Ryton® PPS

Chemical Properties

Table of Contents

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ISO 9002 and A2LA Certified

RYTON SISIR ISO 9000 CERT. NO.: 93-2-0230 SS ISO 9002: 1988

Accredited by the Dutch Council for Certification

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Chemical Resistance

The chemical resistance of Ryton PPS is known to be outstanding, even at elevated temperatures. As an organic polymer, it can be affected by some chemicals under certain conditions, however. Time and temperature are critical factors that must be considered when determining the level of chemical resistance required. An insignificant effect that occurs over a short period, or at a low temperature, may become significant in a few months or at elevated temperatures. For example, chlorinated hydrocarbons (such as chloroform) have no short-term effects on Ryton PPS R-4, but can significantly reduce its mechanical strength after 12 months at 200°F. Therefore, the effective chemical resistance should be measured on the basis of how well the material performs upon exposure, relative not only to the required performance level, but also to the performance of other materials used in the same application. When evaluated using these criteria, the chemical resistance of Ryton PPS is excellent in a wide variety of aggressive environments.

To characterize its chemical resistance, tensile specimens of Ryton PPS R-4 were immersed in various chemicals maintained at 200°F and tested periodically for the retention of tensile strength. This and other data have shown that there are five classes of chemicals from which certain individual members may have some effect on Ryton PPS. These classes of chemicals are (1) oxidizing agents; (2) strong acids; (3) halogens; (4) amines and (5) chlorinated hydrocarbons.

Table I – Chemical Resistance of Ryton® PPS R-4 at 200°F

	% Tensile Retained		
Chemical	24 hr	3 mth	12 mth
37% HCl	72	34	29
10% HNO_3	91	0	0
30% H_2SO_4	94	89	61
85% H_3PO_4	100	99	89
30%NaOH	100	89	63
5% NaOCl	94	97	61
Butyl Alcohol	100	100	80
Cyclohexanol	100	100	86
Butyl Amine	96	90	85
Aniline	100	86	42
2-Butanone	100	100	61
Benzaldehyde	97	47	42
Carbon Tetrachloride	100	48	25
Chloroform	81	77	43
Ethyl Acetate	100	88	58
Butyl Ether	100	89	79
p-Dioxane	100	96	59
Gasoline	100	99	80
Toluene	100	70	41
Benzonitrile	100	79	39
Nitrobenzene	100	63	31
Phenol	100	92	63
Cresyldiphenyl Phosphate	100	100	95
N-Methyl Pyrrolidone	100	92	80

Effect of Exposure to Gasoline/Alcohol

Tensile and Izod impact specimens of Ryton PPS R-4 were immersed in gasoline/alcohol for specified periods of time. The specimens were removed from the solution, wiped clean of excess liquid, weighed and tested. The results in *Table II* demonstrate the negligible effect of gasoline/alcohol on mechanical properties of Ryton PPS R-4.

Table II – Effect of Gasoline/Alcohol Exposure to Ryton® PPS R-4

	% Retention (Change)					
	Room Temperature Exposure			250°F Exposure		
	2 wk	6 wk	12 wk	2 wk	6 wk	12 wk
Gasoline/Methanol [a]						
Tensile Break	92	108	106	94	104	103
Notched Impact	94	95	96	88	86	81
Weight	(-0.02)	(-0.18)	(-0.12)	(+0.24)	(+1.0)	(+0.57)
Thickness	(-0.09)	(-0.19)	(+0.13)	(+0.47)	(+0.66)	(+0.13)
Gasoline/Ethanol [b]						
Tensile Break	95	106	106	103	88	98
Notched Impact	96	95	96	94	92	93
Weight	(-0.04)	(-0.40)	(-0.18)	(-0.06)	(+1.0)	(+0.39)
Thickness	(+0.09)	(-0.28)	(+0.13)	(+0.28)	(+0.51)	(+0.13)

[a] 85% unleaded gasoline and 15% methanol by volume

[b] 85% unleaded gasoline and 15% ethanol by volume

Effect of Long-Term Exposure to Ethanol

This chemical resistance exposure test was performed by the Fuels and Lubricants Division of Ford Motor Company. The test specimens of Ryton PPS R-4 were soaked in an ethanol solution containing 4% methanol, 2% methyl isobutyl ketone, 1% ethyl acetate, and 1% hydrocarbon with 5% additional water and 300 ppm acetic acid. The fuel was changed every two weeks and samples were removed at various times up to fifteen months. Tensile strength, flexural modulus and flexural strength were determined at both room temperature and 200°F. The following results indicate that this solvent has no effect on the mechanical properties of Ryton PPS R-4 after fifteen months. These results are impressive and illustrate the excellent chemical resistance of Ryton polyphenylene sulfide.

