INOFLON™ 640
Granular Polytetrafluoroethylene (PTFE) Resin

INTRODUCTION

INOFLON™ 640 is a white powder with a nominal particle size of 20 µm. This fine cut resin include its very low particle size and relative high bulk density. Low particle size helps to minimize the void content in the part at very low molding pressure. INOFLON™ 640 produces parts with the highest possible mechanical & electrical properties due to its small particle size and low void content. The very low particle size and irregular shape of this resin impart stronger reinforcement and distribution uniformity of fillers which are added to modify the property of molded parts. To achieve the maximum homogeneity in a compound, it is preferred to mix the resin at a high shear rate. The temperature during mixing must be controlled < 19ºC (66ºF) to avoid the agglomeration of the PTFE particles which may result in white spot in final product.

BASICS

PTFE is a polymer with very high melting point and melt viscosity. The first melting point of PTFE is 342°C (648º F) and the melt viscosity is in the range of 10^{11}–10^{12} poise at 380°C (716ºF).This high melt viscosity inhibits any flow similar to that known for other thermoplastics. Hence nonconventional processing methods have been developed to accommodate PTFE's unique properties based on powdered metal processing technology. The main fabrication process is a modified version of compression molding of metallurgical powders.
There are four basic techniques for molding suspension polymerized or granular PTFE. These techniques are- Billet and Sheet molding, Automatic molding, Isostatic molding and Ram extrusion. All of them are variations of compression molding. These techniques are applied to convert granular resins into parts ranging in weight from a few grams to several hundred kilograms. The only continuous process for manufacturing parts from granular PTFE is called ram extrusion.
For INOFLON 640, the recommended processing technique is billet and sheet molding .This resin is highly recommended for compounding process to make all the PTFE compounds available in the market.
This guide describes basic compression molding of PTFE into shapes and articles for conversion to parts for end-use applications.

PTFE powder is compressed into a "preform" at ambient temperature. The preform has just sufficient strength to be handled, roughly equivalent to a blackboard chalk. After removal from the mold, the preform is kept for few hours for stress relaxation and then it is heated in an oven above its melting point and is sintered. The consolidation of particles during sintering is referred to as coalescence, which produces a homogenous and strong structure. Varying the cooling rate, the crystallinity of the part can be controlled. (See Figure 1)

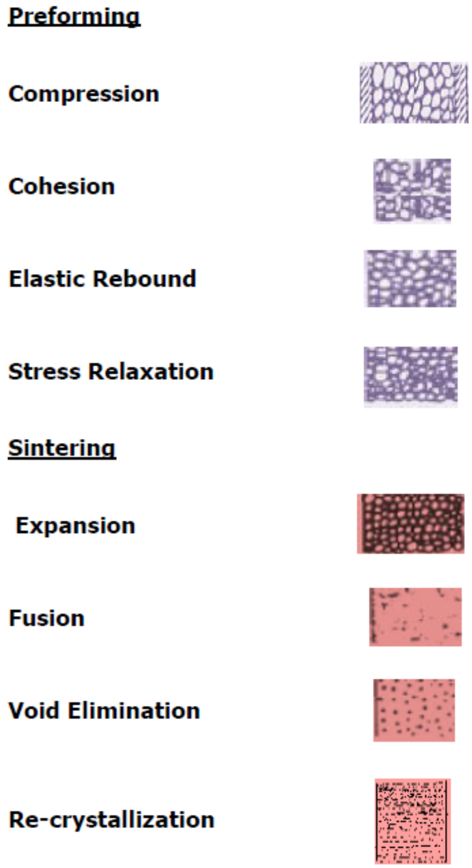


Figure 1- Schematic diagram of preforming and sintering sequence of PTFE

Compression Molding and sintering Guide

PREFORMING:

Before using the powder, it must be conditioned above 19°C (66°F). Preforming at temperatures in the range of 23–28°C (73–82°F) is most preferable. Resin temperature must be above 19˚C (66°F) during molding because of a special molecular transition of PTFE at 19˚C (66°F) (see Figure 2). PTFE molecule, which has a helical shape, tightens up by transition from a helix where 15 carbons are required for 180˚ turn to 13 carbons. Below 19˚C (66°F) PTFE becomes stiff and less conformable, thus there is a chance that molded parts could end up cracked. PTFE powder becomes sticky, forms lumps and flow is reduced at temperatures above 28˚C (82°F).

