Tefzel™ ETFE

Fluoropolymer Resins

Properties Handbook

Chemours™

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INTRODUCTION

Tefzel™ ETFE fluoropolymers are melt-processible thermoplastics. They are part of the family of fluorine-based products that includes Teflon™ PTFE, Teflon™ FEP, and Teflon™ PFA fluoropolymer resins.

This handbook presents data for engineers and others involved in materials selection and product design. It contains detailed information for the evaluation of Tefzel™ ETFE in electrical, mechanical, and chemical applications.

All properties presented in this handbook should be considered as typical values and are not to be used for specification purposes.

A variety of natural and reinforced compositions is available, permitting the selection of resins based on specific applications or processing needs.

For additional technical data, information about the current line of Tefzel™ ETFE grades, or design assistance for a particular application, please contact your Chemours sales representative.

Commercially Available Tefzel™ ETFE Fluoropolymers

Tefzel™ ETFE Grade	Resin Characteristics	Applications
200	General-purpose fluoropolymer resin with intermediate flow rate. Recommended upper service temperature is 150 °C (302 °F)	▪ Electrical sleeving, coil forms, sockets, connectors, and switches
207	Highest MFR among ETFE resins	▪ Ideal for injection molding and thin wall extrusion
280	Premium fluoropolymer resin with a relatively low flow rate, greatly enhanced flex life, and resistance to environmental stress	▪ Components, linings, and molded parts for use in unusually extreme thermal, mechanical, and chemical environments
750	Superior stress crack resistance with superior mechanical properties at high temperatures	▪ Appliance wire ▪ Motor lead wire ▪ Wire and cable
HT-2160	Static dissipating semi-conductive resin	▪ Extruded tubing, pipe, and other profiles for hose ▪ Injection- and blow-molded articles requiring superior electrical, chemical, and thermal properties
HT-2170	Static dissipative resin with lower melting point	▪ Extruded tubing, pipe, and other profiles for hose ▪ Linings of components used in chemical processing industries ▪ Industrial film ▪ Injection- and blow-molded articles requiring superior electrical, chemical, and thermal properties and stress crack resistance
HT-2181	General-purpose resin with improved physical properties	▪ Films ▪ Tubing ▪ Injection-molded articles or linings ▪ Wire and cable
HT-2183	Improved stress crack resistance version of HT-2181	▪ Tubing ▪ Injection-molded articles or linings ▪ Wire and cable
HT-2185	Higher flow rate version of HT-2181	▪ Films ▪ Tubing ▪ Injection-molded articles or linings
HT-2188	Specialty resin with superior stress crack resistance and low melting point	▪ Films ▪ Specialty parts
HT-2202	Special-purpose resin designed to promote adhesion between polyamide and ETFE resins	▪ Tubing, valves, containers, and fasteners ▪ Battery or instrument components
HT-2202HS	Higher MFR version of HT-2202	▪ Tubing ▪ Wire coating
HT-2184	Powder for specialty applications	▪ Ideal for when materials must be dispersed in an ETFE matrix. Materials can be well dispersed in the powder and then either compression molded or melt mixed for additional processing.
HT-2195	Roto-molding and roto-lining grade	▪ Hollow parts ▪ Complex geometries ▪ Lining

Other product grades are also available for special processing needs. Tefzel™ ETFE film is available in a wide range of thicknesses for electrical, chemical, and release applications. These include:

Type LZ:	General-purpose film
Type CLZ:	Treated one side for improved cementability
Type CLZ-20:	Treated both sides for improved cementability

Specifications

The ASTM material specification covering Tefzel™ ETFE is D3159.

Tefzel™ ETFE is also called out in various industrial and military specifications for tubing, molded parts, and film, as well as numerous wire and cable applications.

Description

Tefzel™ ETFE can best be described as a rugged thermoplastic with an outstanding balance of properties. Mechanically, it is tough and has medium stiffness (1,170 MPa [170,000 psi]), impact, and abrasion resistance. Flex life depends upon the grade used.

Tefzel™ ETFE is typically considered to have a no-load continuous use temperature of 150 °C (302 °F). In certain specific applications, Tefzel™ ETFE can have an upper service temperature in excess of 230 °C (392 °F). See "Thermal Properties" section for a more complete discussion of thermal rating.

Tefzel™ ETFE is weather-resistant, inert to most solvents and chemicals, and hydrolytically stable. It has excellent resistance to radiation, but is not immune to damage by long-term exposure to gamma radiation—especially at elevated temperatures. Where specific radiation requirements must be met, adequate testing of the proposed application in the radiation environment must be carried out to establish the suitability of Tefzel™ ETFE for this application.

Electrically, Tefzel™ ETFE is an excellent low-loss dielectric with a uniformity of electrical properties not normally found with other thermoplastics.

A list of typical properties of Tefzel™ ETFE is shown in Table 1.

Tefzel™ ETFE can be extruded or injection-molded easily, using conventional techniques, and, thus, presents no unusual operator training problems. Corrosion-resistant equipment is recommended for extended production runs. Electrically heated dies are recommended for injection molds.

Tefzel™ ETFE can perform successfully in applications where other materials are lacking in mechanical toughness, broad thermal capability, ability to meet severe environmental conditions, or limited by fabricating problems.

As is the case with all new developments, a thorough prototype and test program is recommended to ensure successful performance of Tefzel™ ETFE compositions in specific applications.

Table 1. Typical Properties of Tefzel™ ETFE

Property*	ASTM Method	Unit	Tefzel™ ETFE
Mechanical			
Melt Flow Rate	D3159	g/10 min	7
Ultimate Tensile Strength, 23 °C (73 °F)	D638	MPa (psi)	46 (6,500)
Ultimate Elongation, 23 °C (73 °F)*	D638	%	300
Compressive Strength, 23 °C (73 °F)**	D695	MPa (psi)	17 (2,500)
Flexural Modulus	D790	MPa (psi)	600–1,200 (85,000–170,000)
Impact Strength, 23 °C (73 °F)	D256	J/m (ft·lb/in)	No Break
Hardness, Durometer, Shore D	D2240		67
Coefficient of Friction, Metal/Film	D1894		0.23
Deformation Under Load, 23 °C (73 °F), 1,000 psi, 24 hr	D621	%	0.3
Linear Coefficient of Expansion	E831	mm/mm· °Cx10^{-5} (in/in· °Fx10^{-5})	
0–100 °C (32–212 °F)			13.1 (7.3)
100–150 °C (212–302 °F)			18.5 (10.3)
150–200 °C (302–392 °F)			25.2 (14)
Specific Gravity	D792		1.71
Water Absorption, 24 hr	D570	%	0.007
Electrical			
Surface Resistivity	D257	ohm·sq	>10^{16}
Volume Resistivity	D257	ohm·cm	>10^{16}
Dielectric Strength, 23 °C (73 °F)	D149	kV/mm (V/mil)	
0.25 mm (10 mil)			64 (1,600)
3.20 mm (126 mil)			15 (370)
Dielectric Constant, 22 °C (72 °F), 1 MHz	D1531		2.6
Dissipation Factor, 22 °C (72 °F), 1 MHz	D1531		0.007
Arc Resistance	D495	sec	122
Thermal			
Melting Point	DTA D3418	°C (°F)	220–280 (428–536)
Heat of Fusion	DSC D3417	kJ/kg (Btu/lb)	50.7 (21.8)
Specific Heat	DSC	kJ/kg·K (cal/g·°C)	
25 °C (77 °F)			0.25
100 °C (212 °F)			0.3
150 °C (302 °F)			0.34
300 °C (572 °F) (Melt)			0.38
Heat of Combustion	D240	MJ/kg (Btu/lb)	13.7 (5,900)
Thermal Conductivity		W/m·K (Btu·in/hr·ft^2·°F)	0.24 (1.65)
Limiting Oxygen Index (LOI)	D2863	%	30-32
Heat Deflection Temperature	D648	°C (°F)	
455 kPa (66 psi)			81 (177)
1620 kPa (264 psi)			51 (123)
Continuous Service Temperature		°C (°F)	150 (302)