Table III – Effect of Long-Term Exposure of Ethanol to Ryton® PPS R-4

Property	Temp.	Control	5 wk	3 mth	5 mth	15 mth
Tensile, Ksi	R.T.	18.5	18.5	19.2	18.9	18.8
	200°F	16.1	15.9	16.6	16.5	16.1
Flexural Modulus, Msi	R.T.	1.8	1.8	1.8	1.8	1.7
	200°F	1.2	1.2	1.2	1.2	1.1
Flexural Strength, Ksi	R.T.	25.8	24.2	25.4	25.2	25.1
	200°F	22.6	20.2	20.5	20.3	19.5

Effect of Exposure to Automotive Fluids

To determine what, if any, effect may occur when Ryton PPS is exposed to automotive fluids, tensile and flexural strength specimens of Ryton PPS R-4 were immersed in heated (365°F) motor oil, transmission fluid, and hydraulic fluid for specified periods of time. The specimens were removed from the solution, wiped clean of excess fluid, weighed and tested. Results demonstrate the negligible effect that these fluids have on tensile and flexural strength of Ryton PPS R-4.

Table IV – Automotive Fluids Exposure to Ryton® PPS R-4

R-4 Immersion In Motor Oil at 365°F[(a)]

R-4 Property	No Exposure	3 days	4 weeks
Weight Change, %	–	+0.07	+0.03
Thickness Change, %	–	-0.07	+0.03
Length Change, %	–	-0.03	-0.04
Flexural Strength, Ksi	24.0	22.6	23.0
Tensile Strength, Ksi	18.3	17.0	15.5

R-4 Immersion in Hydraulic and Transmission Fluids At 356°F for 5 Weeks

R-4 Property	Control	Transmission Fluid[(b)]	Hydraulic Fluid[(c)]
Weight Change, %	–	-0.096	+1.24
Thickness Increase, %	–	0.094	0.95
Flexural Strength, Ksi	20.6	17.6	18.5
Tensile Strength, Ksi	15.7	13.7	13.5

(a) SAE 30 motor oil, detergent grade, Phillips 66 Company

(b) Type F transmission fluid, Phillips 66 Company

(c) DOT 3 brake fluid, Phillips 66 Company

Effect of Exposure to Aircraft Hydraulic Fluid

To measure the effect of aircraft hydraulic fluids on Ryton PPS, specimens of Ryton PPS R-4 were immersed in these heated fluids for specified periods of time. The specimens were then removed from the solution, wiped clean of excess fluid, weighed and tested for tensile and impact strength. The results in *Table V* indicate negligible effect of the hot hydraulic fluid on tensile and Izod properties.

Table V – Ryton® PPS R-4 Exposure to Aircraft Hydraulic Fluid

		Temperature					
		200°F	140°F				
Property	Unaged	24 hr	1 wk	2 wk	1 mth	3 mth	1 yr
Tensile, Ksi	20.3	20.3	19.2	21.0	22.5	20.2	–
Izod Impact, ft-lbf/in 1/8 in specimen Unnotched	7.6	4.8	7.4	8.0	7.7	7.3	6.5
Weight Loss or Gain, %	–	+0.03	+0.02	-0.001	-0.01	-0.02	-0.03

Effect of Exposure to Transformer Oil

Injection molded tensile specimens were immersed in transformer oil for 24 hours at ambient temperature and 24 days (maximum weight gain) at 200°F. The tensile strength of Ryton PPS R-4 remained unaffected by either immersion.

Grade	Time	Temp., °F	Weight Gain, %	Tensile, % of Original	Elongation, % of Original
R-4	24 hr	75	0.014	–	–
R-4	24 days	200	0.029	100	100

Water Absorption

ASTM D570

Several Ryton PPS compounds were evaluated for weight gained during water immersion at various conditions specified in the ASTM Procedure Section 6.1 – 24 hours @ 75°F; Section 6.2 – 2 hours @ 212°F; and Section 6.7 – 48 hours @ 122°F. For this test, specimens measuring 1 x 3 inches were cut from 1/8 inch thick injection molded plaques.