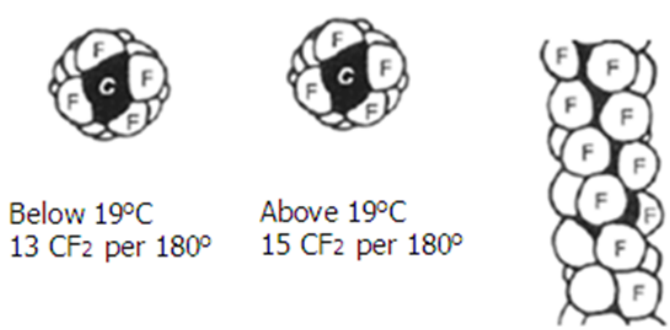


Figure 2- Transition of PTFE Molecule

First the mold is filled manually with the resin. Next, it is compacted into a preform that has a shape similar to the final shape of the desired molding. The preform is then placed in an oven where it undergoes heating and cooling cycles in which heating and cooling rates and dwell times are defined and programmed. The two cycles together are commonly called sintering cycle. The preform is heated to a temperature above the crystalline melting point of the resin during the sintering cycle. The cooling cycle is used to control the crystallinity of the part. The properties of a part are a function of preforming pressure, dwell time, sintering time and temperature, and the cooling rate.

The general effect of preform pressure on the properties of INOFLON™ 640 can be seen in the Figure 3 to 5, when simple billets are molded in the laboratory. One important observation is that INOFLON™ 640 is a highly moldable resin and yield excellent properties at relatively low preform pressures. It is suggested that, processors should determine the optimal pressure as per their own equipment as the exact required preform pressure depends on the type of process, part size and shape and application requirements.

Generally, the lower range of the preform pressure is likely to result in lower end use properties of the finished part, especially in large parts. Preform pressure has a direct bearing on void closure and part properties in applications such as electrical insulation uses. Preform pressure has to be optimized for an application as mould shrinkage and tensile properties vary with preform pressure, sintering conditions and geometry of the part.