*Actual value depends on grade, test specimen, and test conditions.
**Failure defined as stress at 5% strain.

MECHANICAL PROPERTIES

Strength and Stiffness

Tefzel™ ETFE is less dense, tougher, stiffer, and exhibits a higher tensile strength and creep resistance than Teflon™ PTFE and Teflon™ FEP fluoropolymer resins. It is, however, similarly ductile. Tefzel™ ETFE compositions display the relatively nonlinear stress-strain relationships characteristic of nearly all ductile materials.

Tensile Strength vs. Temperature

Figure 1 shows the effect of temperature on tensile strength for Tefzel™ ETFE 200 and Tefzel™ ETFE 280. The effect of temperature on ultimate elongation is shown in Figure 2. These measurements were made on 5″ x 0.5″ x 0.125″ injection-molded tensile bars. Thinner test specimens will result in slightly higher ultimate elongation values.

The effect of temperature on tensile modulus is shown in Figure 3.

Figure 1. Tensile Strength vs. Temperature

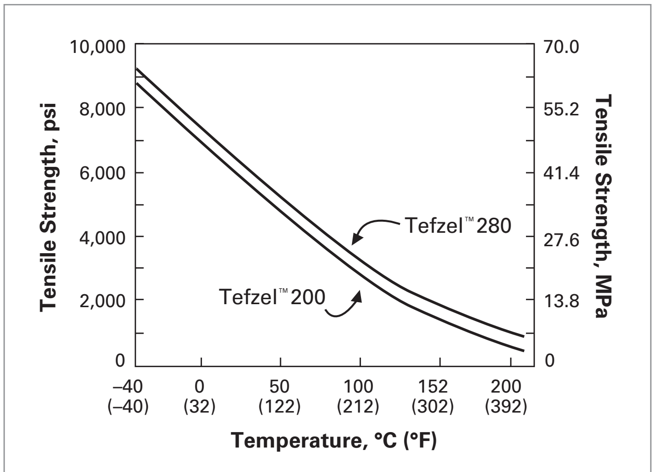


Figure 2. Tefzel™ ETFE 200 and 280—Ultimate Elongation vs. Temperature, 5″ x 0.5″ x 0.125″ Injection-Molded Bars

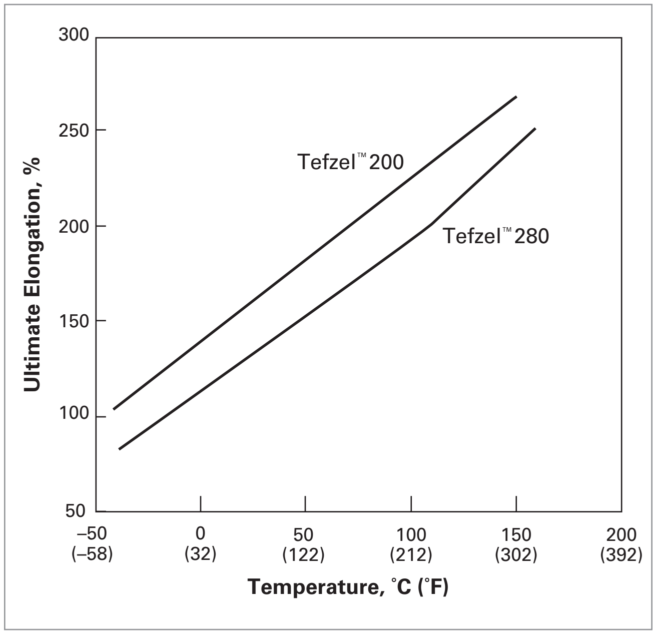
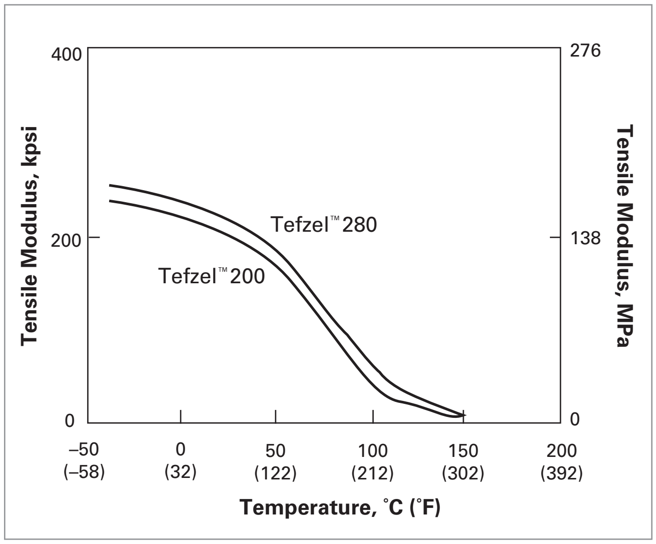


Figure 3. Tefzel™ ETFE 200 and 280—Tensile Modulus vs. Temperature, 5″ x 0.5″ x 0.125″ Injection-Molded Bars



Creep, Apparent Flex Modulus, and Long-Term Strain

As with other plastics, ambient temperatures and duration of load are important to design variables. The usual relationship:

$$\frac{\text{Stress}}{\text{Strain}} = \text{Modulus}$$

applies to short-term loading of an elastic structure. When load is applied, an initial deflection occurs. If the load is not excessive (i.e., for Tefzel™ ETFE, a load producing less than 1% strain), the conventional modulus figure indicates the correct stress-strain relationship, and standard egineering equations may be applied to predict performance.

If, however, the load is maintained continuously, all materials deform or creep, generally at a decreasing rate with time. The "apparent modulus" concept is a way of mathematically describing this creep behavior.

$$\text{Apparent Modulus } (E_a) = \frac{\text{Stress (fixed value)}}{\text{Total strain}}$$

(After a given time of load application at a given temperature) (Measured after the given time of exposure)

Most creep occurs within the first year, and, therefore, the apparent modulus at 10,000 hr can be used in many calculations involving continuous load (substitute E_a for E).

