DAIKIN

PRODUCT INFORMATION

(except for U.S.A)

POLYFLON™
PTFE FINE POWDER

Introduction:

POLYFLON PTFE Fine Powder is a milky white polymer which is separated from a dispersion formed by emulsion polymerization. Having a molecular structure of only carbon and fluorine atoms $-(CF_2\text{-}CF_2)_n-$ POLYFLON PTFE Fine Powder possesses the lowest coefficient of friction and the most superior heat resistance, chemical resistance, electrical properties and non-sticking property of any plastics. POLYFLON PTFE Fine Powder readily absorbs organic solvents, resulting in the formation of a paste, it can be extruded easily. It is widely used for the manufacture of insulated electric wires, spaghetti tubes, thin rods and unsintered tape.

TM: DAIKIN INDUSTRIES trade mark for its fluoroplastics

DAIKIN INDUSTRIES Ltd.

EGE-31e(E)

1. POLYFLON PTFE Fine Powder and their properties

The particles which from the basis of POLYFLON PTFE Fine Powder are extremely small, measuring approximately 0.2-~0.4μm. In appearance a large number of these tiny particles aggregate, forming secondary particles of approximately 500μm.

Table 1 Types of POLYFLON PTFE Fine Powder and Their Properties

Property and application	F-104	F-201	F-203	F-302
Particle diameter★[1] (μm)	Approx. 500	Approx. 500	Approx. 500	Approx. 500
Apparent density★[1] (g/ml)	Approx. 0.45	Approx. 0.45	Approx. 0.45	Approx. 0.45
Melting point★[1] (℃/° F)	326～328 /619～622	326～328 /619～622	326～328 /619～622	326～328 /619～622
Specific gravity★[1]	Approx. 2.17	Approx. 2.18	Approx. 2.17	Approx. 2.15
Tensile strength★[2] (Mpa (psi))	More than 19.6 (2842)	More than 19.6 (2842)	More than 19.6 (2842)	More than 19.6 (2842)
Elongation★[2] (%)	More than 350	More than 220	More than 220	More than 220
Reduction ratio★[3]	1000	4000	4000	1500
Range of application	・Unsintered tape ・Sealing tape ・Low specific gravity tape ・Wrapping tape ・Tape for wrapping flat cables ・Tubes	・Spaghetti tubes ・Small diameter tubes ・Fine electric wire smaller than AGW16	・Spaghetti tubes ・Small diameter tubes ・Fine electric wire smaller than AWG12	・Small and large diameter tubes ・Shrinkable tube ・Thick electric wire larger than AGW16 as well as jacketed ingot tubes

Note: *[1] Method: ASTM D-1457
*[2] Method: JIS-K6891
*[3] The “reduction ratio” refers to a ratio of the cross-section area of the resin inside the cylinder of the extruder (S1) and the cross-section area of the resin in the die land (S2). R.R.=S1/S2

POLYFLON PTFE F-104 is used for the manufacture of unsintered tape, and tubes molded with a low reduction ratio; F-201 and F-203 are used for the manufacture of items molded with a high reduction ratio, such as insulated electric wires, spaghetti tubes, and small-diameter tubes. F-302 is a thick material with outstanding properties for secondary processing and thermal fusion of thick insulated electric wire, jacketing, medium to large diameter tubes and ingot tubes, etc.

2. Properties of DAIKIN-POLYFLON PTFE Fine Powder

2-1 Thermal properties

POLYFLON PTFE can be used continuously at temperature up to 260° (500°F), and for short periods at even higher temperatures. It also possesses excellent low temperature strength. With these superior thermal properties, products such as electric or electronic machinery components, pipe linings, insulated electric wires, etc., made with POLYFLON PTFE Fine Powder are widely used.

2-2 Chemical properties

POLYFLON PTFE possesses the excellent property of almost absolute resistance to all commonly used chemicals. When used with some special chemicals under extremely severe conditions, such as fused alkali metals, high-temperature, high-pressure fluorine or trichlorofluorine gas, slight changes may occur. With ordinary acids, alkalis, and oxidants at high temperatures POLYFLON PTFE remains completely stable. Even contact with organic compounds does not cause dissolution or swelling. The basic reason for POLYFLON PTFE's extensive use in the chemical industry for pipe linings, wire-braid hoses, gaskets, tubes and bellows is in its chemical inertness.

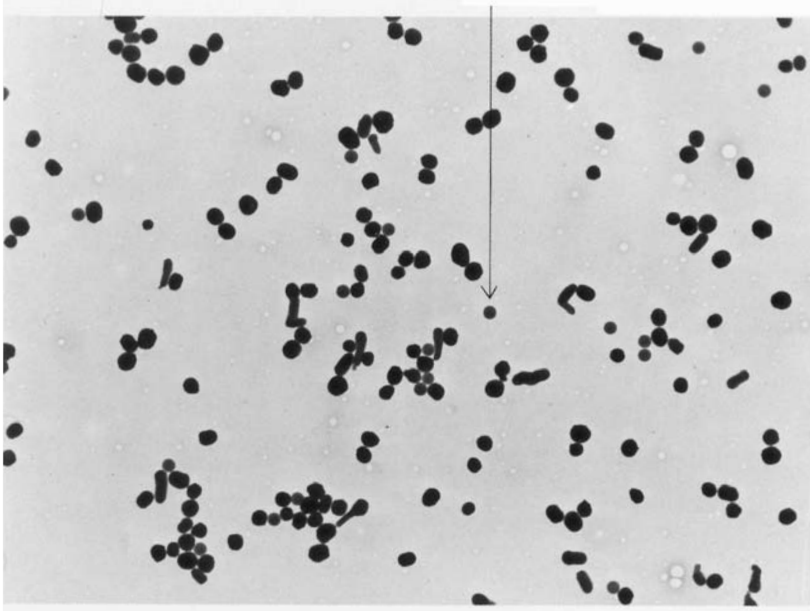
2-3 Electrical properties

Since the molecular structure of POLYFLON PTFE is non-polar, it is ideal for use as high-frequency insulating material not only because of its applicability over a wide temperature range, but also because of its low, uniform dielectric constant and dissipation factor over a wide frequency range.
POLYFLON PTFE Fine Powder is used for the manufacture of insulation covering for use in aircraft, electrical wiring, small coaxial cables, industrial control cables, spaghetti tubes and wrapping tapes.

2-4 Low abrasion, non-sticking property

Under ordinary conditions of use, POLYFLON PTFE possesses the lowest coefficient of friction of any solids. Moreover, its remarkable non-sticking property prevents most adhesive materials from adhering to it. Tubes made of POLYFLON PTFE Fine Powder are therefore used as transport tubes for liquid adhesives, cableway pipes, etc., for automobile and other mechanical industries, and other similar applications. In addition, unsintered tape made of POLYFLON PTFE Fine Powder, being extremely soft and malleable, forms tightly to the threads of bolts to provide an excellent sealing effect.

(Polystyrene)

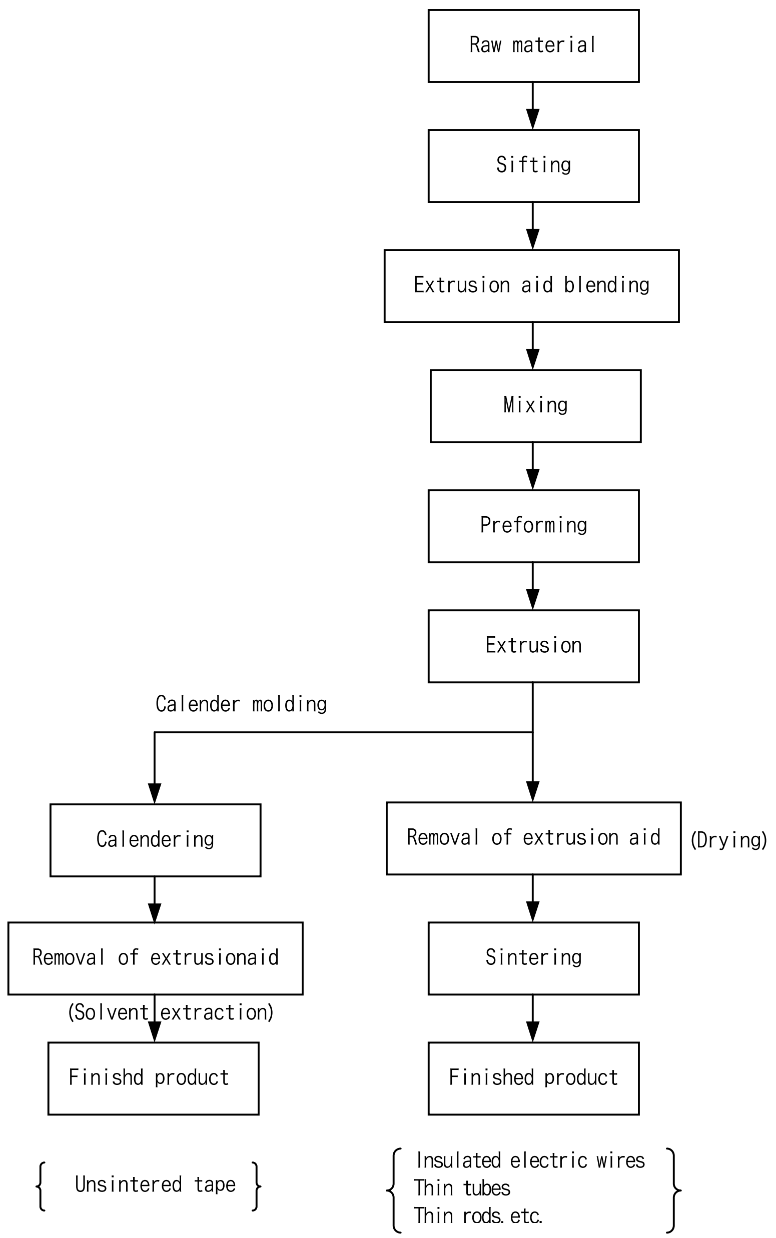


Note: The spheres in this photograph are particles of polystyrene, approximately 0.234μm in size.