Figure 3- Effect of Preforming Pressure on Density of INOFLON™ 640

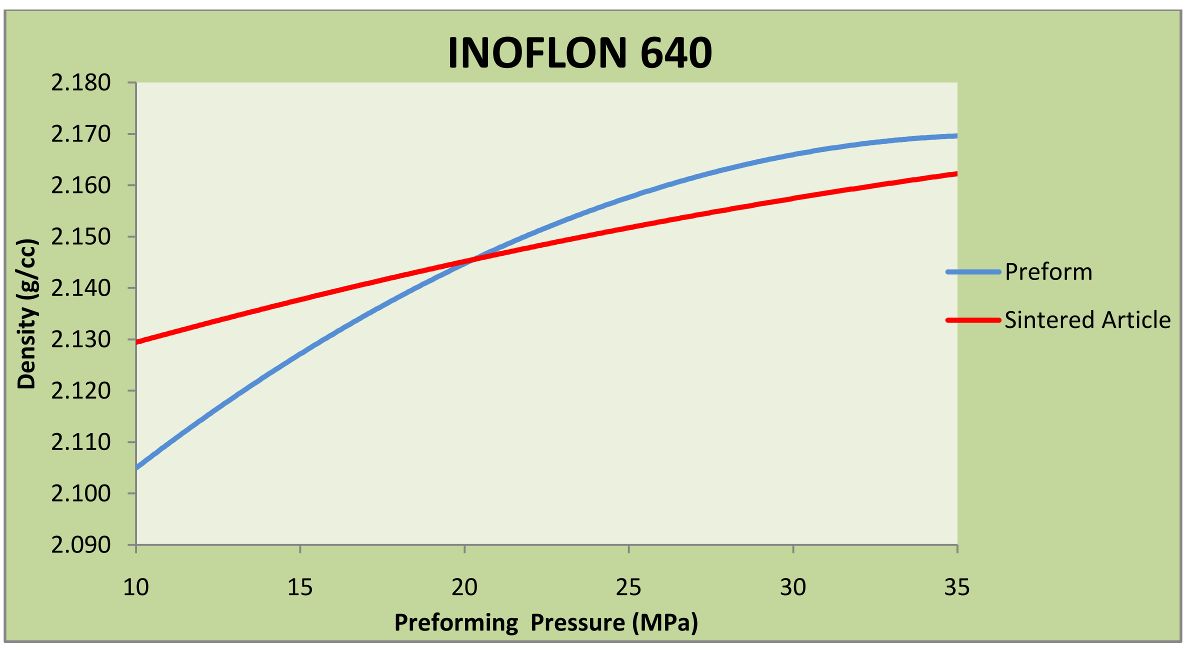


Figure 4- Effect of Preforming Pressure on Tensile Strength of INOFLON™ 640

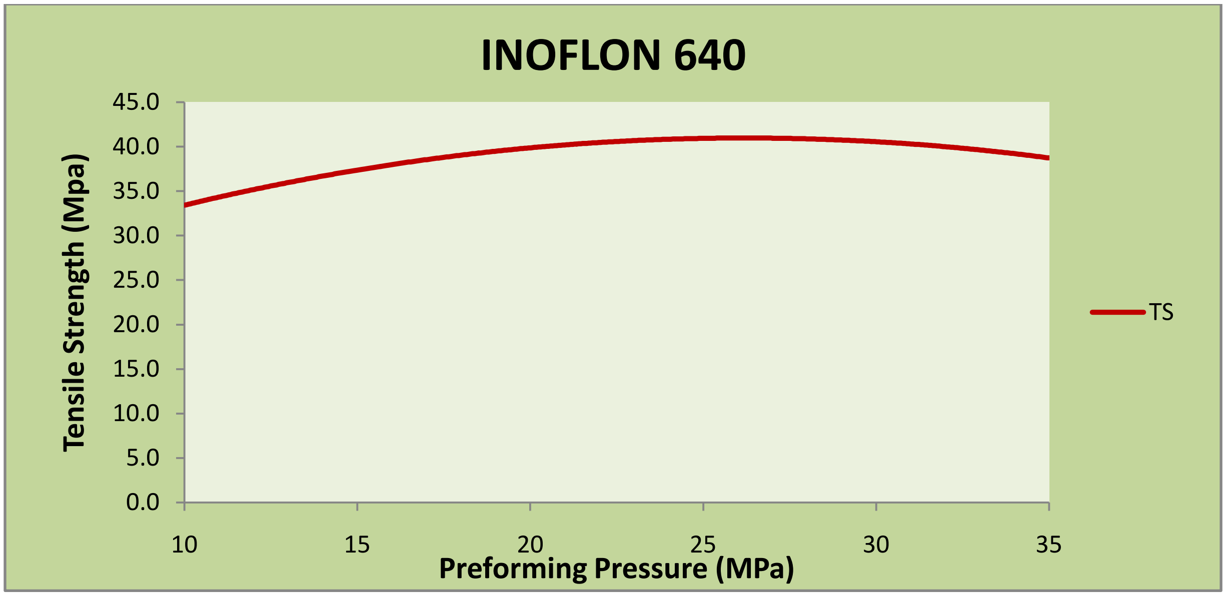
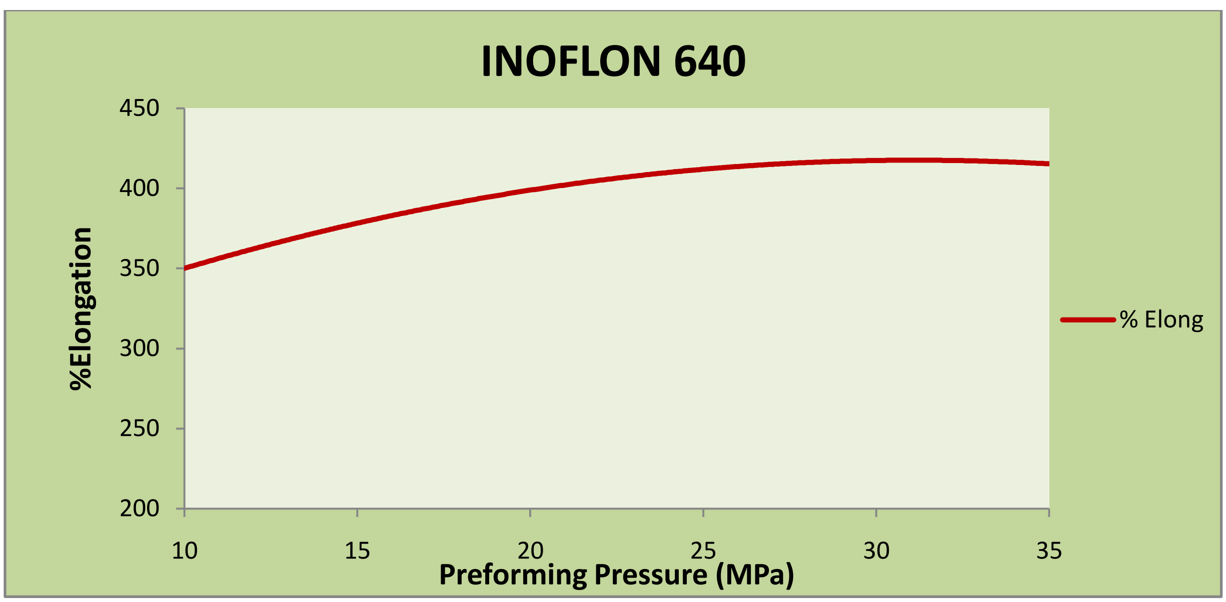