Creep can also be presented to show actual deformation under load vs. time. Figure 4 shows percent strain at 23 °C (73 °F) and 100 °C (212 °F) for Tefzel™ ETFE 200 at two pressures.

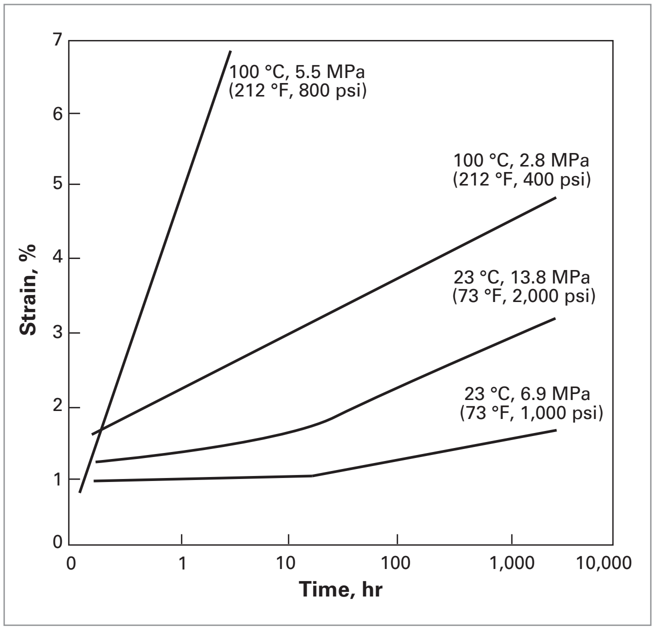
Flex Fatigue

For best fatigue performance, stress levels below 12.1 MPa (1,750 psi) are suggested for Tefzel™ ETFE 200.

Impact Strength

Tefzel™ ETFE has high impact strength, ranking among the highest of all plastics over a broad temperature range. The low temperature embrittlement point is below –100 °C (–148 °F).

Figure 4. Tefzel™ ETFE 200 Flexural Creep, 5" x 0.5" x 0.125" Injection-Molded Bars



THERMAL PROPERTIES

Tefzel™ ETFE is a modified copolymer of tetrafluoroethylene and ethylene and, as such, has a melting range rather than a sharp melting point. The melting range of Tefzel™ ETFE is 220–280 °C (428–536 °F).

Temperature Rating

Tefzel™ ETFE is typically considered to have a no load continuous use temperature of 150 °C (302 °F). This continuous use temperature rating is based on 10,000 hr aging tests that involve exposure of standard tensile test specimens and wire insulations to a series of elevated temperatures to determine the rate of change of various physical properties with time. Elongation and tensile strength are properties that change significantly with temperature exposure. These data were fit to an Arrhenius plot (the logarithm of the rate of change of a physical property is a straight line when plotted against the reciprocal of the absolute temperature of exposure). The Arrhenius plots for elongation and tensile strength are presented in Figures 5 and 6, respectively.

In practice, the upper service temperature of a material depends on the specific nature of the end-use application. According to Underwriters Laboratory, fixed property level and percent-of-unaged property level are two end-of-life criteria that appear to have the most significance in relation to end-use applications. Tables 2 and 3 contain estimated upper service temperatures depending on different possible end-use requirements. These results are consistent with the information provided graphically in Figures 5 and 6. Actual upper service temperatures may differ from the results in the table, depending on such factors as aging under load, chemical exposure, support from substrate, etc. These upper service temperatures should be used as guidelines.

End-use performance testing should be done to verify the acceptability of Tefzel™ ETFE for each specific application.

One conventional definition of upper service temperature is the lowest temperature at which one of the key physical properties is diminished by one half after 20,000 hr. Using Tables 2 and 3, Tefzel™ ETFE 200 has a 20,000 hr half-life temperature of approximately 159 °C (318 °F). (For Tefzel™ ETFE, elongation decreases faster than tensile strength; thus, the 20,000 hr half life for tensile strength is 176 °C [349 °F].)

Another definition of upper service temperature is the temperature at which the elongation drops to 50% after 20,000 exposure hr. The expected upper service temperature would be 175 °C (347 °F) (see Table 2).

Table 2. Estimated Upper Service Temperatures (°C), No Load Thermal Aging End-of-Life Criterion Based on Elongation and Exposure Time

End-of-Life Criterion		Exposure Time, hr					
Actual Elongation, %	Elongation Retained, %	1000	3000	10,000	20,000*	50,000*	100,000*
135	50	210	195	172	159	143	132
50	18	**	211	188	175	158	147
25	9	**	**	196	182	165	153

*These estimates were extrapolated from 10,000 hr aging results.
**Estimates are not available for these exposure regions.

Table 3. Estimated Upper Service Temperatures (°C), No Load Thermal Aging End-of-Life Criterion Based on Tensile Strength and Exposure Time

End-of-Life Criterion		Exposure Time, hr			
Actual Tensile Strength	Tensile Strength Retained, %	10,000	20,000*	50,000*	100,000*
26 MPa (3,750 psi)	50	190	176	159	147
14 MPa (2,000 psi)	27	204	190	172	158

*These estimates were extrapolated from 10,000 hr aging results.

Figure 5. Retention of Room Temperature Tensile Elongation After Aging—Tefzel™ ETFE 200

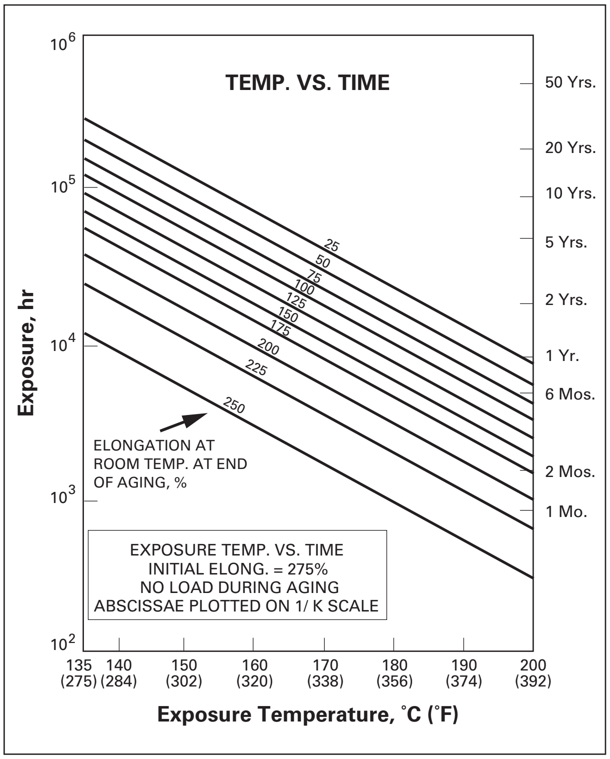
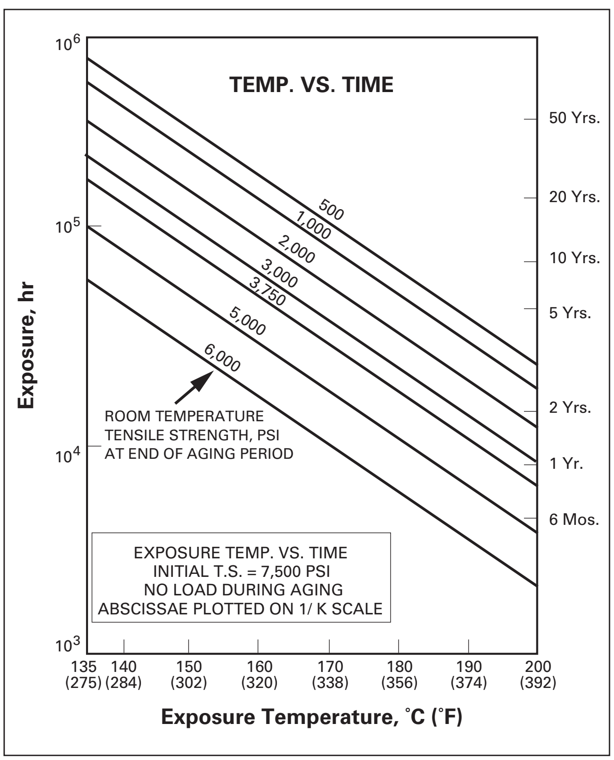