3. DAIKIN-POLYFLON PTFE Fine Powder Extrusion process

Compared with ordinary molding powder, POLYFLON PTFE Fine Powder has a smaller molecular weight (3,000,000~5,000,000) and consists of extremely small particles. For this reason, the affinity between POLYFLON PTFE Fine Powder and organic solvents is excellent, and with the addition of ordinary petroleum solvent as an extrusion aid, it can be molded in the from of an organosol. The ordinary molding process for POLYFLON PTFE Fine Powder is shown in Fig. 1 below.

Fig. 1 The Extrusion Process for POLYFLON PTFE Fine Powder



3-1 Care and handling of the raw material

POLYFLON PTFE Fine Powder must be in a completely powdered from, so as to enable even pouring when it is blended with an extrusion aid. Strong vibrations and shocks should be avoided as much as possible during transport, because these may cause the powder to form lumps. If the powder is to be stored, it should be stored at the temperature of 25°C (77°F) or below. Ideal strage conditions are a dry place with a temperature range of 5~20°C (41~68°F).
Powder stored in these conditions will be less susceptible to lumping, and, should lumping occur, more easily restored to its powdered form, thereby greatly simplifying its care and handling. If lumps exist in the powder prior to blending with the extrusion aid, the powder should be sifted, using a No. 4 mesh sieve. In doing this, care must be taken to pour the powder very gently into the sieve. If a scoop is used, care must be taken not to crush the powder particles while inserting the scoop. If a sieve with too fine a mesh is used. It may require an excessive amount of force, and cause lumps to form in the powder. Care should be taken not to apply too much force to the powder while sifting. Any lumps which do not pass through the sieve should be carefully removed and placed in a different container (such as a wide -mouth bottle, etc.), filling the container until it is approximately 1/3 full. The container should then be shaken to break the lumps apart, and then the powder should again be sifted. It is very important the powder is not contaminated while it is being sifted. Contamination may cause stains or discoloration to occur in the product, and result in degradation of the electrical properties.

3-2 Extrusion aid

In the extrusion process for POLYFLON PTFE Fine Powder, an extrusion aid is used. This acts as a lubricant to enable smooth, even extrusion. The extrusion aid must be able to completely saturate the resin, and must be easily removable from the product after extrusion. If the product is to be sintered, the extrusion aid must be one which will not color the product. That is to say, the volatizing temperature of the extrusion aid must be lower that the sintering temperature. The types of extrusion aids ordinarily used are shown in Table 2. The amount of extrusion aid to be added to the resin varies according to the application, and according to the processing conditions. Ordinarily 15~25% of extrusion aid is used.

Table 2 Applications and types of Extrusion Aids

Application	Type and manufacturer	Specific gravity (15/4℃)	Boiling point (℃(°F))
Tubes	Super VM & P Naphtha (Shell Chemicals)	0.752	118～144 (244～291)
Insulated electric wires	Super VM & P Naphtha (Shell Chemicals)	0.752	118～144 (244～291)
Spaghetti tubes	Isopar-E (Exon)	0.723	115～142 (239～288)
Unsintered tape	Isopar-M (Exon)	0.781	207～257 (405～495)
	Smoil P-55 (Matsumura Petroleum)	0.831	314～373 (567～703)

3-3 Extrusion aid blending

Fill a clean, dry, wide-mouth container up to but not exceeding 2/3 full with the powder sifted in step 3-1. Pour the prescribed quantity of extrusion aid into this container, and then cover the container. Seal the cover securely so that the extrusion aid will not volatize. Then use an appropriate method to agitate the container. This can be done, for example, by placing the container horizontally on a two-roller rolling-type agitator for approximately 10~20 minutes at 30-45 rpm. The next step after blending the powder / extrusion aid mixture is preforming. Prior to this, however, it is suggested that the container be left sealed for approximately 5~15 hours at room temperature (23°C (73°F) or above) in order to allow the extrusion aid to completely permeate the surface of any powder not sufficiently permeated by the blending process.

3-4 Preforming

The object of preforming is to remove most of the air from the powder after it has been blended with the extrusion aid, and to mold it into a shape which can be inserted into the cylinder of the extruder. After blending with the extrusion aid, place the powder into the preforming mold, and press until the volume of the powder is reduced to approximately 1/3 of its original volume to produce the preform. The pressure used in preforming should be 1.0~4.9MPa (145~711psi), and the pressing speed should be 50 mm/min or less. Excessive shearing stress muset not be applied, and no air should remain in the material after preforming. Maintain the powder in this pressed condition for 5~10 minutes, and then gently release the pressure. The diameter of the preform must be 0.5~2 mm smaller than the diameter of the extruder. After preforming, the powder is removed from the preforming mold and inserted into the extruder. Extreme care must be taken at this time, however, to avoid mixing any foreign matter into the preform. The specific gravity of the preform should be approximately 1.3~1.6g/ml.

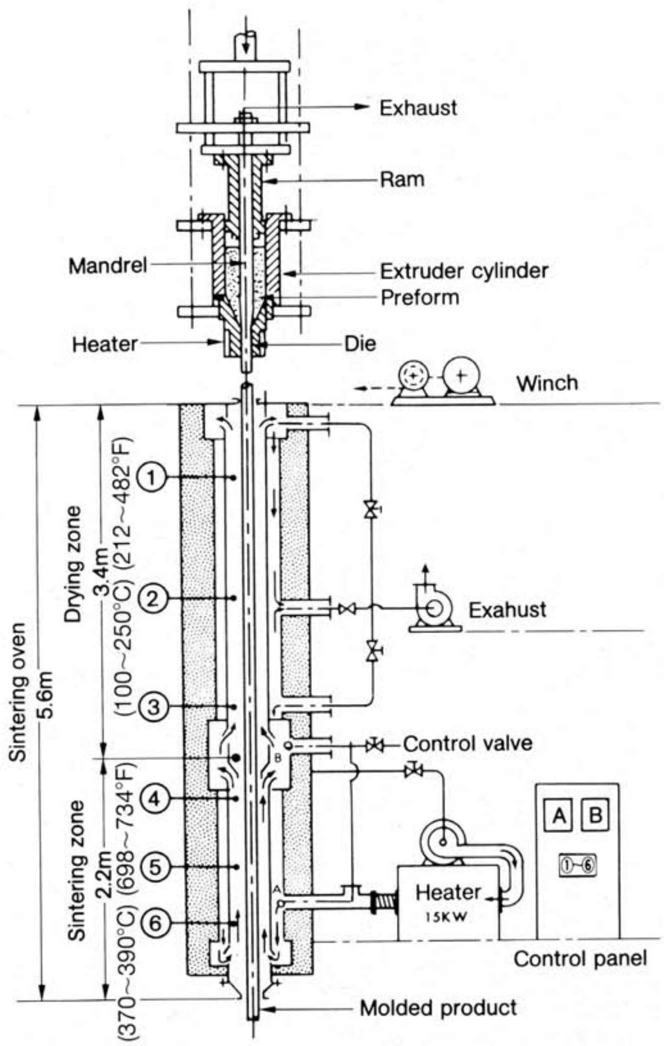
3-5 Tube extrusion

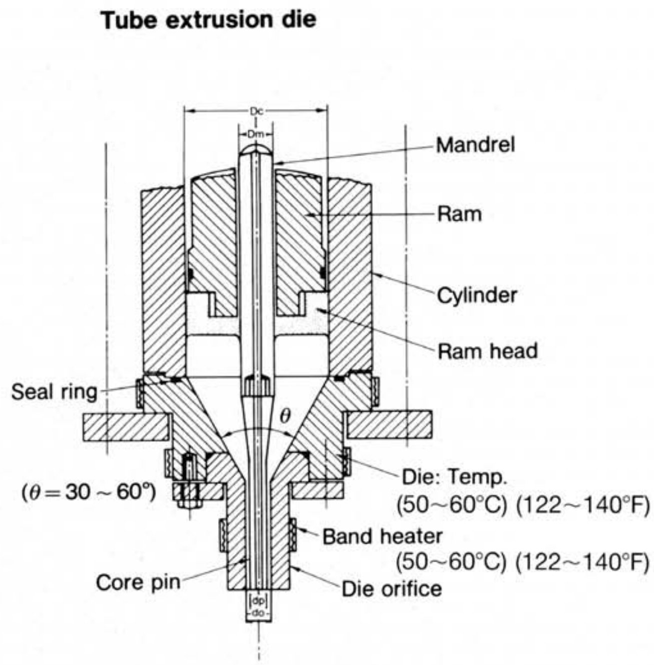
(1) Extrusion

The basic tube extrusion equipment is illustrated in Fig. 2. The extruder consists of a cylinder, a ram, a driving mechanism (hydraulic or screw type) a die, a mandrel, etc. The cylinders generally used in extruders range from 50~200 mm in diameter, and from 500~1800 mm in length. Because the extrusion of POLYFLON PTFE Fine Powder is done by the batch system, the molding efficiency is improved as the weight per batch is increased. The length of the cylinder, however, is physically limited. For this reason, the weight of the batch is ordinarily increase in accordance with an increase in the diameter of the cylinder. If products of prescribed dimensions are to be made, it must be remembered that the use of a large-diameter cylinder will tend to increase the reduction ratio, thereby increasing the extrusion pressure. The relation of the reduction ratio and the extrusion pressure is shown in Fig. 3. It can be seen from this figure that F-104 meets the needs of low reduction-ratio molding, and F-201 is suited to high reduction-ratio molding.

