 mil thicknesses ASTM D-149-40T |
| 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 arc resistance | over 100 secs. | Does not track, carbonizes under high energy spark ASTM D-495-42 |
| 7. Corona resistance | good | |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PLASTIC BEARINGS.
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FIG. 1.