Figure 6. Retention of Room Temperature Tensile Strength After Aging—Tefzel™ ETFE 200



ELECTRICAL PROPERTIES

Tefzel™ ETFE exhibits high resistivity and low losses. Tefzel™ ETFE has a dielectric constant of 2.5–2.6 at frequencies below 10 MHz. At higher frequencies, the value decreases to approximately 2.3 at 10 GHz. The dissipation factor is below 0.001 at low frequencies, but gradually increases to a peak at about 0.023 at approximately 100 MHz—after which it decreases to below 0.01 at 10 GHz. The changes are shown graphically in Figures 7 and 8. The effects of both frequency and temperature on both dielectric constant and dissipation for Tefzel™ ETFE 200 are shown in Figures 9 and 10.

The dielectric breakdown strength at various thickness levels is shown in Figure 11.

As with other materials, exposure to radiation raises the losses.

Figure 7. Tefzel™ ETFE 200 Dielectric Constant—Room Temperature

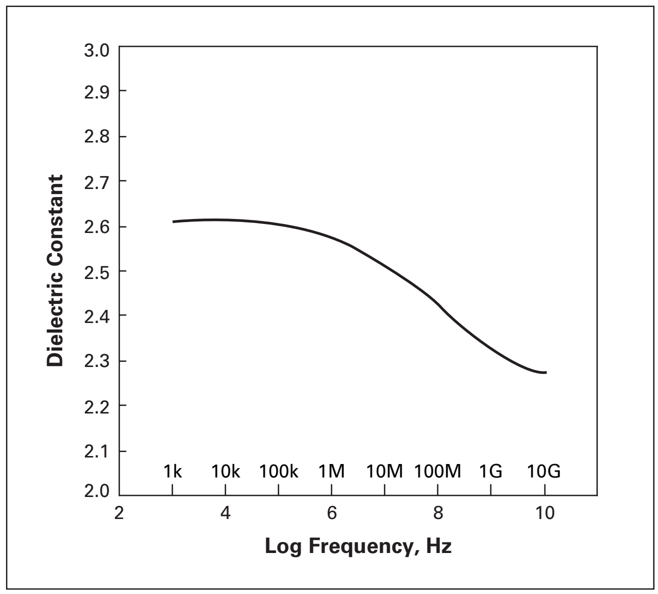


Figure 8. Tefzel™ ETFE 200—Dissipation Factor—Room Temperature

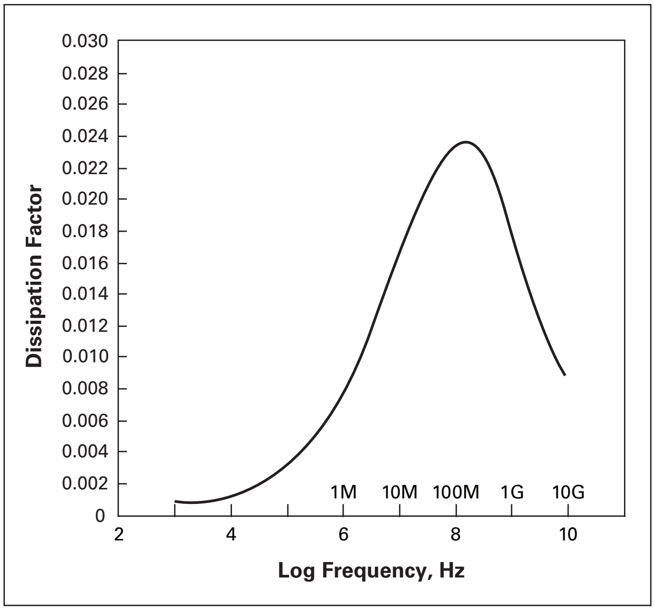


Figure 10. Tefzel™ ETFE 200—Dissipation Factor—Elevated Temperature

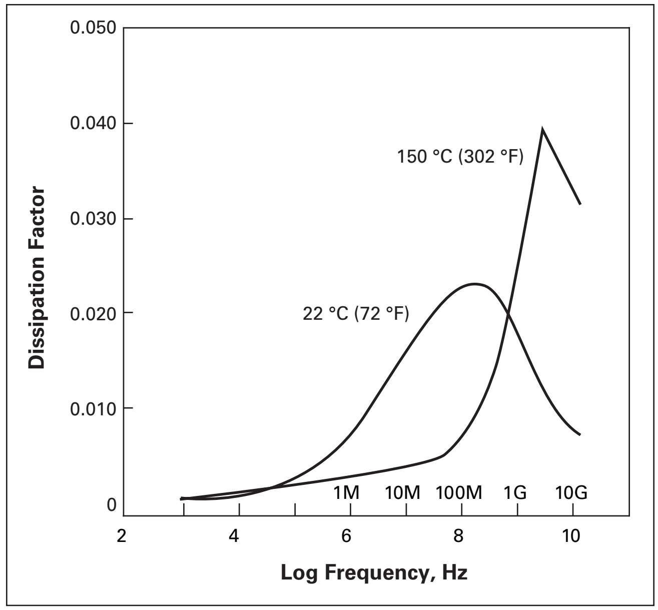


Figure 9. Tefzel™ ETFE 200—Dielectric Constant—Elevated Temperature

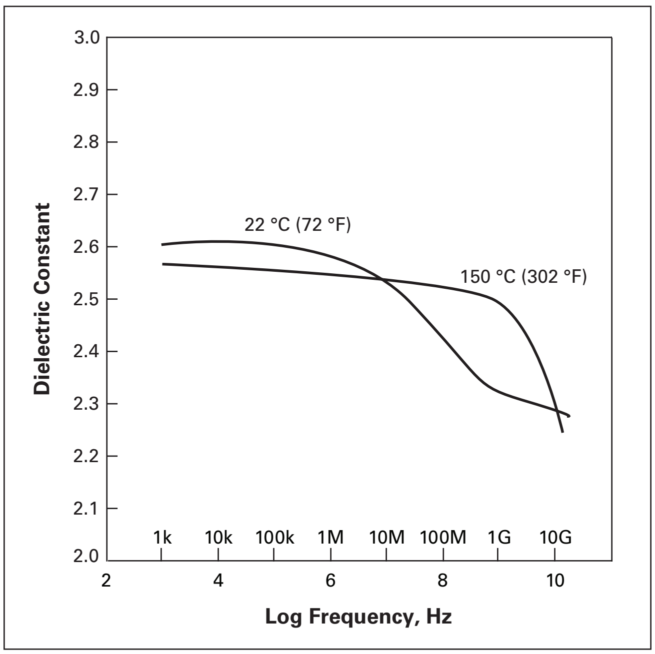
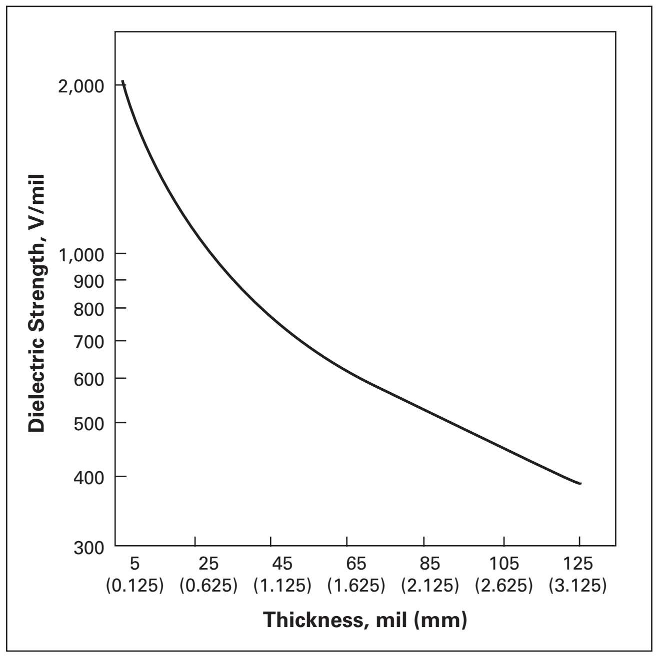


Figure 11. Dielectric Breakdown Strength at Various Thickness Levels for Tefzel™ ETFE 200



ENVIRONMENTAL EFFECTS

Environmental behavior refers to the reaction of Tefzel™ ETFE when exposed to chemicals, sunlight, moisture, radiation (gamma or electron beam), or the effects of temperature aging.

Chemical Resistance

Tefzel™ ETFE has outstanding resistance to attack by chemicals and solvents that often cause rapid deterioration of other plastic materials. It is surpassed only by Teflon™ fluoropolymers in resistance to chemicals. Tefzel™ ETFE is inert to many strong mineral acids, inorganic bases, halogens, and metal salt solutions. Carboxylic acids, anhydrides, aromatic and aliphatic hydrocarbons, alcohols, aldehydes, ketones, ethers, esters, chlorocarbons, and classic polymer solvents have little effect on Tefzel™ ETFE. Under highly stressed conditions, some very low surface tension solvents tend to reduce the stress-crack resistance of the lower molecular weight products. Very strong oxidizing acids such as nitric, organic bases such as amines, and sulfonic acids at high concentrations and near their boiling points will affect Tefzel™ ETFE to varying degrees.

Table 4 presents data on the effect of various chemicals on the tensile properties of Tefzel™ ETFE and weight gain, if any, during exposure.

Hydrolytic Stability and Water Absorption

Hydrolytic stability is indicated by lack of deterioration in physical properties after long periods of exposure to boiling water.

Using room temperature tensile strength and elongation as control properties, Tefzel™ ETFE is essentially unaffected after 3,000 hr exposure to boiling water.

Data are shown in Table 5.

Water absorption for unfilled Tefzel™ ETFE is less than 0.03% by weight as determined by ASTM D570.

Weather Resistance

Tefzel™ ETFE has excellent resistance to outdoor weathering. Long-term outdoor exposures show little detrimental effects.

Effects of Radiation