During extrusion tube wall out is difficult to control. For example, wall out is caused by the method of extrusion aid blending as well as by gaps between the extrusion cylinder and the preform. In this case, prior to extrusion, carry out preforming again within the extrusion cylinder and if the gap between the preform is eliminated wall out will be lessened.

Fig. 2 Tube Extrusion Equiment of POLYFLON PTFE Fine Powder

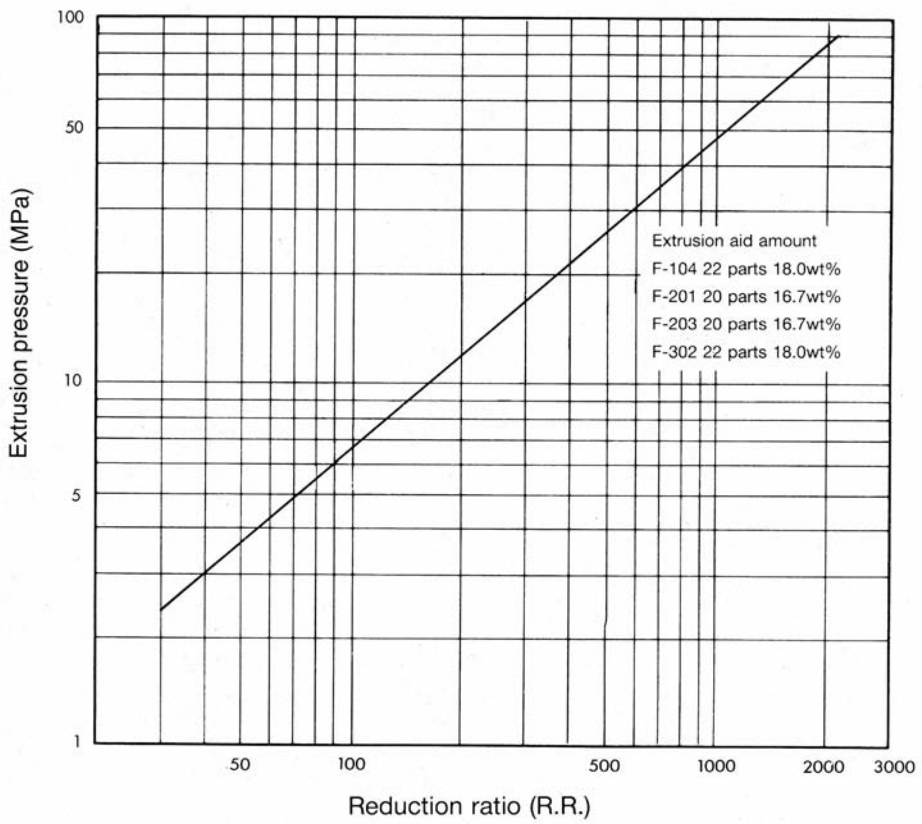




$$R.R. = \frac{Dc^2 - Dm^2}{do^2 - dp^2}$$

Dc: Cylinder inside diameter
Dm: Mandrel outside diameter
do: Die orifice inside diameter
dp: Core pin outside diameter

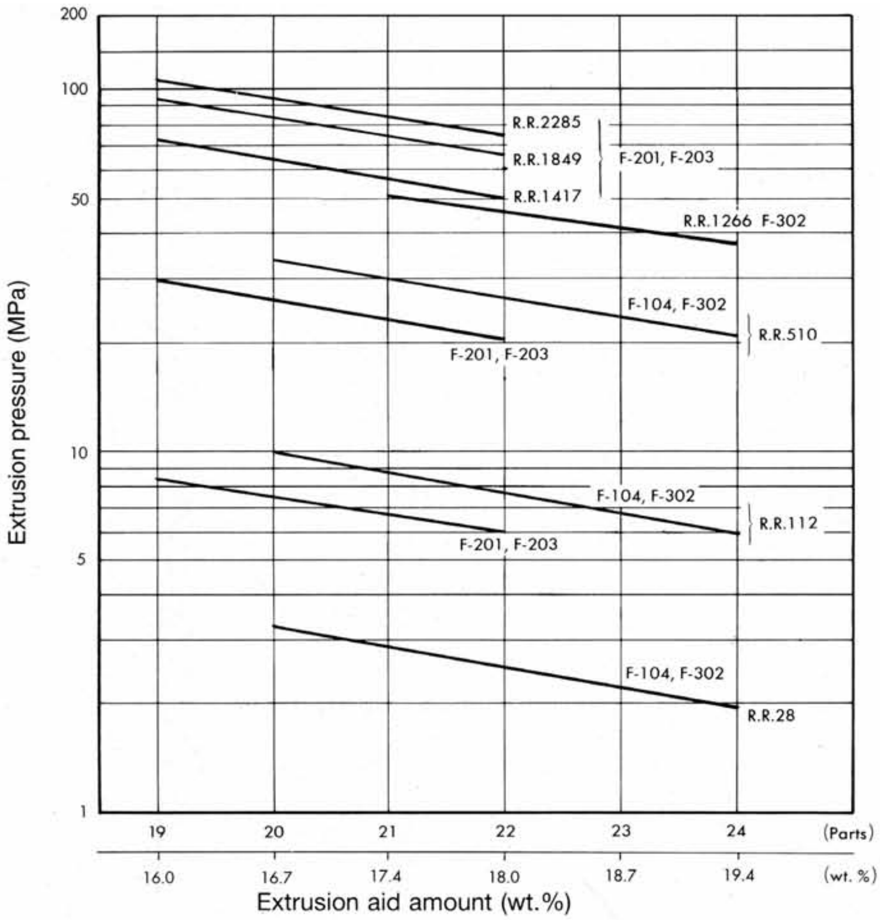
Fig. 3 Relation of Reduction Ratio and Extrusion Pressure



Note: Extrusion aid used: Isopar-E
Extruder used: Jennings extruder

Either a hydraulic or a screw-type ram driving mechanism is suitable.The speed of the extrusion is no effected by the pressure exerted on the ram. Hydraulic-type driving mechanism is most often used in large-scale extruders. The function of the die is to change the shape of the preform into a molded product of the specified shape. The construction of the die greatly influences the extrusion pressure. The die angle varies according to the reduction ratio, but 20~60º is suitable. This angle is decreased as the reduction ratio increases. The length of the die land is ordinarily 3~10 times its diameter. And, whereas extrusion molding is normally done at room temperature (23~25ºC(73~77ºF)), the die is heated to 50~60ºC (122~140ºF). The extrusion pressure varies according to the reduction ratio, die angle, length of the die land, and extrusion speed. Adjustment of this pressure is done by varying the amount of the extrusion aid added to the powder. If the extrusion pressure is too great, a severe burden will be placed on the extrusion equipment. This, in turn, may cause excessive shearing strength to act on the resin particles, resulting in defects, such as cracks or deformations, in the molded product. If the extrusion pressure is too low, the resulting molded product will be porous. The relation between the amount of extrusion aid the extrusion pressure is shown in Fig. 4.

Fig.4 Relation of Extrusion Aid Amount and Extrusion Pressure

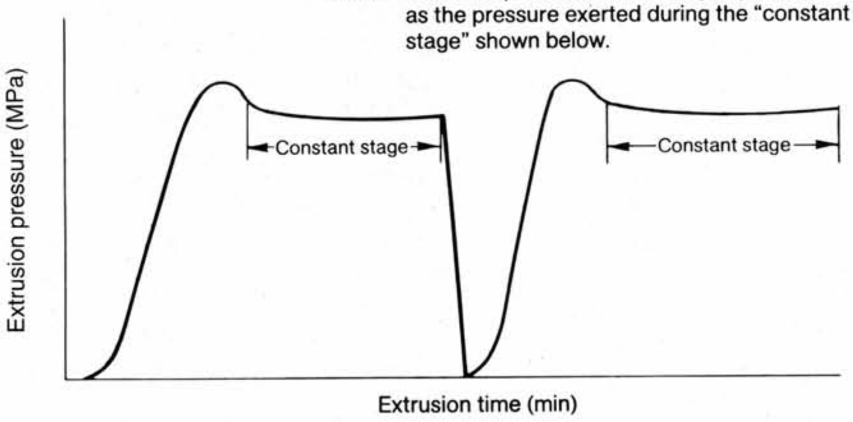


Note: Extrusion aid used: Isopar-E

Extrusion molding is generally done by the batch system. When the preform inside the cylinder is extruded, the machine is stopped, the ram is returned, a new preform is inserted, and the ram is driven once again. The extrusion pressure, therefore, changes periodically for each molding operation. This periodic change is shown in Fig. 5.

Fig.5 Extrusion Time and Extrusion Pressure

Note: Extrusion pressure is ordinarily expressed as the pressure exerted during the "constant stage" shown below.



If the molding process is a continuous one, the extrusion speed will be effected by the capability of the next two steps-the drying process and the sintering process. Although this speedvaries according to the dimensions of the product to be molded, the range is generally from 0.1~20 m/min.