Figure 5- Effect of Preforming Pressure on Elongation of INOFLON™ 640



SINTERING:

A PTFE preform has limited cohesive strength and is essentially useless; sintering allows coalescence of the resin particles, which provides strength and void reduction. Sintering cycle profiles of time and temperature affect the final properties of the billet. Sintering temperatures exceed the melting point of PTFE 342°C (648°F) and range from 360°C to 380°C (680–716°F).

Various steps of the sintering process are described here. First the preform completes its elastic recovery and begins to thermally expand past the PTFE melting point, 342°C (648°F). The expansion can reach up to 25–30% by volume depending on the type of resin, powder, preforming pressure and temperature. Above 342°C (648°F), PTFE is a transparent gel due to the absence of a crystalline phase. At the sintering temperature, adjacent melted PTFE particles fuse together and coalesce. After two particles have completely coalesced, they would be indistinguishable and from a larger particle and voids are eliminated under the driving force of surface tension. Smaller particle resins and higher preform pressures improve coalescence.
Coalescence and void elimination require time because of the limited mobility of PTFE molecules. The sintering temperature is held for a period of time to allow fusion, coalescence and void elimination to proceed and maximize properties in the part. A time is reached beyond which the part properties no longer improve and degradation begins. Property development should be balanced against cost in selecting a sintering cycle.