Tefzel™ ETFE is much more resistant to electron beam and gamma radiation than other fluoropolymers. Tests have shown that both elevated temperatures and the presence of oxygen have a deleterious effect on physical properties when Tefzel™ ETFE is exposed to gamma radiation. The effect on physical properties is significantly decreased in an inert atmosphere, such as nitrogen.

Tefzel™ ETFE appears to be degraded much less with electron beam radiation than with gamma radiation at equivalent levels of total exposure. The difference is probably due to the much higher dosage rate under electron beam conditions. The higher dosage rate apparently allows cross-linking reactions to predominate, while the much slower rate under gamma radiation apparently allows competing oxidation and degradation reactions to predominate. Controlled exposure to low levels of electron beam radiation, especially in inert atmospheres, appears to result in a low level of cross-linking with an inherent improvement in some properties. However, exposure beyond the low level controlled conditions results in detrimental effects on physical properties. As with gamma radiation, oxidation reactions are inhibited under inert atmospheres.

Vacuum Outgassing

Under vacuum conditions, Tefzel™ ETFE gives off little gas at recommended maximum use temperatures. Values for Tefzel™ ETFE are comparable to Teflon™ fluoropolymers. Data are given in Table 6.

Table 4. Actual Laboratory Tests on Chemical Compatibility of Tefzel™ ETFE with Representative Chemicals

Chemical	Boiling Point		Test Temperature		Days	Retained Properties, %		
	°C	°F	°C	°F		Tensile Strength	Elongation	Weight Gain
Acid/Anhydrides								
Acetic Acid (Glacial)	118	244	118	244	7	82	80	3.4
Acetic Anhydride	139	282	139	282	7	100	100	0
Trichloroacetic Acid	196	384	100	212	7	90	70	0
Aliphatic Hydrocarbons								
Mineral Oil	—	—	180	356	7	90	60	0
Naphtha	—	—	100	212	7	100	100	0.5
Aromatic Hydrocarbons								
Benzene	80	176	80	176	7	100	100	0
Toluene	110	230	110	230	7	—	—	—
Functional Aromatics								
o-Cresol	191	376	180	356	7	100	100	0
Amines								
Aniline	185	365	120	248	7	81	99	2.7
Aniline	185	365	120	248	30	93	82	—
Aniline	185	365	180	356	7	95	90	—
N-Methylaniline	195	383	120	248	7	85	95	—
N-Methylaniline	195	383	120	248	30	100	100	—
N, N-Dimethylaniline	190	374	120	248	7	82	97	—
n-Butylamine	78	172	78	172	7	71	73	4.4
Di-n-Butylamine	159	318	120	248	7	81	96	—
Di-n-Butylamine	159	318	120	248	30	100	100	—
Di-n-Butylamine	159	318	160	320	7	55	75	—
Tri-n-Butylamine	216	421	120	248	7	81	80	—
Tri-n-Butylamine	216	421	120	248	30	100	100	—
Pyridine	116	240	116	240	7	100	100	1.5
Chlorinated Solvents								
Carbon Tetrachloride	78	172	78	172	7	90	80	4.5
Chloroform	62	144	61	142	7	85	100	4.0
Dichloroethylene	77	170	32	90	7	95	100	2.8
Methylene Chloride	40	104	40	104	7	85	85	0
CFC-113	46	115	46	115	7	100	100	0.8
Ethers								
Tetrahydrofuran	66	151	66	151	7	86	93	3.5
Aldehyde/Ketones								
Acetone	56	132	56	132	7	80	83	4.1
Acetophenone	201	394	180	356	7	80	80	1.5
Cyclohexanone	156	312	156	312	7	90	85	0
Methyl Ethyl Ketone	80	176	80	176	7	100	100	0
Esters								
n-Butyl Acetate	127	260	127	260	7	80	60	0
Ethyl Acetate	77	170	77	170	7	85	60	0
Polymer Solvents								
Dimethylformamide	154	309	90	194	7	100	100	1.5
Dimethylformamide	154	309	120	248	7	76	92	5.5
Dimethylsulfoxide	189	373	90	194	7	95	90	1.5
Other Organics								
Benzyl Alcohol	205	401	120	248	7	97	90	—
Benzoyl Chloride	197	387	120	248	7	94	95	—