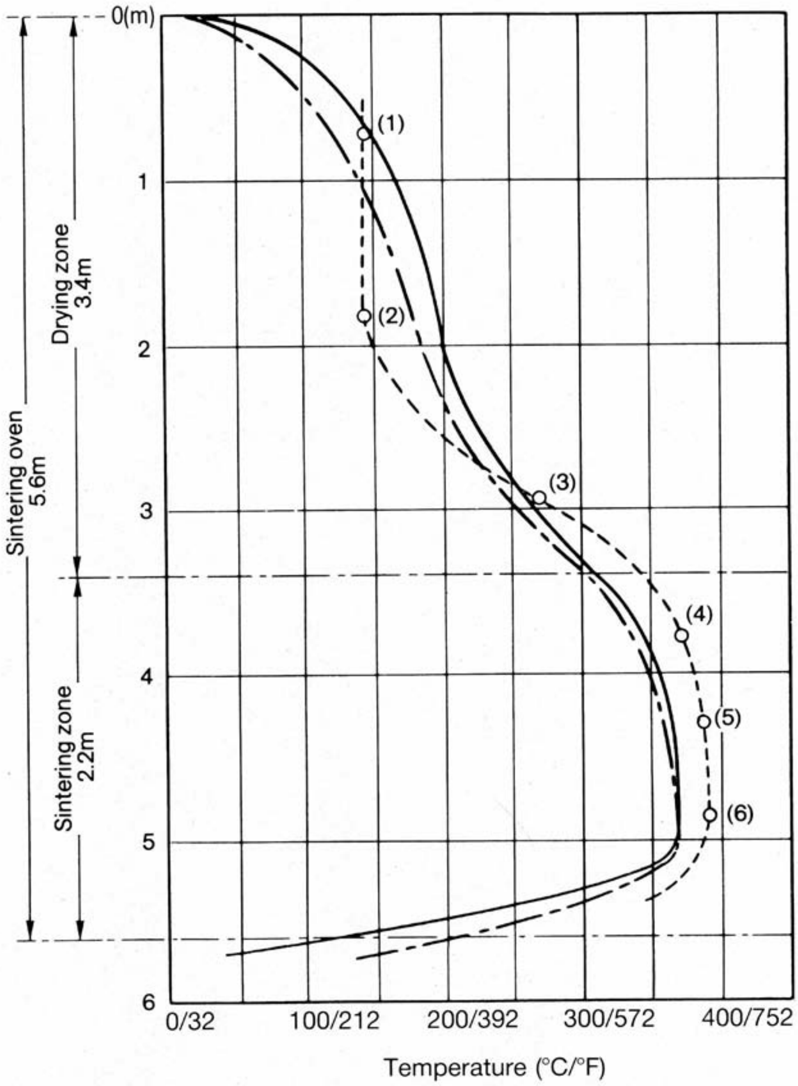
(2) Drying

In order to remove the extrusion aid contained in the product which was extruded in step(1), the product is placed in an oven and heated to a temperature high enough to evaporate the extrusion aid. Inside the drying oven, the extrusion aid must spread to the surface of the product, and then be evaporated. The speed of this spreading and evaporating process depends on the temperature of the oven, but the process must be appropriately controlled in order to prevent blistering. The temperature of the drying oven varies according to the thickness and diameter of the product, the extrusion speed, and the type of extrusion aid used. Ordinarily, however, the temperature at the entrance of the oven is approximately 100ºC (212ºF), and at the exit of the oven is approximately 250ºC (482ºF). The temperature of the drying oven is adjusted by controlling the temperature of the oven‘s heat source, and by varying the air current inside the oven. Because the extrusion aid is flammable, care must be taken to avoid fire. and sufficient ventilation must be provided. The drying oven must be 2~3 times longer than the sintering oven. If the drying oven is too short deformities will occur due to inadequate drying.

(3) Sintering

Immediately after the extrusion aid has been removed from the product, the temperature is raised to 360~390ºC (680~734ºF) and the product is sintered. If the extrusion speed is high, the temperature should be increased to approximately 400~420ºC (752~788ºF). Since the sintering time depends on several factors, such as the thickness and diameter of the product, the extrusion speed, etc., the appropriate time must be determined by experience. Fig. 6 shows the relation of oven temperature distribution and the sintering temperature for tubes. A change in the volume of the product occurs during the latter part of the drying process and continues through the sintering process, shrinking the volume of the final product by 25~30%. There is a directional nature to this shrinkage. The most significant shrinking occurs in the direction of extrusion. This shrinkage is restricted to a large degree by the sintering equipment itself (such as in suspension-type sintering, in which the product‘s own weight is exerted.) In general, the most important factor is the direction of the diameter of the product. This proportion is found by the calculation (die diameter-tube diameter) / die diameter, is in the 0~10% range, but, for accuracy, must be determined according to the specifications of the equipment being used, and according to experience.

Fig.6 Relation of Oven Temperature and Tube Sintering Temperature



Note: 1. (1)~(6):Corresponding to oven temperature measuring points (Refer to Fig.2. Point A = 420ºC(788ºF), Point B = 200ºC(392ºF))
2. Extrusion conditions

——— Die diameter/Core pin diameter = 8/6 mm, extrusion speed = 0.65-0.7 m/min

\- - - - - - Die diameter/Core pin diameter = 8/7 mm, extrusion speed = 1.1-1.2 m/min

(4) Product

Examples of extruded tubes and spaghetti tubes, and their properties, are described in Table 3 and Table 4.

Table 3 Examples of Tubes Extruded from POLYFLON PTFE

Item	F-201			F-203			F-104		F-302		
	I	II	III	I	II	III	I	II	I	II	III
Die diameter (outside, mm)	4.0	8.0	25.0	4.0	8.0	25.0	25.0	47	8.0	14.8	47
Core pin diameter (inside, mm)	3.0	7.0	22.0	3.0	7.0	22.0	22.0	44	6.0	12.0	44
Clearance (thickness, mm)	0.5	0.5	1.5	0.5	0.5	1.5	1.5	1.5	1.0	1.4	1.5
Reduction ratio (R.R.)	1090	510	112	1090	510	112	112	28	273	102	28
Extruder Cylinder diameter (mm)	90	90	130	90	90	130	130	90	90	90	90
Mandrel diameter (mm)	21.6	21.6	34	21.6	21.6	34	34	21.6	21.6	21.6	21.6
Die angle (degree)	30	30	60	30	30	60	60	60	30	30	60
Die temperature (°C/°F)	50/122	50/122	50/122	50/122	50/122	50/122	50/122	50/122	50/122	50/122	50/122
Amount of extrusion aid blended*[1]											
(Weight part)	21	21	20	21	21	20	22	22	22	22	22
(wt.%)	17.4	17.4	16.7	17.4	17.4	16.7	18.0	18.0	18.0	18.0	18.0
Preforming pressure (MPa(psi))	1.5 (218)	1.5 (218)	1.5 (218)	1.5 (218)	1.5 (218)	1.5 (218)	1.5 (218)	1.5 (218)	1.5 (218)	1.5 (218)	1.5 (218)
Extrusion pressure (MPa(psi))	44.1 (6395)	35.5 (3408)	7.5 (1088)	43.6 (6322)	23.3 (3379)	7.4 (1073)	8.4 (1218)	3.2 (464)	12.7 (1842)	7.8 (1131)	3.2 (464)
Extrusion speed (m/min)	2.0	1.2	0.28	2.0	1.2	0.26	0.25	0.11	0.6	0.48	0.10
Product dimensions											
Outside diameter (mm)	3.79	7.58	22.5	3.80	7.60	22.8	23.2	41.3	7.6	13.3	40.0
Inside diameter (mm)	2.87	6.53	19.7	2.88	6.55	20.0	20.3	37.4	5.8	10.3	37.2
Thickness (mm)	0.46	0.53	1.4	0.46	0.53	1.4	1.4	1.4	0.9	1.45	1.4
Outside diameter shrinkage proportion (%)	5.2	5.3	10.0	5.0	5.0	8.8	8.4	12.1	5.0	10.1	14.9
Length shrinkage proportion (%)	25.1	23.4	18.2	26	25.0	19.0	20.0	23.0	23.0	21	22.0
Tensile strength (MPa(psi))											
Longitudinal direction		51.0 (7395)	33.3 (4829)		41.2 (5974)	39.2 (5684)	41.2 (5974)	39.7 (5757)	49.0 (7105)	47.7 (6917)	41.2 (5974)
Transverse direction		37.2 (5394)	20.6 (2987)		—	36.3 (5264)	28.1 (4075)	28.2 (4089)	—	25.5 (3698)	34.3 (4974)
Elongation (%)											
Longitudinal direction		320	260		300	360	232	232	280	300	320
Transverse direction		450	330		—	420	441	375	—	400	420
Specific gravity of product		2.157	2.156		2.152	2.150	2.158	2.152	2.168	2.168	2.150