Figure 6 and Figure 7 provide examples of sintering cycles for a variety of cylindrical shapes and dimensions. These examples should be used as a *conservative* starting cycles, which allow a margin for shortcomings in the molding and degassing operations. They can be further refined, optimized and possibly shortened by processors.

Figure 6- Typical Sintering Cycle for INOFLON PTFE, Solid Billets (Ref. - Table 1)

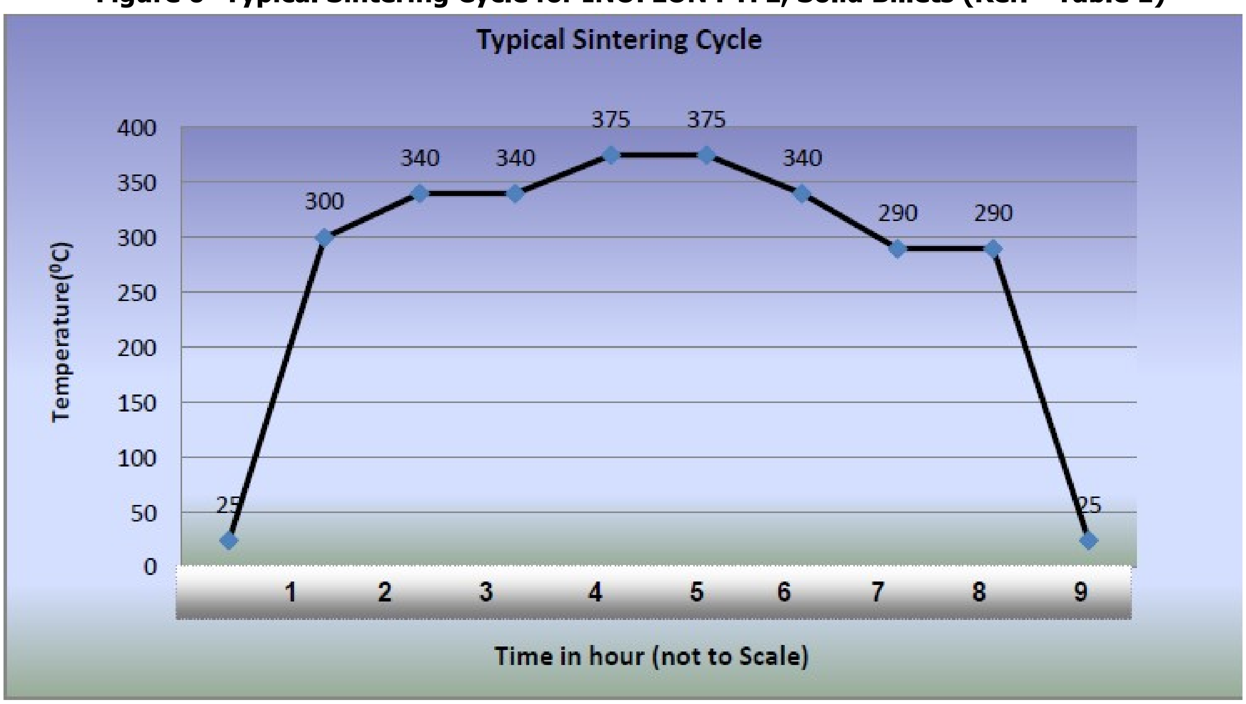


Table 1-Typical Sintering Cycle for INOFLON™ PTFE, Solid Billets:

<table>
<tr><th rowspan="2">Cycle</th><th rowspan="2">Diameter(mm)</th><th colspan="9">Time Duration (hour)</th><th rowspan="2">Total time (hrs)</th></tr>
<tr><th>1</th><th>2</th><th>3</th><th>4</th><th>5</th><th>6</th><th>7</th><th>8</th><th>9</th></tr>
<tr><td>A</td><td>25</td><td colspan="4">6</td><td>2</td><td colspan="4">6</td><td>14</td></tr>
<tr><td>B</td><td>50</td><td colspan="4">6 ½</td><td>4</td><td colspan="4">6 ½</td><td>17</td></tr>
<tr><td>C</td><td>75</td><td>2 ½</td><td>2</td><td>1</td><td>1</td><td>5 ½</td><td>1</td><td>1</td><td>1 ½</td><td>3</td><td>18 ½</td></tr>
<tr><td>D</td><td>100</td><td>2 ½</td><td>2</td><td>1 ½</td><td>2</td><td>6</td><td>2</td><td>2</td><td>1 ½</td><td>2 ½</td><td>22</td></tr>
<tr><td>E</td><td>125</td><td>4</td><td>2 ½</td><td>1</td><td>2 ½</td><td>6</td><td>2 ½</td><td>2</td><td>2</td><td>4</td><td>26 ½</td></tr>
<tr><td>F</td><td>150</td><td>6</td><td>4</td><td>2</td><td>3</td><td>10</td><td>2 ½</td><td>2</td><td>2</td><td>5</td><td>36 ½</td></tr>
</table>

Note: These process parameters are under typical laboratory condition

Figure 7- Typical Sintering Cycle for INOFLON PTFE, Annular Billets (Ref. - Table 2)

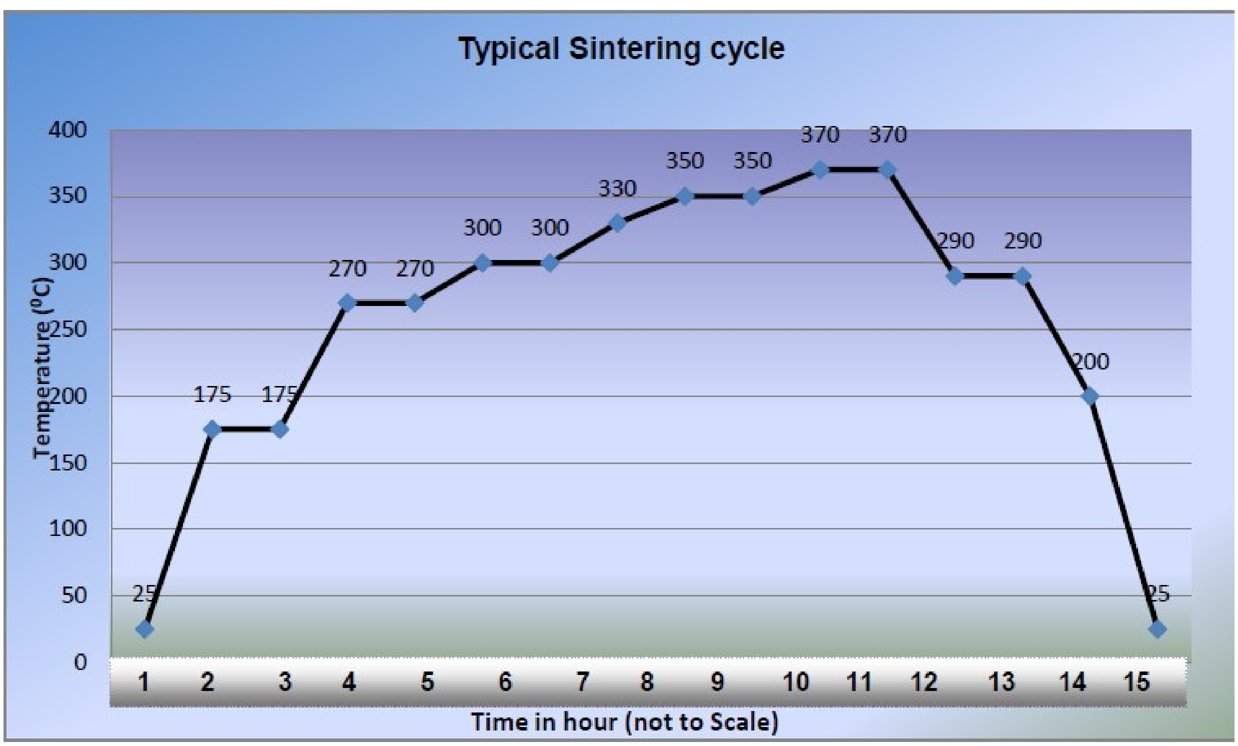


Table 2 -Typical Sintering Cycle for INOFLON™ PTFE, Annular Billets:

Cycle	Thickness (mm)	Time Duration(hr.)															Total time (hrs)
		1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	
I	25						6½					2½		6½			15½
II	50			3½			1½		4½			7	5½	1	5		28
III	75			3½			3		5½			8½	5½	1½	5		32½
IV	100			4 ½			3½		5½			11½	6½	3	3½	4	42
V	125	3	1	2	2½	1	2½	2	2	3	4	13	8	4	3½	4	55
VI	150	4	1	4	3	1½	3	2	2	3½	4	22	8	4½	4½	4	71

Note: These process parameters are under typical laboratory condition

Table 3 Typical properties of INOFLON™ 640

Properties	Test Method	Unit	640
Bulk Density	**ASTM D 4894**	**g/L**	**380**
Avg Particle size	**ASTM D 4894**	**micron**	**20**
Mold shrinkage Max	**ASTM D 4894**	**%**	**4**
Std. Specific Gravity	**ASTM D 4894**	**-**	**2.15-2.18**
Melting Point Initial	**ASTM D 4894**	**°C**	**342**
Melting Point Second	**ASTM D 4894**	**°C**	**327**
Tensile Strength (min)	**ASTM D 4894**	**M.Pa**	**30**
Elongation (min)	**ASTM D 4894**	**%**	**350**

*These are typical properties and not to be used for specification purpose

SAFETY PRECAUTIONS:

Handling and processing of PTFE must be done in ventilated area to prevent personnel exposure to the fumes liberated during sintering and heating of the resin. Fumes should not be inhaled and eye and skin contact must be avoided. In case of skin contact wash with soap and water. In case of eye contact flush with water immediately and seek medical help. Smoking tobacco or cigarettes contaminated with PTFE may result in a flu-like condition including chills, fever and sore throat that may not occur until a few hours after exposure has taken place. This symptom usually passes within about 24 hours. Vapors and gases generated by PTFE during sintering must be completely removed from the factory areas. Mixtures of some metal powders such as magnesium or aluminum are flammable and explosive under some conditions. These metal powders should be kept away from the resin.

Please read the Material Safety Data Sheet and the detailed information in the "*Guide to the Safe Handling of Fluoropolymer Resins"* published by the Fluoropolymer Division of The Society of the Plastics Industry available at www.Fluoropolymers.org .

HANDLING AND STORAGE:

For best results the powder processing areas should be kept clean and free of all contamination. Organic contamination and foreign matter usually appear as dark spots often easily visible against the white PTFE background. Organic contamination material degrades at the sintering temperatures and forms discolored spots. They oxidize away as carbon dioxide wherever sufficient oxygen exposure takes place. It is, therefore, not unusual to encounter discoloration inside a part away from the surface where hardly any oxygen is present.

NOTE warning: Do not use any of INOFLON™ PTFE resins in medical devices that are designed for permanent implantation in the human body. For other medical uses, prior permission of GFL may be sought.

For more information, please contact Gujarat Fluorochemicals Limited at:

Corporate & Marketing Office:
INOX Towers, Plot No.17, Sector 16A
Noida- 201301, U.P., INDIA
Tel: +91 - 120 - 306 3600
Fax: +91 - 120 - 306 3610

Works:
12/A, GIDC Dahej Industrial Estate, Tehsil Vagra,
Distt. Bharuch - 392130, Gujarat, INDIA
Website: www.gfl.co.in
Email: inoflon@gfl.co.in