Table 4. Actual Laboratory Tests on Chemical Compatibility of Tefzel™ ETFE with Representative Chemicals (cont'd.)

Chemical	Boiling Point		Test Temperature		Days	Retained Properties, %		
	°C	°F	°C	°F		Tensile Strength	Elongation	Weight Gain
Other Organics (continued)								
Benzoyl Chloride	197	387	120	248	30	100	100	—
Decalin	190	374	120	248	7	89	95	—
Phthaloyl Chloride	276	529	120	248	30	100	100	—
Acids								
Hydrochloric (Conc)	106	223	23	73	7	100	90	0
Hydrochloric (Conc)	106	223	106	223	7	96	100	0.1
Hydrobromic (Conc)	125	257	125	257	7	100	100	—
Hydrofluoric (Conc)	—	—	23	73	7	97	95	0.1
Sulfuric (Conc)	—	—	100	212	7	100	100	0
Sulfuric (Conc)	—	—	120	248	7	98	95	0
Sulfuric (Conc)	—	—	150	302	*	98	90	0
Aqua Regia	—	—	90	194	*	93	89	0.2
Nitric—25%	100	212	100	212	14	100	100	—
Nitric—50%	105	221	105	221	14	87	81	—
Nitric—70% (Conc)	120	248	23	73	105	100	100	0.5
Nitric—70% (Conc)	120	248	60	140	53	100	100	—
Nitric—70% (Conc)	120	248	120	248	2	72	91	—
Nitric—70% (Conc)	120	248	120	248	3	58	5	—
Nitric—70% (Conc)	120	248	120	248	7	0	0	—
Chromic	125	257	125	257	7	66	25	—
Phosphoric (Conc)	—	—	100	212	7	—	—	—
Phosphoric (Conc)	—	—	120	248	7	94	93	0
Halogens								
Bromine (Anhy)	59	138	23	73	7	90	90	1.2
Bromine (Anhy)	59	138	57	135	7	99	100	—
Bromine (Anhy)	59	138	57	135	30	94	93	3.4
Chlorine (Anhy)	—	—	120	248	7	85	84	7
Bases								
Ammonium Hydroxide	—	—	66	150	7	97	97	0
Potassium Hydroxide—20%	—	—	100	212	7	100	100	0
Sodium Hydroxide—20%	—	—	120	248	7	94	80	0.2
Peroxides								
Hydrogen Peroxide—30%	—	—	23	73	7	99	98	0
Salt-Metal Etchants								
Ferric Chloride—25%	104	220	100	212	7	95	95	0
Zinc Chloride—25%	104	220	100	212	7	100	100	0
Other Inorganics								
Sulfuryl Chloride	68	115	68	155	7	86	100	8
Phosphoric Trichloride	75	167	75	167	7	100	98	—
Phosphoric Oxychloride	104	220	104	220	7	100	100	—
Silicon Tetrachloride	60	140	60	140	7	100	100	—
Water	100	212	100	212	7	100	100	0
Miscellaneous								
Skydrol	—	—	149	300	7	100	95	3.0
Aerosafe	—	—	149	300	7	92	93	3.9
A-20 Stripper Solution	—	—	140	284	7	90	90	—

*Exposed for 6 hr

NOTES: Change in properties -15% is considered insignificant. Samples were 10–15 mil microtensile bars. TS/E and wt. gain determined within 24 hr after removal from exposure media.

Table 5. Resistance to Boiling Water—Tefzel™ ETFE 200

	Tensile Strength		
Product	psi	MPa	Elongation, %
Tefzel™ 200 (No exposure)	5,800	40	145
3,000 hr Boiling Water	5,790	40	135

*Measured at 23 °C (73 °F) after immersion in boiling water

Table 6. Vacuum Outgassing—Tefzel™ ETFE

Weight Loss, %	
Maximum	0.12
Generally Accepted Maximum	1.00
Minimum	0.04
Average	0.07
Volatile Condensable Material Weight (VCMW), %	
Maximum	0.02
Minimum	0.00
Average	0.01

*Tests consist of exposing 30 mil thick specimens for 24 hr in a hard vacuum at 149 °C (300 °F) and measuring weight loss and the volatile gases that are collected in liquid air traps.

Permeability

Tests measured on 4 mil thick film per ASTM D1434 at 25 °C (77 °F) show the following permeabilities:

Material	Permeability, $cm^3/100\ in^2 \cdot 24\ hr \cdot atm/mil$*
Carbon Dioxide	250
Nitrogen	30
Oxygen	100

*Multiply by 15.5 to obtain $cm^3/m^2 \cdot day \cdot atm$

Water vapor transmission by ASTM E96 is 1.65 g/ 100 $in^2 \cdot 24$ hr/mil.

Flame Resistance and Smoke

Tefzel™ ETFE is rated UL 94 V-0 for unpigmented resins down to 0.062 in thick. Its limiting oxygen index (LOI) is 30 by ASTM D2863, which means that an atmosphere containing at least 30% oxygen is required to maintain combustion in a downward burning flame. By ASTM D635, Tefzel™ ETFE has an average time of burning (ATB) of less than 5 sec and an average length of burn (ALB) of 10 mm (0.39 in).

Loss of Weight with Aging

The weight loss of Tefzel™ ETFE below the melting point is from 0.1 to 0.3%, most of which is moisture.

The weight loss above 300 °C (572 °F) is shown in Table 7.