Note: *[1] Extrusion aid used: Isopar-E

Table 4 Examples of Spaghetti Tubes Extruded from POLYFLON PTFE

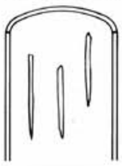
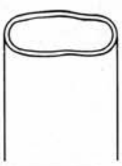
Item	F-201				F-203			F-302	
	I	II	III	IV	I	II	III	I	II
Die diameter (outside, mm)	1.270	1.321	1.397	1.90	1.321	1.397	1.90	1.60	1.90
Core pin diameter (inside, mm)	1.043	1.043	1.043	1.50	1.043	1.043	1.50	1.27	1.50
Clearance (thickness, mm)	0.116	0.139	0.177	0.2	0.139	0.177	0.2	0.165	0.20
Reduction ratio (R.R.)	2285	1849	1417	870	1849	1417	870	1266	870
Extruder Cylinder diameter (mm)	38	38	38	38	38	38	38	38	38
Mandrel diameter (mm)	16	16	16	16	16	16	16	16	16
Die angle (degree)	20	20	20	20	20	20	20	20	20
Die temperature (°C/°F)	50/122	50/122	50/122	50/122	50/122	50/122	50/122	50/122	50/122
Amount of extrusion aid blended★[1]									
(Weight part)	20	20	20	20	20	20	20	20	22
(wt.%)	16.7	16.7	16.5	16.5	16.5	16.5	16.5	18.0	18.0
Preforming pressure (MPa(psi))	2.5 (363)	2.5 (363)	2.5 (363)	2.5 (363)	2.5 (363)	2.5 (363)	2.5 (363)	2.5 (363)	2.5 (363)
Extrusion pressure (MPa(psi))	93.1 (13500)	78.4 (11368)	62.7 (9092)	52.9 (7671)	77.4 (11223)	61.7 (8947)	51.9 (7526)	58.8 (8526)	52.9 (7671)
Extrusion speed (m/min)	25	20	13	16	19	12	15	20	15
Drying zone temperature★[2] (°C/°F)	200/392	200/392	200/392	200/392	200/392	200/392	200/392	200/392	200/392
Sintering zone temperature★[2] (°C/°F)	400/752	400/752	400/752	400/752	400/752	400/752	400/752	400/752	400/752
Product dimensions									
Outside diameter (mm)	1.12	1.21	1.32	1.52	1.23	1.34	1.50	1.41	1.54
Inside diameter (mm)	0.92	0.95	0.99	1.22	0.97	1.01	1.30	1.10	1.24
Thickness (mm)	0.10	0.13	0.165	0.15	0.13	0.165	0.15	0.155	0.15
Tensile strength									
Longitudinal direction (MPa(psi))		70.6 (10237)	70.6 (10237)		68.6 (9947)	66.6 (9657)		59.8 (8671)	
Elongation									
Longitudinal direction (%)		350	350		360	365		340	

Note: *[1] Extrusion aid used: Isopar-E
*[2] Corresponding to Jennings extruder (30-ton) as shown in Fig. 7

(5) Flaws and countermeasures

Flaws which might occur during tube extrusion, and countermeasures to prevent them, are shown in Table 5.

Table 5 Flaws in Tube Extrusion and Appropriate Countermeasures

Flaw	Causes	Countermeasures
Fingernail flow 	• Excessive shearing strength exerted on powder • Too much extrusion aid • Wet spots inside billet	• Improve method of powder handling • Decrease amount of extrusion aid • Disperse uniformly
Longitudinal slit 	• Not enough extrusion aid • Drying temperature too high • Inside tube/outside tube temperature gradient is too steep	• Increase amount of extrusion aid • Check and adjust drying temperature • Decrease temperature gradient
Surface irregularity 	• Dry spots inside billet • Not enough extrusion aid • Temperature of resin is too low	• Disperse uniformly • Increase amount of extrusion aid • Raise storage and operating temperatures
Swelling, blisters 	• Drying temperature too high • Water in extrusion aid and/or powder • Air contained in material	• Decrease extrusion speed; lower drying temperature • Check extrusion aid and powder • Check preforming conditions (pressure, speed, time)
Curl, irregular flow 	• Uneven density in billet • Deviation in extrusion aid amount, or volatization • Incorrectly centered, bend in mandrel	• Check preforming process (charging pressure) • Check preforming process (operation) • Reassemble or repair
Out of round 	• Excessive tension during drying and/or sintering • Exhaust inside tube is too strong • Tube moved during molding	• Decrease tension • Decrease suction force • Reduce the size of openings in the entrance and exit of the oven; decrease the flow of air.
Product discoloration, spots	• Insufficient volatization of extrusion aid • Volatized extrusion aid is cooling inside the mandrel, and dripping	• Adjust exhaust • Adjust exhaust

3-6 Electric wire insulation

(1) Extrusion equipment

A rough diagram of typical electric wire insulating system of POLYFLON PTFE Fine powder is shown in Fig. 7(a). This system consists of a wire pay-off, a wire haul-off, an extruder, a drying/sintering oven, a spark tester and a wire take-up.

(i) Extruder

The extruder contains a cylinder, a ram, a drive mechanism (hydraulic or screw type), a die, a mandrel, etc. A cylinder with an inside diameter of 19~76 mm (¾~3“) is ordinarily used, and extruders are generally designed so the cylinder can be exchanged in accordance with the dimensions of the product. The drive mechanism and ram must be capable of developing 137.2MPa (19894 psi) of pressure, and the ram speed and extrusion pressure must be independently controlled. The structure of a die for the molding of electric wire insulation (spaghetti tubes) is shown in Fig. 7(b). Because the shape, dimension, and surface condition of the die have a significant effect on the extrusion pressure during the molding process, and on the overall molding capability, extreme precision is required in its construction.

Fig.7(a) Extrusion Molding of Electric Wire Insulating Extrusion Process of POLYFLON PTFE Fine Powder (“Jennings” Electric Wire Insulating System (Hydraulic.))

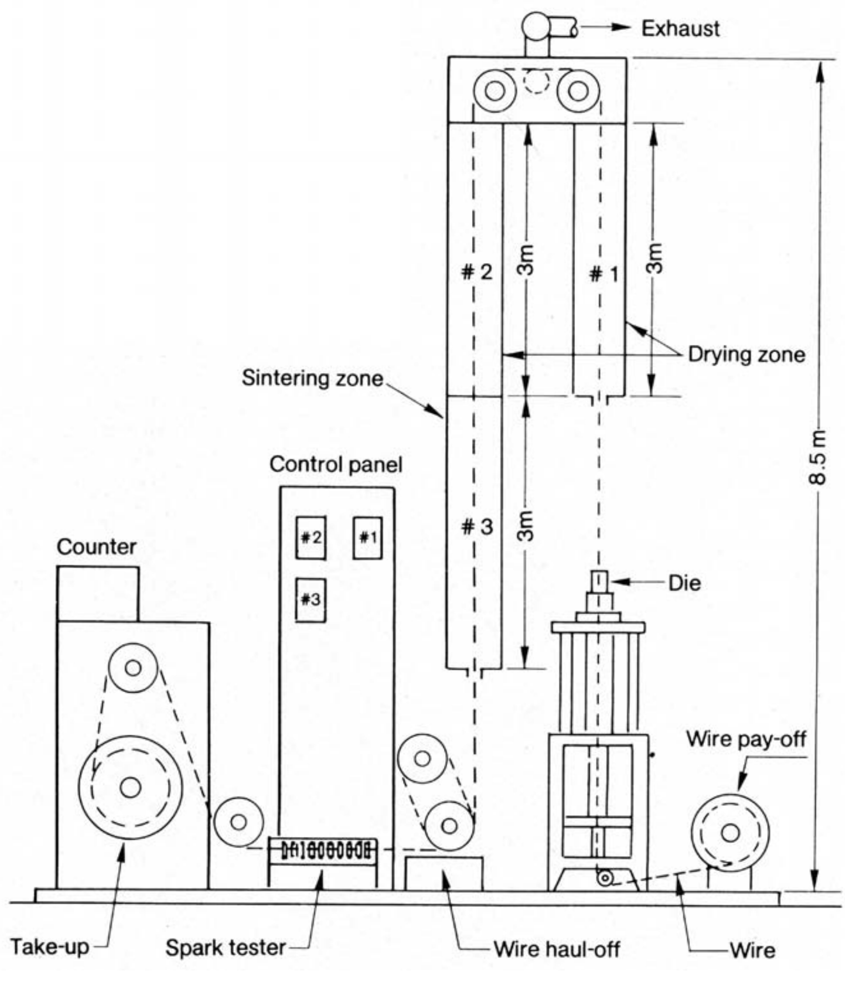
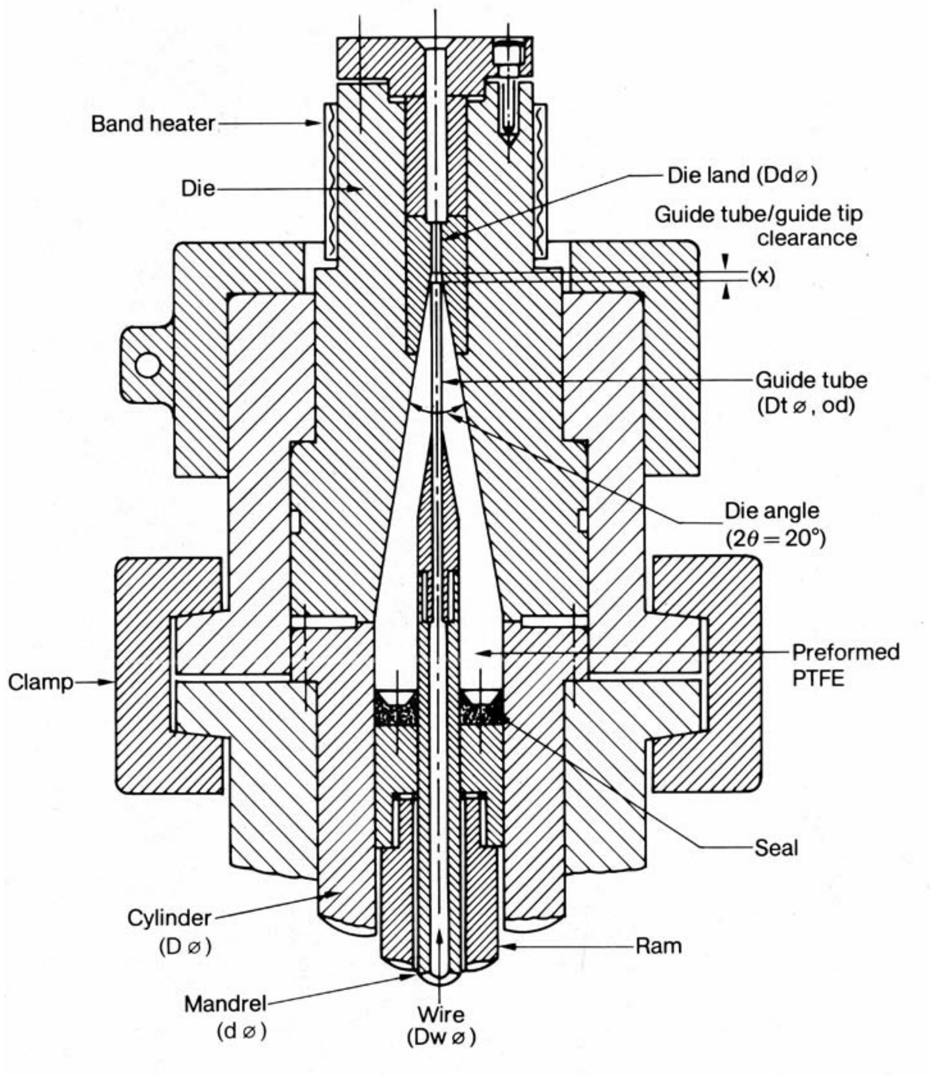


