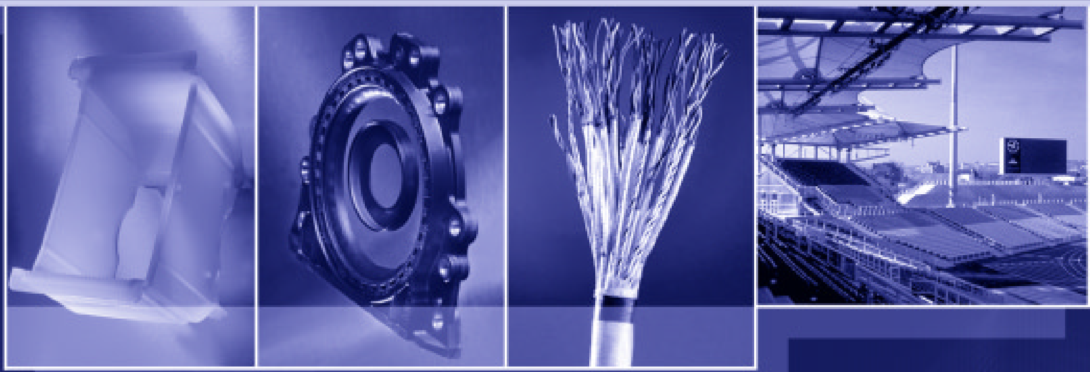
Fluon®



Fluon® - Lubricant Powders - a guide to Applications, Properties & Processing

Technical Service Note FTI500

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INTRODUCTION

Fluon® is the trade name for AGC Chemicals Europe, Ltd. polytetrafluoroethylene (PTFE) and fluorinated ethylene propylene (FEP) lubricant powders developed for use as additives for a wide variety of media such as thermoplastics, elastomers, oils, greases, inks and coating systems. These finely divided, clean, inert, white powders impart the high performance properties of PTFE to the host material, resulting in improved surface lubricity and reduced wear over a wide temperature range.

All Fluon® lubricant powders are manufactured from virgin rather than reprocessed PTFE or FEP feedstock sources to ensure consistent high performance and quality.

Fluon® lubricant powders are virtually immune from chemical attack, do not absorb water, have a wide working temperature range (-190°C to +260°C for PTFE and -100°C to +200°C for FEP) and have excellent weathering and ageing characteristics. They also possess very low coefficients of friction, typically 0.01 for PTFE lubricant powders (0.3 for FEP), allowing for excellent non-stick and sliding properties.

HOW Fluon® LUBRICANT POWDERS WORK

Fluon® lubricant powders are low molecular weight, soft materials which smear to form dry lubricating films under light contact pressure. When this contact pressure continues between two mating surfaces, either of which contains a Fluon® powder, a transferal of the fluoropolymer lubricant to the opposing surface takes place. This results in the build up of a microscopically thin lubricating film allowing for excellent antifrictional properties.

Fluon® GRADE RANGE

A summary of the different properties of the Fluon® lubricant powder range is shown on page 3.

Fluon® FL1680 Fluon® FL1680 is a finely divided PTFE powder with a mean particle size typically in the region of 9-12 micron (depending on the test method used). It has the lowest surface area and porosity of all the Fluon® range of lubricant powders and is particularly suitable for use in printing inks and industrial finishes.

Fluon® FL1690 Fluon® FL1690 is a finely divided PTFE powder which has a slightly coarser mean particle size to FL1680, typically 17 microns. It also has a less compact and more porous structure than FL1680. The absence of processing additives makes it particularly suitable for incorporation into thermoplastics.

Fluon® FL1700 Fluon® FL1700 is a friable PTFE powder which can be broken down to sub-micron particles by high-shear mixing in liquid media. The extent of the reduction in particle size depends largely on the degree of shear. For example, mixing Fluon® FL1700 with a medium viscosity lubricating oil and subsequently passing the mixture twice through a triple-roll mill gives a submicronic particle size range with many particles measuring 0.3 micron. Fluon® FL1700 is particularly suitable for addition to inks for can coatings as well as oils, greases and elastomers.

Fluon® FL1710 Fluon® FL1710 is a finely divided PTFE lubricant powder with good flow properties but a much finer particle size distribution compared to FL1700. The mean particle size is 3 to 6 microns, depending on the test methods used. It disperses easily in liquids in both high and low-shear mixers. The resulting dispersions have relatively low viscosity compared with those produced from other PTFE lubricant powders. They are particularly suitable for use with low viscosity lubricating oils and industrial finishes.

Fluon® FL1710H

Fluon® FL1710H is a finely divided PTFE lubricant powder manufactured from a special feedstock to ensure maximum product consistency and fitness for more demanding surface coating applications. It has a mean particle size of 3 to 6 microns, (depending on the test method used) which is similar to FL1710, but possesses a narrower particle size distribution.