Table 7. Initial Weight Loss of Tefzel™ ETFE Resins Above 300 °C (572 °F)

Temperature		
°C	°F	Tefzel™ ETFE 200 wt loss, %/hr
300	572	0.05
330	626	0.26
350	662	0.86
370	698	1.60

OPTICAL PROPERTIES

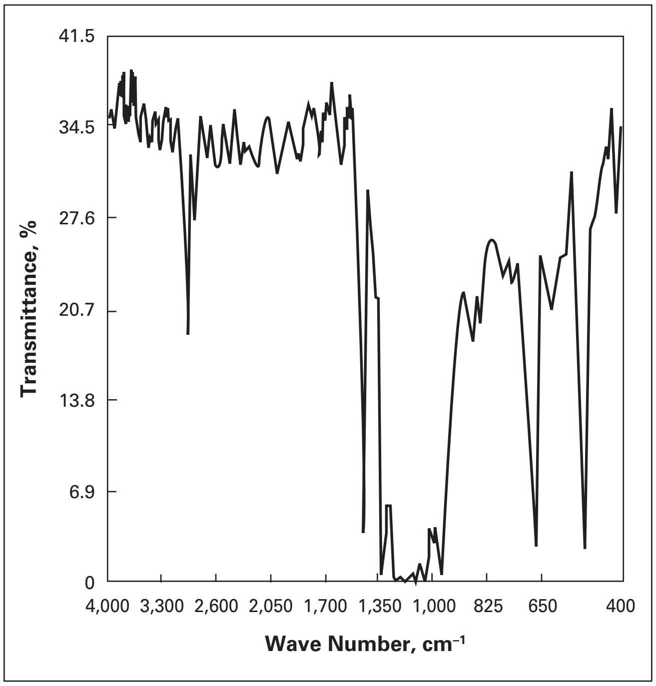
Data on percent transmittance vs. wavelength is given in Table 8. Figure 12 shows a typical infrared scan of Tefzel™ ETFE films.

Table 8. Transmittance vs. Wavelength Data Normalized to 0.025 mm (1.0 mil) Films (Beer's Law)

Wavelength, nm	Tefzel™ ETFE Film Transmittance, %*
Ultraviolet Range	
200	91.5
250	92
300	92
350	93
400	94
Visible Range	
500	
94	
600	94
700	95
800	95

*Hitachi Model V-3210 spectrometer with 60 mm diameter, 151-0030 integrating sphere, scan speed 60 mm/min

Figure 12. Infrared Scan of Tefzel™ ETFE, 0.025 mm (1 mil)



FABRICATION TECHNIQUES

Tefzel™ ETFE, as a thermoplastic polymer, can be processed by most techniques applicable to this type of resin. Included are:

- Injection molding
- Compression molding
- Rotational molding
- Extrusion

Tefzel™ ETFE can also be formed, machined, colored, and printed upon using techniques described in appropriate processing bulletins.

ASSEMBLY TECHNIQUES

The success of many applications depends on the ability of Tefzel™ ETFE to be economically assembled using one or more of a variety of assembly techniques. Some of these techniques suitable for Tefzel™ ETFE compositions are described below. More information or assistance in evaluating these for use in specific projects involving Tefzel™ ETFE is available through your Chemours representative.

Screw Assemblies

Self-tapping screws are used for joining parts of Tefzel™ ETFE. Either of two types (thread cutting that taps a mating thread as the screw is driven or the thread forming that mechanically displaces material as the screw is driven) can reduce assembly cost.

A rule of thumb is that the boss diameter should be about 2½ times the screw diameter for maximum holding power. Lubricants should be avoided for maximum stripping torque.

Threaded inserts are also used. They can be molded in place, pressed in, or driven in ultrasonically.

Snap-Fit

The advantage of snap-fit joints is that the strength of the joint does not diminish with time because of creep.

Two types of snap-fits are:

- A cylindrical snap-fit for joining a steel shaft and a hub of Tefzel™ ETFE.
- A cantilevered lug snap-fit for inserting a Tefzel™ ETFE part into another part.

In a cylindrical snap-fit joint (Figure 13), the maximum strain at the inside of the hub is the ratio of interface (I) to diameter (Ds) (x 100 for percent). A maximum strain of about 5% is suggested.

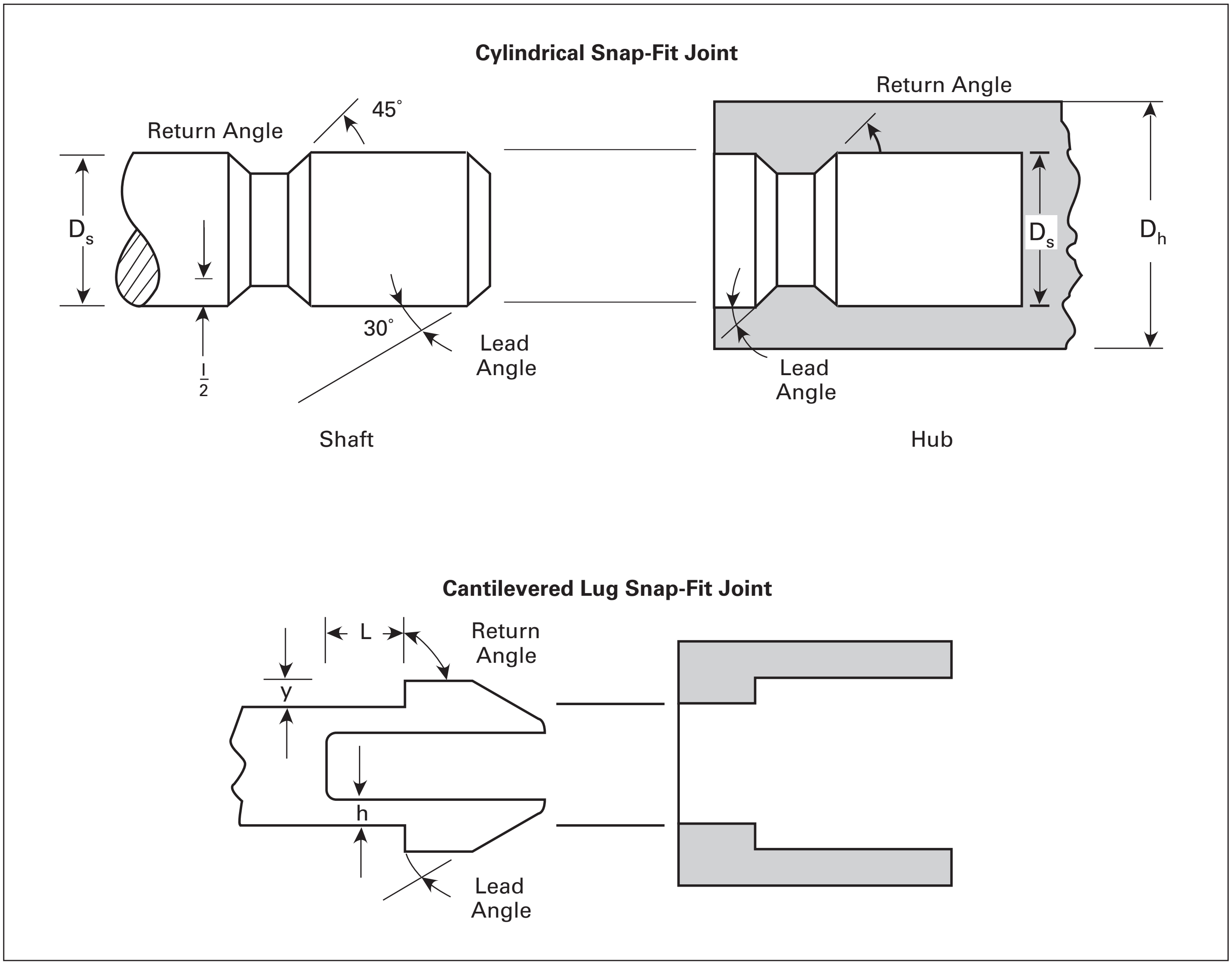
$$\text{Maximum Strain} = I/Ds \times 100 - 5\%$$

For the cantilevered lug snap-fit joint, the maximum strain is expressed by the equation:

$$\text{Maximum Strain} = 3yh/2L^2 \times 100 < 5\%$$

Again, a 5% maximum strain is suggested.