Fig.7(b) Structure of Electric Wire Insulation Extruder Die



(ii) Drying and sintering oven

Since the preform of wire insulation and spaghetti tubes can be curved, the drying and sintering oven used differs from those ordinarily used for tubes. A multiple-turn type can be used, which greatly increases the molding speed. The temperature in the U-turn type shown in Fig. 7(a) is controlled in three locations, and the diameter of the upper pulleys is 300 mm. Since the extrusion aid is evaporated in the drying zone of this oven, and because a small amount of decomposed gas is produced in the sintering zone, an exhaust system utilizing a blower is necessary.

(2) Core wire

Silver or nickel plated annealed copper wire (braided or salid) is used as the core wire (conductor) of insulated electric wires made from POLYFLON PTFE. Silver plated wire is used for heat-resistant, high-frequency electric wires, and can be used continuously up to the temperature of 200ºC (392ºF). The heat resistance of nickel plated wire superior to silver plated, and can be used continuously up to 260ºC 500ºF). Extreme care should be taken in the selection of the core wire, as the quality of the braiding and plating has a large influence on the processibility and quality of the insulation made from POLYFLON PTFE Fine Powder.

(3) Processing

The processing for electric wire insulation is similar to tubes. Examples of electric wire insulation molded from POLYFLON PTFE are described in Table 6. The main difference between the extrusion process for tube and wire is that, for electric wire insulation, a clearance must be provided between the guide tube and the guide tip. If this clearance is too small, the flow section of the resin is reduced, which raises the extrusion pressure and causes the insulation to waver and be intermittent. On the other hand if this clearance is too large, the flow speed of the resin will decrease and an excessive shearing force will be exerted on the resin particles which contact the core wire. This can cause a loss of resin fluidity, resulting in the cutting of the core wire, or producing defects in the insulation. The optimum clearance should be determined by testing each batch of wire to be insulated, but an approximate value can be obtained by using the formula shown on the next page.

The resin which is extruded from the die enters the drying and sintering zone together with the core wire.

The specific gravity of the insulating resin after drying is approximately 1.5~1.6, with little strength. After this, however, the insulation is fused and shrunk by the sintering process, and becomes a strong, voidless insulating layer.

Table 6 Examples of Electric Wire Insulation extruded from POLYFLON PTFE

Item	F-201			F-203			F-302
	I	II	III	I	II	III	I
Core wire structure (no. of strands/diameter mm)	7/0.127	19/0.127	19/0.287	19/0.127	19/0.361	19/0.455	37/0.404
Wire plating	Ag	Ag	Ni	Ag	Ni	Ni	Ni
Wire outside diameter (mm)	0.38	0.64	1.14	0.64	1.80	2.28	2.83
AGW NO.	28	24	16	24	14	12	10
Extruder Cylinder diameter (mm)	38	38	38	38	38	38	38
Mandrel diameter (mm)	16	16	16	16	16	16	16
Die angle (degree)	20	20	20	20	20	20	20
Die tip diameter (mm)	0.762	1.32	2.2	1.32	2.54	3.10	3.81
Guide tube diameter (mm)	0.406	1.06	1.78	1.06	2.40	2.94	3.77
Reduction ratio (R.R.)	2750	890	420	890	355	280	190
Amount of extrusion aid blended★1							
(Weight part)	21	21	19	21	19	19	21
(wt.%)	17.5	17.5	16.0	17.5	16.0	16.0	17.5
Preforming pressure and time (MPa(psi)×min)	2.5(363) ×5	2.5(363) ×5	2.5(363) ×5	2.5(363) ×5	2.5(363) ×5	2.5(363) ×5	2.5(363) ×5
Guide tube/guide tip clearance	0.3	0.43	1.7	0.43	2.4	2.65	6.25
Calculated value★2 (mm)	(0.62)	(0.73)	(0.76)	(0.73)	(1.4)	(1.45)	(2.1)
Die temperature (°C/°F)	50/122	50/122	50/122	50/122	50/122	50/122	50/122
Extruder ram speed (mm/min)	11	18.5	19	18.5	14	20	27
Haul-off speed (m/min)	18.2	15.2	7.0	15.1	4.9	4.6	4.0
Extrusion pressure (MPa(psi))	89.2	53.5	37.7	53.9	30.9	28.8	27.4
	(12934)	(7758)	(5467)	(7816)	(4481)	(4176)	(3973)
Oven temperature #1 (drying) (°C/°F)	95/203	150/302	150/302	150/302	150/302	150/302	150/302
#2 (drying) (°C/°F)	205/401	250/482	250/482	250/482	250/482	250/482	250/482
#3 (sintering) (°C/°F)	400/752	500/932	500/932	500/932	500/932	500/932	500/932
Extruded product dimensions							
Outside diameter (mm)	0.68	1.15	1.95	1.16	2.30	2.85	3.60
Insulation thickness (mm)	0.15	0.25	0.25	0.26	0.25	0.28	0.38

Note: *1 Extrusion aid used: Isopar-E
*2 Clearance value (x)

$$X = \frac{\cot\theta}{2}\left[\sqrt{Dt^2 + \sec\theta\,(Dd^2 - Dw^2)} - Dd\right]$$

θ: 2/1 of die angle
Dt: Guide tube outside diameter (mm)
Dw: Wire outside diameter (mm)
Dd: Die tip inside diameter (mm)

(4) Insulated wire properties

The dielectric constant and dissipation factor of the insulated electric wire made from POLYFLON PTFE Fine Powder at various frequencies are shown in Fig. 8, and the result of a heat aging test are shown in Fig. 9.

Fig.8(a) Electrical Properties of Insulated Electric Wire* made from POLYFLON PTFE Fine Powder Dielectric Constant at Various Frequencies