Fluon® FL1710H disperses easily in liquids in both high and low-shear mixers. The resulting dispersions have relatively low viscosity compared with those produced from other PTFE lubricant powders. They are particularly suitable for use with low viscosity lubricating oils and industrial finishes.

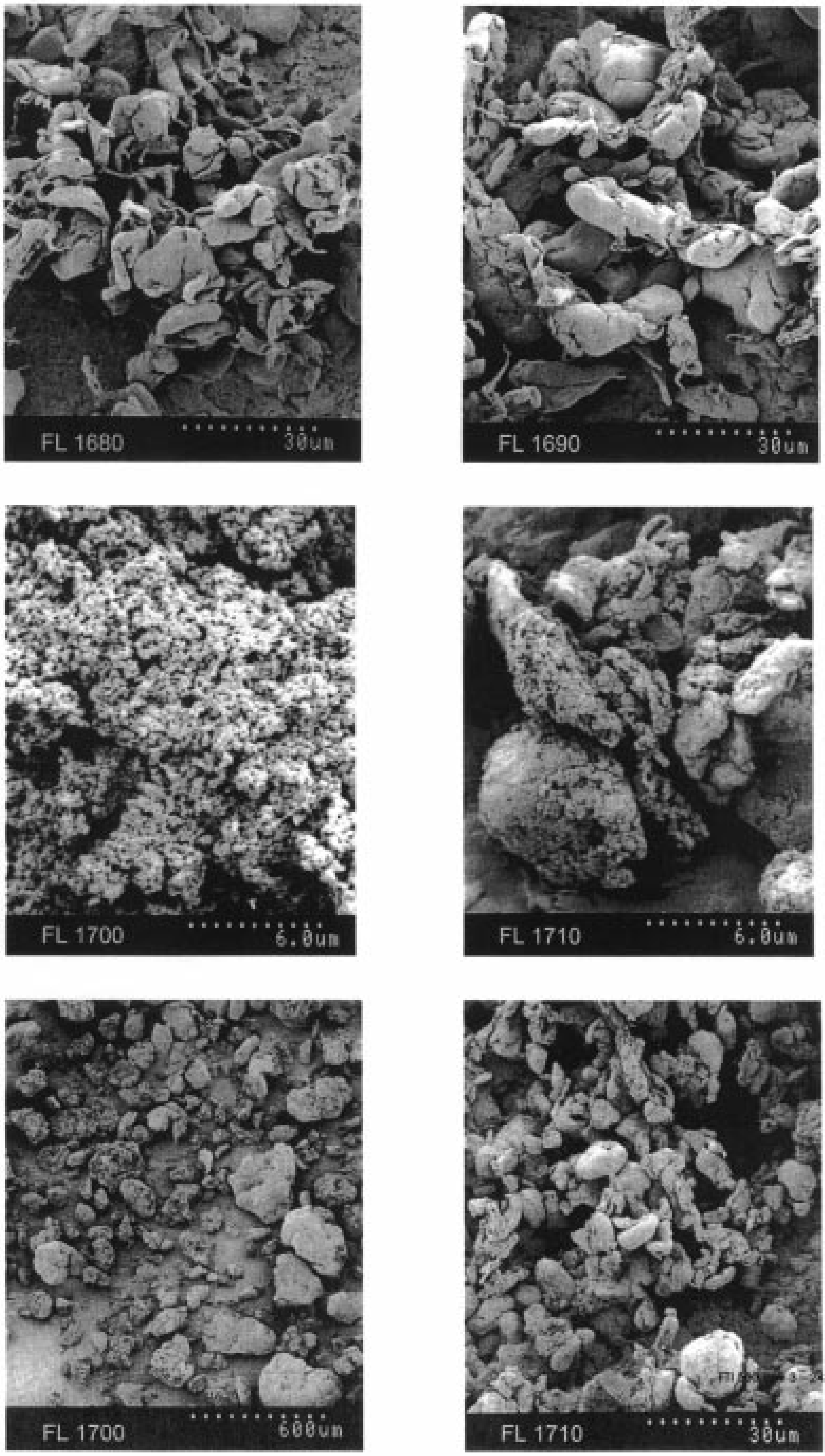
Fluon® LUBRICANT POWDER PROPERTY DATA

PROPERTY	UNITS	TYPICAL VALUE FL 1680	TYPICAL VALUE FL 1690	TYPICAL VALUE FL 1700	TYPICAL VALUE FL 1700H	TYPICAL VALUE FL 1710	TYPICAL VALUE FL 1710H
BULK DENSITY	g/l	450	480	530	560	400	450
RELATIVE DENSITY	-	2.2	2.2	2.2	2.2	2.2	2.2
PARTICLE SIZE (HEGMANN GAUGE)	Microns : AVE	9	17	< 2	< 2	3	3
PARTICLE SIZE (MALVERN LASER DIFFRACTION) (SEE NOTE 1)	Microns : AVE	13	21	95	85	9	7
	10% <	5	8	25	20	4	4
	90% <	28	50	150	140	17	13
PARTICLE SIZE (OPTICAL S.E.M.)	Microns : AVE	11	16	< 1	< 1	6	6
SURFACE AREA (KRYPTON ABSORPTION)	m^2/g	0.8	1.0	3.1	3.1	2.3	2.3
MELTING PEAK TEMPERATURE (D.S.C.)	°C	328	335	335	335	335	335
SERVICE TEMPERATURE RANGE	°C	- 190 + 260	- 190 + 260	- 190 + 260	- 190 + 260	- 190 + 260	- 190 + 260
FDA COMPLIANCE (SEE NOTE 2)	-	Yes	Yes	Yes	Yes	Yes	Yes

Note 1 : The particle size results quoted for FL1700 on the Malvern Laser Diffraction Analyser are higher than the Hegmann gauge technique due to the method of sample preparation. No shear is applied to the powder with the laser diffraction technique.

Note 2 : All Fluon® lubricant powders meet the compositional requirements of the Food and Drug Administration (FDA) regulation 21 CFR 177.1550.

HIGH RESOLUTION SCANNING ELECTRON MICROGRAPHS OF FLUON LUBRICANT POWDERS



Fluon® APPLICATIONS

In most applications the performance of compositions containing Fluon® lubricants will be limited by the properties of the base material. The chemical inertness of PTFE prevents any reaction between the Fluon® lubricant powder and the other constituent, and ensures that it will outlast the base material in corrosive environments. Its wide service temperature range ensures that it will survive temperatures encountered by most materials in which it may be incorporated.

The following, are a number of applications for Fluon® lubricant powders with the recommended grades and processing data for each end use.

1. PRINTING INKS

1.1 Advantages of Using Fluon® Lubricant Powders

Fluon® lubricant powders have the following advantages compared with conventional anti-scuff agents in the preparation of offset, heat-set, gravure and flexographit printing inks:-

1. Improved rub and scuff resistance preserve the attractive finish of printed stock through to its final destination.

2. Reduced blocking and set off can eliminate costly wastage thereby improving efficiency and lowering reject rates, especially with reeled stock on high speed printing machines.