To determine the effects of long-term immersion, injection molded tensile bars were immersed in 212°F water and weighed periodically to identify the point of saturation. The Ryton PPS R-4 specimens required 31 days to reach equilibrium, at which time the tensile strength and elongation were determined, as shown in *Table VI*. The loss in Ryton PPS R-4 tensile strength in 212°F immersion might be attributed to the loss of bond strength between the glass fiber and polymer. Some applications may require compounds developed for enhanced moisture stability of that interface.

Table VI – Water Absorption

Ryton PPS Specimens	Time, hr	Temp., °F	Weight Gain, %	Tensile, % of Orig.	Elongation, % of Orig.
R-4 Tensile Bars	[a]	212	1.01	87	86
R-4 Plaques	2	212	0.080	–	–
	6	212	0.131	–	–
	48	122	0.047	–	–
	24	75	0.008	–	–
R-10 7006A Plaques	24	75	0.01–0.04	–	–

[a] Test time to equalibrium, 31 days.

Dimensional Stability in Water

ASTM D1041

The samples used in the water absorption test were also measured for dimensional changes per ASTM D1041, Measuring Changes in Linear Dimensions of Plastics. No measurable changes were detected.

Table VII – Dimensional Stability in Water

Ryton PPS Grade	Immersion	% Change in Length
R-4	24 hr	0
R-7	168 hr	0
R-4 04	24 hr	0
A-200	24 hr	0

Effect of Exposure to High Temperature Water

Unfilled PPS polymer is highly resistant to hydrolysis. In fact, it exhibits very little change in properties after 20 weeks exposure to hot water. Some glass-reinforced PPS compounds, however, do exhibit a decrease in strength during the first 6 to 8 weeks of exposure, and then leveling at approximately 50% of the initial property value. Apparently, the hot water reduces adhesion of the glass reinforcement to the polymer. This phenomenon is not unusual with glass fiber reinforced plastics. Several Ryton PPS compounds have been designed for applications requiring particularly good resistance to high temperature water and humidity, so moisture-resistant additives are included to enhance the strength and stability of the fiberglass/polymer interface.

Even without moisture-resistant additives, Ryton PPS compounds have been used quite successfully in hot water applications for many years. Their successful field service history indicates that proper design can compensate for the initial loss of strength.

The effect of water at 248°F on flexural strength of Ryton PPS R-4 was determined. The results are shown in *Table VIII*.

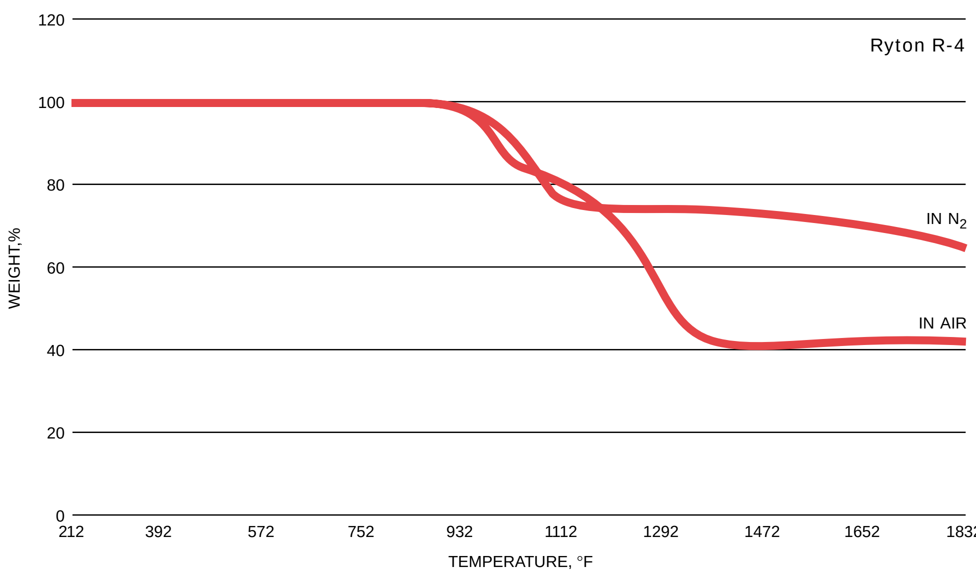
Table VIII – High Temperature Water Exposure to Ryton® PPS R-4