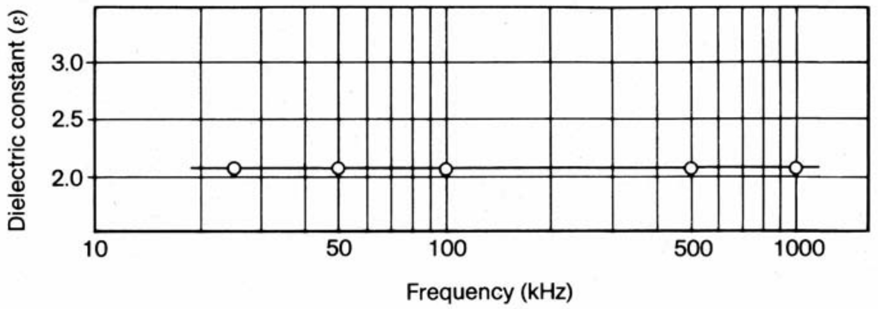
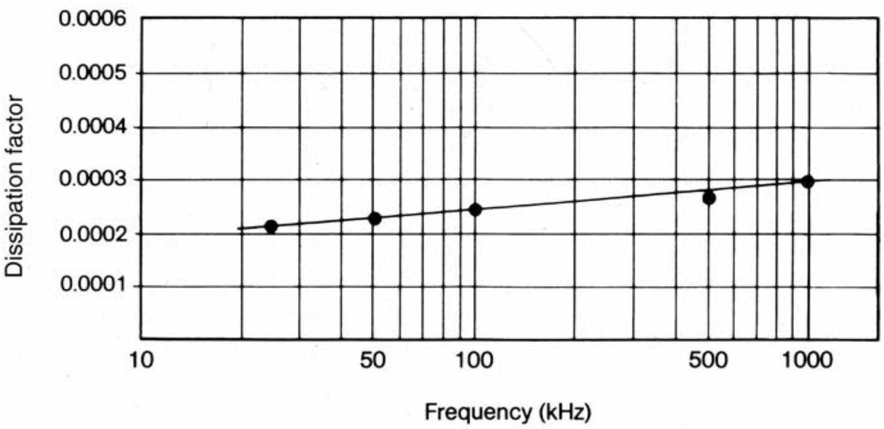
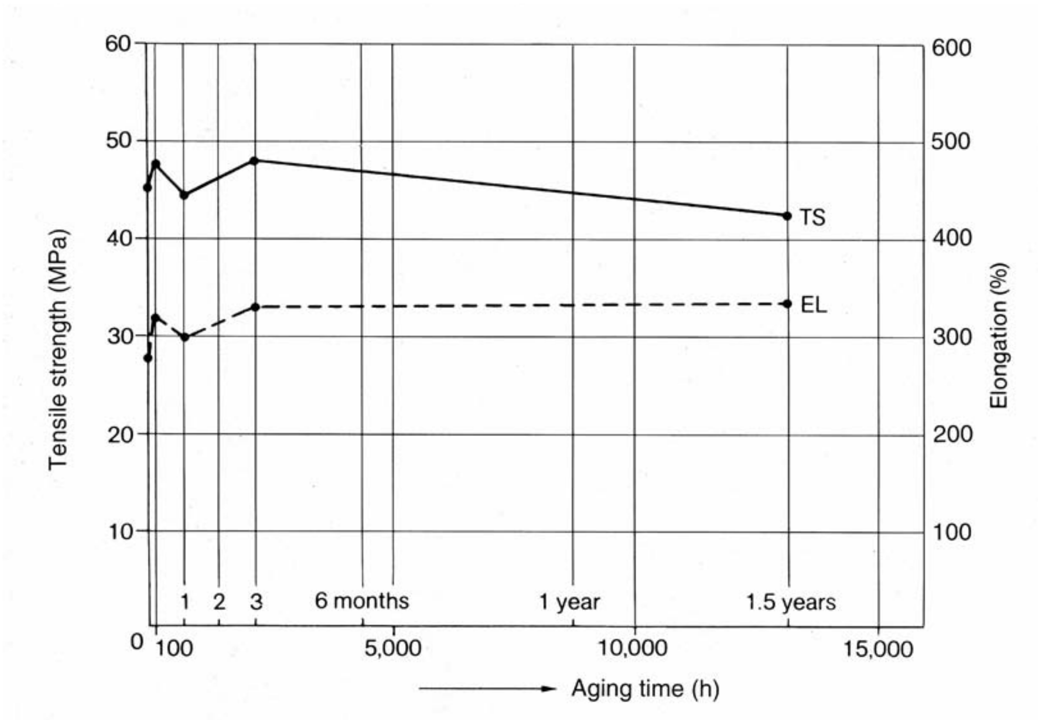


Fig.8(b) Electrical Properties of Insulated Electric Wire* made from POLYFLON PTFE Fine Powder Dielectric Constant at Various Frequencies



* [Test sample] Raw Material: Daikin-Polyflon PTFE F-201
Insulated wire: UL-1180 (PTFE 0.36 mm)
Core wire: AWG22 (710.254 Ag)

Fig. 9 Insulated Wire* made from POLYFLON PTFE Fine Powder Heat Aging Test (Temperature: 250ºC (482ºF))



* Test sample Raw material: POLYFLON PTFE-F-201
Insulated wire: MIL-W-168781. E-20
Core wire: 7/0.320 Ag
Coating thickness of POLYFLON PTFE: 0.25 mm

The results of heat treatment at an internal oven temperature of 380ºC (716ºF) with a tube (8/7) as the test material are shown below.

Fig.10(a) Tubes made from POLYFLON PTFE Fine Powder Heat Aging Test (Temperature:380ºC/716ºF)
= Specific gravity =

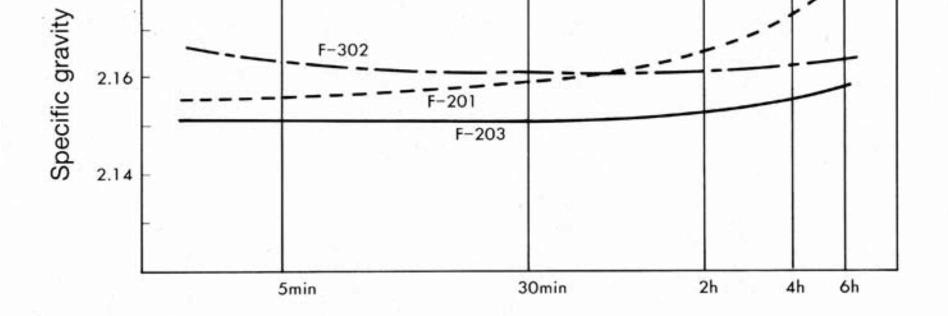


Fig.10 (b) Tubes made from POLYFLON PTFE Fine Powder Heat Aging Test (Temperature:380ºC/716ºF)
= Elongation =

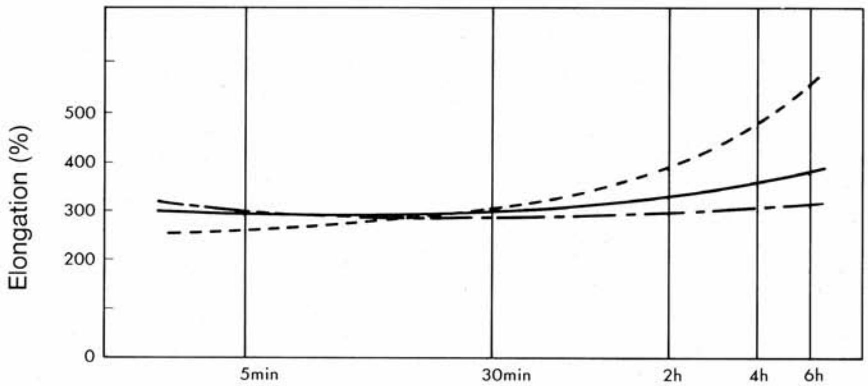
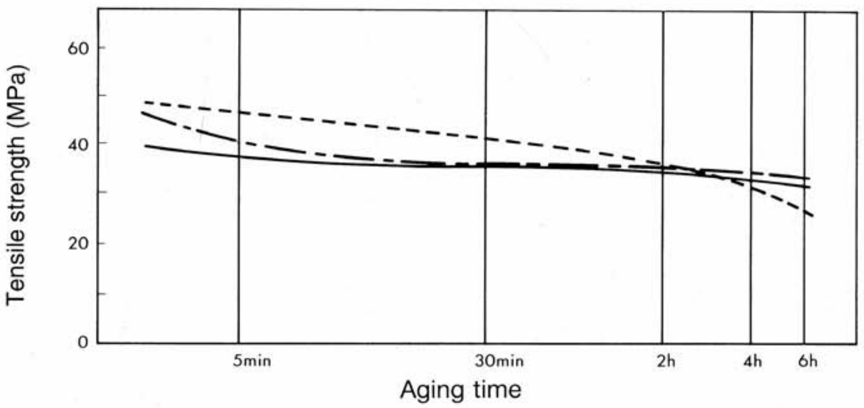


Fig.10 (c) Tubes made from DAIKIN-POLYFLON PTFE Fine Powder Heat Aging Test (Temperature:380ºC/716ºF)
= Tensile strength =



3-7 Calender processing

As shown in Fig. 1, POLYFLON PTFE Fine Powder can be processed into unsintered tape by calender processing. The processing for ordinary unsintered tape is illustrated in Fig. 11.

(1) Extrusion

The extrusion of unsintered rods (cylindrical rod, square rod) is done in the same way as in tube extrusion. However, because calendering is done in an unsintered state, an extrusion aid with lubricating properties rather than volatile properties should be selected. Generally, an extrusion cylinder 100~250 mm in diameter, a round die of 10~30 mm in diameter, or a rectangular die 15×6mm or 20×10mm, is used.

(2) Calendering

Calendering is usually done in several steps, but if a 300~500 mm roll is used, it can be done in a single step. The calender roll should be 300~500 mm in diameter. It should be capable of being heated to 50~80ºC (122~176ºF), have a rolling speed of 5~30 m/min, and possess a polished surface with no eccentricity. Table 7 describes the processing conditions and properties of unsintered tape made from POLYFLON PTFE Fine Powder.

(3) Extraction of extrusion aid

After extrusion and calendering has been completed, it is necessary to remove the extrusion aid contained in the tape. Usually it is dried and the extrusion aid is extracted in the calender roller and hot air furnace, etc. (Take care igniting, the air out and discharge gasses).

(4) Finishing

Tape made in this way is called unsintered tape. It is generally slit into 13 mm widths, and wound in fixed lenghts onto reels.

(5) Properites of unsintered tape

Unsintered tape made from POLYFLON PTFE Fine Powder has the same excellent chemical and thermal properties of molded products made from POLYFLON PTFE Fine Powder, plus its own unique mechanical properties. It is porous, having a specific gravity of approximately 1.5, compared to 2.2 for molded products made from POLYFLON PTFE Fine Powder. Its elongation perpendicular to the calendering direction reaches 1000~2000%. With these unique properties, it is extremely malleable and provides an excellent sealing effect, ideal for use as a pipe thread seal.