Figure 13. Snap-Fit Joints



Press-Fit

Press-fit joints are simple and inexpensive; however, the holding power is reduced with time. Creep and stress relaxation reduce the effective interference, as do temperature excursions, particularly when materials with different thermal expansions are joined.

With Tefzel™ ETFE joined to Tefzel™ ETFE, the press-fit joint may be designed with an interference resulting in strains of 6–7%.

$$\text{Strain} = \frac{\text{Interference (on diameter)} \times 100}{\text{Shaft Diameter}}$$

Shaft Diameter

If a part of Tefzel™ ETFE and one of metal are to be joined, lower strain levels may be used.

Assembly can often be made easier by inserting a cooled part into a heated hub.

Cold or Hot Heading

Rivets or studs can be used in forming permanent mechanical joints. The heading is accomplished with special tools and preferably with the rivet at elevated temperatures.

Formed heads tend to recover part of their original shape if exposed to elevated temperatures, so joints can become loose. Forming at elevated temperatures tends to reduce recovery.

Spin Welding

Spin welding is an efficient assembly technique for joining circular surfaces of similar materials.

The matching surfaces are rotated at high speed relative to each other (one surface is fixed) and then brought into contact. Frictional heat melts the interface; and when motion is stopped, the weld is allowed to solidify under pressure.

Ultrasonic Welding

The ultrasonic welding of Tefzel™ ETFE has been demonstrated with weld strengths up to 80% of the strength of the base resin. The success of developments involving this technique depends upon joint design and the experimentally determined welding parameters of contact time and pressure. Typical welding conditions are 25 psi contact pressure and one- or two-second cycle time. Both employ a small initial contact area to concentrate and direct the high-frequency vibrational energy.

Potting

Potting of wires insulated with Tefzel™ ETFE has been accomplished with the aid of a coating of a colloidal silica dispersion using various polysulfide potting compounds. Such pretreatment tends to increase the pull-out strengths by 25 to 50%.

Adhesive Bonding

Because of the outstanding chemical resistance of Tefzel™ ETFE, surface treatment is required to allow adhesive bonding. Chemical etch, corona, or flame treatments can be used to make surfaces of Tefzel™ ETFE more receptive to adhesives. Polyester and epoxy compounds are suitable adhesives when surfaces are properly prepared.

Melt Bonding

Tefzel™ ETFE responds well to melt bonding. It has been bonded to untreated aluminum, steel, and copper with peel strengths in excess of 20 lb/in. It can also be melt bonded to itself using such techniques as hot plate welding.

The bond is achieved by heating the materials to 270–275 °C (520–530 °F) and then pressing the parts together during cooling.

Typical Applications

No other plastic resin comes as close to fluoropolymers in chemical and electrical properties while providing a high level of mechanical ruggedness and easy, economical processing. Tefzel™ ETFE allows a range of opportunities for design engineers to achieve better product performance in many application areas.

Fasteners

Cable and hydraulic line clamps, cable straps, and other fasteners molded of Tefzel™ ETFE perform in high temperature, corrosive environments. Nuclear applications are possible because of the radiation resistance of Tefzel™ ETFE. Moisture absorption is low, providing uniformity of mechanical properties regardless of humidity. High impact strength and UV resistance are additional advantages.

Outstanding electrical properties, solvent resistance, an SE-O flammability rating,* and excellent high temperature aging characteristics make Tefzel™ ETFE an ideal material for high performance electrical components. Coil forms, connectors, encapsulated parts, sockets, and insulators are typical applications.

Valve Linings

Tefzel™ ETFE has replaced other polymers and glass as a valve lining. The outstanding resistance of Tefzel™ ETFE to acids, bases, and solvents over a broad temperature range, combined with abrasion resistance and ease of processing, results in a durable and economical valve.

Film Form Available

Film of Tefzel™ ETFE can be heat sealed, thermoformed, welded, heat laminated, and coated to make pressure-sensitive tapes, flexible printed circuits, liquid pouches, and other constructions where strength, thermal resistance, and electrical integrity are required.

Tubing

Heat-shrinkable, plain, and corrugated tubing is available in a wide range of thicknesses and diameters. It is being used at high temperatures as electrical insulation and in service with strong chemicals.

Heat-shrinkable tubing conforms to electrical terminations, hose connections, and other components to insulate, guard against abrasion, and prevent corrosion.

Wire and Cable

Tough insulation of Tefzel™ ETFE is being used on conductors ranging from AWG #30 for wrapped computer terminations to 535 MCM for heavy power circuits. Tefzel™ ETFE is performing well on steel mill cables, airframe wire, down-hole oil well logging cable, rapid transit car and locomotive control wire, and other rugged service wire and cable. It is receiving special consideration for use in nuclear power plants and other areas where exposure to radiation may be encountered.

Biomedical/Labware

High impact strength, chemical resistance, resistance to high heat sterilization, and ease of processing are properties needed for biomedical and labware applications. Oxygen respirator components, blood analyzer valves, evaporating dishes, and centrifuge tubes are examples.

Pump Components

Chemical resistance, dimensional stability, and structural strength make Tefzel™ ETFE a candidate for pump impellers, vanes, gears, and bodies.

* Numerical flame spread ratings are not intended to reflect hazards presented by this or any other material under actual fire conditions.

SAFETY PRECAUTIONS

WARNING!

VAPORS CAN BE LIBERATED THAT MAY BE HAZARDOUS IF INHALED.

Before using Tefzel™ ETFE, read the Safety Data Sheet (SDS) and detailed information in the "Guide to the Safe Handling of Fluoropolymer Resins," published by the Plastics Industry Association (www.plasticsindustry.org) or by PlasticsEurope (www.plasticseurope.org).

Open and use containers only in well-ventilated areas using local exhaust ventilation (LEV). Vapors and fumes liberated during hot processing of Tefzel™ ETFE should be exhausted completely from the work area. Contamination of tobacco with these polymers must be avoided. Vapors and fumes liberated during hot processing that are not properly exhausted, or from smoking tobacco or cigarettes contaminated with Tefzel™ ETFE may cause flu-like symptoms, such as chills, fever, and sore throat. This may not occur until several hours after exposure and that typically pass within about 24 hr. Mixtures with some finely divided metals, such as magnesium or aluminum, can be flammable or explosive under some conditions.

For more information, visit Teflon.com

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