Time, mth	Flexural Strength, Ksi
0	23.0
1/4	15.0
1/2	12.5
1	12.0
2	11.0
4	11.0
6	10.5
8	10.5
12	11.0

High Temperature Stability in Air and Nitrogen

The thermogravimetric apparatus (TGA) is used to determine weight loss at increasing temperature in selected atmospheres. Degradation of Ryton PPS proceeds rapidly in air at temperatures exceeding 932°F. In a nitrogen atmosphere, the degradation begins at the same temperature as in air, but about 60% of the polymer remains at temperatures between 1112 – 1652°F.

Figure 1 – Dielectric Constant vs Frequency and Temperature



Thermal Aging of Ryton® PPS

The long-term thermal endurance of Ryton PPS compounds has been documented very thoroughly under the Component Recognition Program of Underwriters Laboratories (UL). The relative thermal indices and supporting discussion are presented later in the section on Underwriters Laboratories.

Plastics used in appliances and structural electrical/electronic components must survive rigorous scrutiny by Underwriters Laboratories Inc. (UL). Such detailed examinations are intended to reduce possible electrical and flammability hazards. Other than end-product tests performed on actual molded parts, various standards require plastics to meet or exceed minimum performance requirements established for many properties specific to the material. In order to minimize the test procedures required of manufacturers, Phillips has undertaken extensive and ongoing test programs to document the performance of various Ryton polyphenylene sulfide molding compounds in the most critical of material-specific properties.

Under its Component Recognition Program, UL maintains this documentation with complete reports on the performance of Ryton PPS molding compounds in File NO. E54700. For ease of reference, UL also publishes excerpts from all such reports in its “Recognized Component Index” (Yellow Book) and issues individual updated entries on “Yellow Cards”. Unfortunately, the brevity of the “Yellow Card” format provides little explanation of the information, and some discussion may explain its significance. For the specific Underwriter Laboratories tests, the actual values are ranges, and these ranges can be found in the description of the actual test.

Effect of Weathering on Natural and Black Ryton® PPS R-4

Ryton PPS R-4 and R-4 with 2% carbon black were aged in an Atlas Weather-Ometer for 10,000 hours. Tensile strength and elongation were measured at specific time intervals indicated in *Table IX*. The Ryton PPS R-4 contained no UV inhibitor. The black compound contained 2% carbon black as UV absorber.

Table IX – Weathering Effects

	Ryton PPS R-4		Ryton PPS R-4 with 2% carbon black	
Hours Exposed	Tensile, Ksi	% Elongation	Tensile, Ksi	% Elongation
0	16.7	1.1	17.4	1.2
2,000	15.3	1.2	17.3	1.1
6,000	15.5	1.4	17.3	0.9
8,000	14.4	1.2	16.8	1.0
10,000	10.6	0.6	–	–
% Retention	63	55	97	79
Erosion, Mils	13		2	

Effects of Radiation on the Properties of Ryton® PPS R-4

Ryton PPS is used in many nuclear installation applications because it can withstand both neutron and gamma particle radiation. As shown in *Table X*, Ryton PPS R-4 exhibits no significant deterioration of mechanical properties with relatively high exposures to gamma and neutron radiation. By comparison, the effects of similarly intense exposures on the mechanical performance of other Ryton PPS compounds may seem significant. In general, however, the changes fall well within normal experimental variance.

Table X – Effect of Radiation on Mechanical Properties of Ryton® PPS R-4

Conditions	In Reactor Core	In Water Pool
Temperature	95°F	86°F
Radiation	Mainly neutrons	Mainly gamma
Intensity	10^8 rad	10^7 rad
Used Particle Detectors	Calorimeter and activation detectors	Ionization chamber

Radiation Dose	Flexural Strength, Ksi	Mod. of Elasticity, Msi
0	28.7	1.90
Gamma		
5 x 10^8 rad	29.7	1.81
1 x 10^9 rad	30.2	1.84
5 x 10^9 rad	28.5	1.82
Neutron		
5 x 10^8 rad	29.0	1.91
1 x 10^9 rad	28.9	1.88

Table XI – Comparison of Radiation Effects on Mechanical Properties of Ryton® PPS Compounds