Fig.11 Production of Unsintered Tape made from POLYFLON PTFE Fine Powder

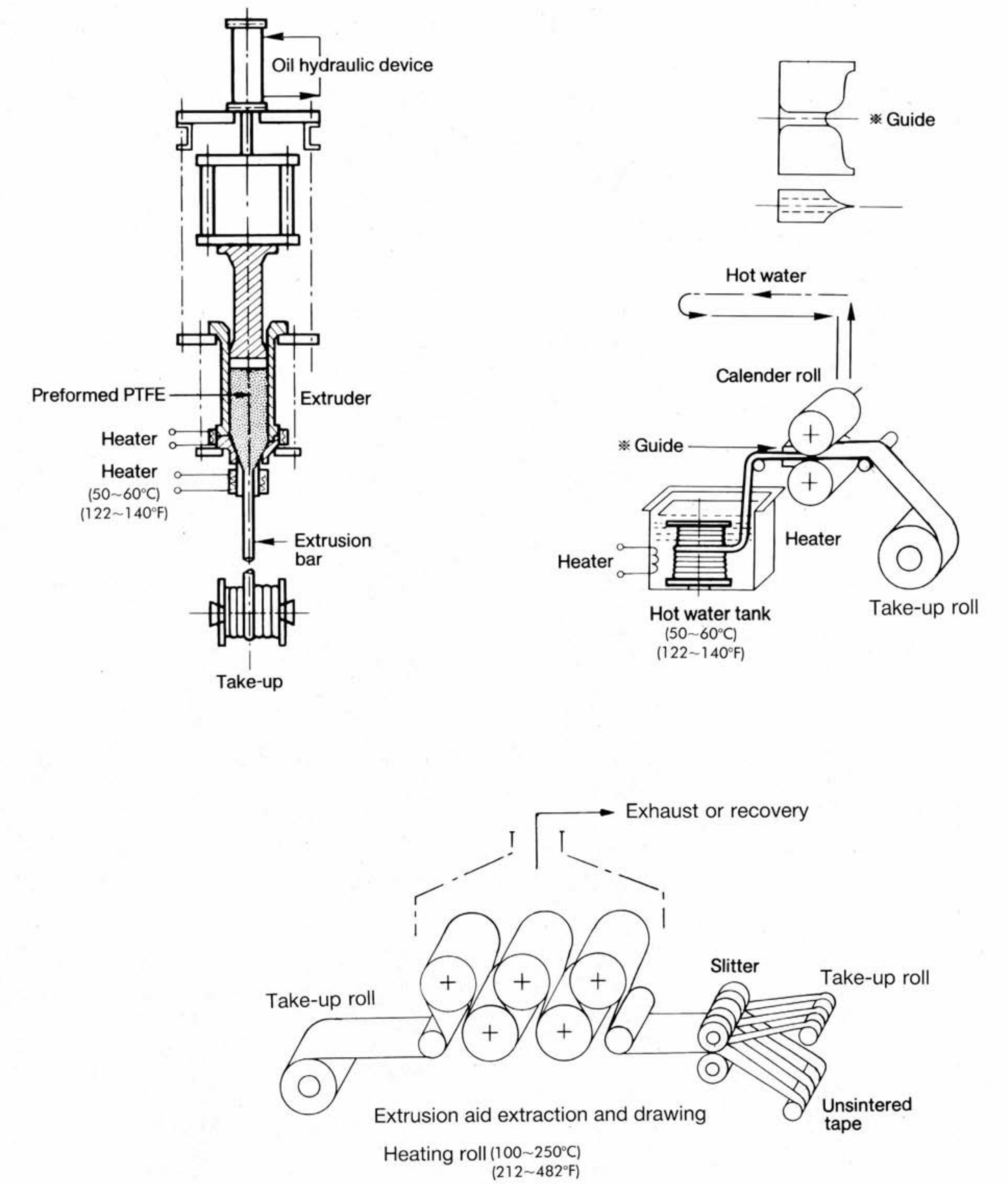


Table 7 Processing Conditions; Properties of Unsintered Tape made from POLYFLON PTFE Fine Powder

Item	F-104
Shape of unsintered rod	Cylindrical rod
Die diameter (mm)	16
Extruder cylinder diameter (mm)	130
Die angle (degree)	60
Die temperature (℃/° F)	50/122
Reduction ratio (R.R.)	66
Amount of extrusion aid belended	Isopar-M
(weight part)	24
(wt.%)	19.4
Preforming pressure and time (MPa(psi)×min)	1.5 (218)
Extrusion pressure (MPa(psi))	3.9(566)
Extrusion speed (m/min)	3.2
Calender roll diameter (mm)	500
Calender roll temperature (℃/° F)	70/158
Rod temperature (℃/° F)	60/140
Calender speed (m/min)	20
Tape Width (mm)	270～280
Thickness (mm)	0.09
Tensile strength	
Calendering direction (MPa(psi))	14.7(2132)
Perpendicular to calendering direction (MPa(psi))	2.0(290)
Elongation	
Calendering direction(%)	250
Perpendicular to calendering direction(%)	1200
Specific gravity	Approx. 1.55

4. Uses of Products Made from POLYFLON PTFE Fine Powder

4-1 Insulated electric wire

Since POLYFLON PTFE has excellent electrical properties, it is ideal for use as an electric wire insulating material. It also combines the properties of excellent heat resistance and chemical resistance. Typical uses are the following: electric wiring for airplanes, rockets, and missiles; wiring for electric circuit transformers and electric motors; various types of electronic industrial wiring; wiring which is subject to high temperatures, such as in the vicinity of power stations, electric furnaces, or vacuum tubes; and wiring which is effected by strong chemicals used in chemical industries.

4-2 Hoses, tubes

POLYFLON PTFE's superior resistance to heat and chemicals and its non-sticking property are utilized in the following applications: pipes for jet engine fuel and rocket fuel; pipes for high-temperature or corrosive fluids in chemical or nuclear plants; pipes for fluids containing food or chemicals; steam hoses; transport pipes for viscous substances; hoses for oil hydraulic control equipment; and insulation for electronic equipment.

4-3 Thin rods

POLYFLON PTFE's excellent electrical properties and resistance to heat and chemicals are utilized in the manufacture of pump and valve parts, terminals, bushings, and outer insulators.

4-4 Unsintered tape

(1) For sealing
Unsintered tape is ideal as a sealing material for threaded joints. Wrapped around the threads, it forms a tight seal with excellent chemical resistance, and heat resistance. Its self-lubricating property also makes removal easy, and it completely prevents the inside of the pipe from being contaminated.

(2) Insulation
When unsintered tape is wrapped around an wire or coil and heated to 330ºC (626ºF), it shrinks approximately 33% in the direction of calendering, making it possible to cover the article completely. Layers of tape fuse together forming a completely sealed insulation with no gaps. Unsintered tape is also used for splicing or repairing extrusion- insulated wires made from POLYFLON PTFE Fine Powder.

(3) Film
When unsintered tape is sintered under tension, a film is produced which is used as an insulating material.

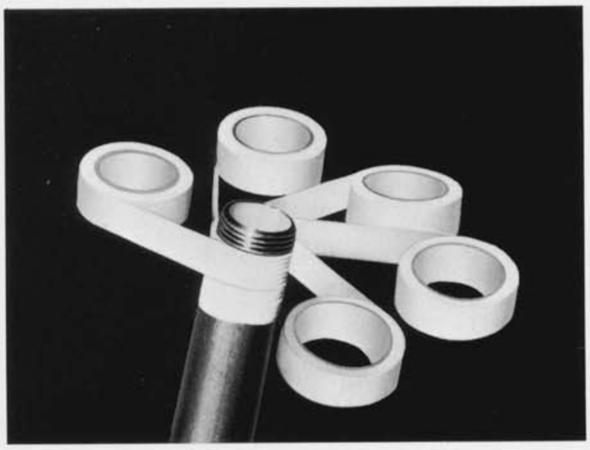
[NOTE]

The usage examples noted above are considered general uses.
Daikin industries does not guarantee that they can be used in these ways.

Applications of products made from POLYFLON PTFE Fine Powder

Insulated wires

Wire braid hose



Unsintered tape

Caution on handling

Although POLYFLON PTFE Fine Powder presents no hazard under normal processing conditions, these safe handling points should be followed:

WARNING: VAPORS HARMFUL IF INHALED.

- The work area should be adequately ventilated at all times because HF, COF_2 begin to be produced at approximately above 260ºC and the volume increases at approximately 400ºC. If PTFE is incinerated, the acidic gases must be removed by alkaline scrubbing techniques.
- Personnel should be cautioned against inhaling the fumes liberated during processing and provided with suitable protective equipment.
- Do not smoke in the work areas as harmful vapors and gases can be produced if POLYFLON PTFE becomes transferred onto tobacco.
- Avoid breathing dust and contact with eyes.
- Wash hands and face after handling
- Waste generated during processing should be treated by waste treatment specialists and disposed of in accordance with federal, state and local waste disposal regulations.
- Read the „Material Safety Date Sheet“ before use.

- DAIKIN INDUSTRIES, LTD. and DAIKIN AMERICA.INC. have obtained the ISO 14001 (*1) certification which is an International Standard concerning the environmental management system. DAIKIN INDUSTRIES, LTD has obtained the ISO 9001 (*2) and DAIKIN AMERICA. INC has obtained the ISO 9002 (*3).

*1. ISO 14001 is a standard established by the ISO (International Organization for Standardization) which applies to environmental preservation activities. Activities, products and services of our fuorochemicals plant have been certified as being environmentally sound by an internationally recognized certification body.

*2. ISO 9001-2000 is a certification system for quality control established by the ISO which certifies our quality control system concerning our products.

*3. ISO 9002-1994 is a plant certification system for quality control established by the ISO which certifies our quality control system concerning manufacture and inspection of the products manufactured at our plant (division).

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