Conditions	Gamma	Mainly Neutron
Temperature	122 – 131°F	122 – 131°F
Dosage	3 x 10^8 rads	4 x 10^8 rads

		Gamma		Mainly Neutron	
Property	Unexposed	Exposed	% Change	Exposed	% Change
Ryton PPS R-4					
Tensile, Ksi	21.4	21.4	0	19.3	-9.8
Elongation, %	1.08	1.09	+0.9	0.98	-9.3
Flexural Modulus, Msi	1.8	1.9	+2.0	1.9	+2.0
Flexural Strength, Ksi	26.7	24.9	-6.7	23.0	-13.9
Izod Impact, ft·lbf/in, Notched	1.48	1.42	-4.1	1.30	-12.2
Ryton PPS R-10 5002C					
Tensile, Ksi	11.0	10.7	-2.7	9.3	-15.5
Elongation, %	0.30	0.33	+1.1	0.36	+20.0
Flexural Modulus, Msi	2.3	2.4	+2.7	2.3	+.09
Flexural Strength, Ksi	15.5	15.3	-1.3	14.6	-5.8
Izod Impact, Ft·lbf/in Notched	0.74	0.71	-4.1	0.71	-4.1
Ryton PPS R-10 7006A					
Tensile, Ksi	13.8	14.1	+2.2	12.0	-13.0
Elongation, %	0.37	0.49	+32.4	0.58	+56.7
Flexural Modulus, Msi	2.2	2.2	+1.5	2.1	-3.5
Flexural Strength, Ksi	20.9	20.6	-1.4	19.9	-4.8
Izod Impact, ft·lbf/in, Notched	0.86	0.83	-3.5	0.80	-7.0

Liquid Permeability

To measure the liquid permeability of Ryton PPS, a 5 mil film sample was formed as a baked coating by spraying unfilled PPS onto aluminum foil. The film was freed by dissolving the foil in a sodium hydroxide bath. Die-cut samples from this film were fitted to the tops of wide-mouth glass bottles by using a rubber gasket and a lid, cut to expose a surface area of 15 $inch^2$. The liquids were placed in the bottles, gaskets and film put in place, and the cut-out lid tightly screwed in place. The apparatus was then inverted in order for the liquid to be in direct contact with the film. Weight loss was determined at one-week intervals throughout four weeks of conditioning. The weight loss was calculated in terms of g·mil/100 in^2·24 hr.

Chemical	Weight Loss @ 73.4°F
Water	0.8
Hydrochloric Acid (37%)	0.1
Acetic Acid	2.0
Benzene	6.3
Methyl Alcohol	0.3

Water Vapor Transmission

ASTM E96, Condition E

This specimen was a 5 mil film of PPS. Its water vapor transmission rate was 1.66 g·mil/100 in^2·24 hr.

Gas Transmission

ASTM D1434, Method M (Manometer)

This test was performed on a specimen of 5 mil film prepared from a Ryton PPS coating. It provides for a constant pressure and constant vacuum rather than the diminishing pressure and vacuum procedure.

Gas	Specimen Thickness, inch	Transmission Rate,cc·mil/100 in^2·24 hr
Oxygen	0.005	30
Carbon Dioxide	0.005	75
Hydrogen	0.005	420
Ammonia	0.005	15
Hydrogen Sulfide	0.005	3
Oxygen	0.035	15 – 20
Air	0.035	20 – 30

Results are expressed in terms of 1 atmosphere total driving pressure.

MATERIAL SAFETY DATA SHEET

MSDS# 1605

Quadrant EPP
2120 FAIRMONT AVENUE
P.O. BOX 14235
READING, PA. 19612-4235

TELEPHONE NUMBERS:
PRODUCT INFORMATION
610-320-6600
TRANSPORTATION EMERGENCY (CHEMTREC) - 800-424-9300

IDENTIFICATION

PRODUCT NAME: Ryton PPS
CAS NUMBER: 26125-40-S
PRODUCT CODE: VR-1040 / PSGF
CHEMICAL FAMILY: Polymer
CHEMICAL NAME: Poly (1,4-Phenylen. Sulfide)
TSCA LISTING: Appears on the Inventory of Chemical Substances published by the U.S. Environmental Protection Agency Standard 29 CFR 1910. 1200

INGREDIENTS

NAME	CAS NO	TLV (ACGIH)
Polytetrafluoroethylene	09002-84-0	10 mg/me
Milled glass fibers	65997-17-3	10 mg/rn^3
Zeothix	07631-86-9	10 mg/rn^3

PHYSICAL DATA

MELTING POINT: 296°C (565°F)
VAPOR DENSITY: N/A
% VOLATILES BY VOLUME: N/A
SOLUBILITY IN WATER: Insoluble
DENSITY: 1.66 gm/cm^3
APPEARANCE AND ODOR: Solid rods, tubes, plates or fabricated parts. Odorless. Brown color

FIRE AND EXPLOSION HAZARD DATA

FLASH POINT: 930°F.
EXTINGUISHING MEDIA: Water, CO_2, Foam, Dry Chemical (Class B).
SPECIAL FIRE FIGHTING PROTECTIVE EQUIPMENT: Self-contained breathing apparatus.
UNUSUAL FIRE AND EXPLOSION HAZARDS: Toxic fluorine compounds evolved in fire. Does not burn without an external source of fuel.

REACTIVITY DATA

STABILITY: Stable under normal conditions.
CONDITIONS TO AVOID: Not established.
MATERIALS TO AVOID: Not established.
HAZARDOUS POLYMERIZATION: Will not occur.
HAZARDOUS DECOMPOSITION PRODUCTS: Degradation temperatures above ° 400 C give off carbon dioxide, carbon monoxide, sulfur dioxide, carbonyl sulfide, tetrafluoroethylene, hexafluoropropylen,, per-fluoroisobutylene, carbonyl fluoride.

EFFECTS OF OVEREXPOSURE / TOXICITY DATA

PRIMARY ROUTE OF EXPOSURE: Treat dust from machining and/or fabrication as nuisance particulate.

ACUTE EFFECTS OF OVEREXPOSURE:

INGESTION (swallowing): Not applicable.
INHALATION (breathing): Not applicable (NOTE: particles can be inhaled when molded shapes or part. are machined causing respiratory irritation.)
EYE CONTACT: Not applicable (NOTE: When a molded part is machined, dust and particles formed can enter the eye and may cause irritation.)
SKIN CONTACT: No significant irritation expected other than possible mechanical irritation.

CHRONIC EFFECTS OF OVEREXPOSURE

CARCINOGENITY: NONE
REPRODUCTI VE: NONE
MUTAGENICITY: NONE
TARGET ORGANS: NONE

EMERGENCY AND FIRST AID PROCEDURES

INGESTION (swallowing): Not applicable.
INHALATION (breathing): Particles can be inhaled when the molded part is machined causing respiratory irritation. If this occurs seek medical attention.
SKIN CONTACT: Not applicable.
EYE CONTACT: Not applicable. (NOTE: when a molded part is machined, particles and/or dust may enter the eye causing mechanical irritation. If this occurs, wash thoroughly with water for 15 minutes. If irritation continues, contact a physician.)

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SPECIAL PROTECTION INFORMATION

RESPIRATORY PROTECTION: None required. When machining the product use a NIOSH approved dust respirator.
VENTILATION: Provide local exhaust to minimize exposure if material in heated above 500° F.
LOCAL EXHAUST: Recommend when appropriate to control employee exposure during machining or high temperature fabrication and/or processing .
PROTECTIVE GLOVES: Not required.
EYE PROTECTION: When machining the molded product wear safety glasses or goggles.

SPILL OR LEAK PROCEDURE

STEPS TO BE TAKEN IN CASE OF SPILLAGE: None required.
WASTE DISPOSAL METHOD: Dispose of in an industrial or municipal landfill in compliance with federal, state and local environmental regulations.

SPECIAL PRECAUTIONS

Wash hands and face after handling to avoid transfer of PTFE to smoking tobacco or cigarettes. Smoking material must not be allowed in the work areas where these materials are being handled. PTFE exposed to temperatures above 300°C (572° F) or smoking tobacco or cigarettes that have been contaminated with PTFE can create influenza-like symptoms. Symptoms will pass within 36-48 hours. Use good industrial hygiene practices.

MISCELLANEOUS INFORMATION

Prepared by: T.W. Swavely, Division Quality Manager/jr

Issued: **05/14/01 Rev 00**

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NE = Not established.
> = New or revised information in this section when " > " appears in the left margin.