3. Easy dispersion at room temperature can make processing cheaper and more efficient.

4. Reduce friction allows printed stock to slide and stack easily.

5. Chemical inertness enables these powders to be used in any formulation without danger of chemical reaction or solvent attack.

6. Simplified stock control (because one Fluon® lubricant may replace a wide range of natural and synthetic waxes).

7. Excellent temperature resistance enable the powders to be used at temperatures up to 260°C. When used in heat-set inks they remain dispersed in the ink during exposure in the drying oven, allowing fast solvent release and giving excellent print gloss. Fluon® lubricant powders thus enable faster printing speeds to be achieved.

In gravure ink applications there is a need for a small particle sized Fluon® lubricant powder since the PTFE may have a tendency to settle in the cell of the gravure plate, displacing the ink and resulting in a visual flaw in the printed image. Most gravure ink printing cells are typically 5 to 35 microns deep by 100 to 150 microns wide; the PTFE particle should be small and hence the light enough to enter and leave the cell without causing blocking.

A small particle size Fluon® lubricant powder is also required for offset printing, where an aluminium plate is coated with a thin film of photographic emulsion.

Typical particle size of the inks are 5 to 7 microns. The ideal size of the Fluon® lubricant should be less than 5 microns to avoid abrading the emulsion coating on the plate.

Fluon® lubricant powders can be used in both "paste" inks for metal decoration and high quality paper printing applications and also "liquid" inks for less demanding areas such as cardboard packaging and newspapers. Paste inks tend to be solvent based whereas liquid inks are more commonly water based.
Fluon® lubricant powders may also be used in combination with polyethylene or polypropylene waxes.

The different physical properties of Fluon® FL1680, FL1690, FL1700 and FL1710 make different methods of incorporation necessary.

1.2 Recommended Fluon® Lubricants and Processing Information

Fluon® FL1680 and FL1690

Dispersion is readily achieved in a paddle mixer. Triple roll milling with a tight nip is not advised as this may deform the particles, but de-aeration of the ink on a triple roll mill is satisfactory, provided that the rolls are set fairly loose. The proportion of Fluon® FL1680 and FL1690 required is typically 1 to 3% by weight of the non-volatile constituents of the ink.

Fluon® FL1700

This PTFE lubricant disperses easily, with or without grinding, but has been specifically designed to be friable to suit applications such as gravure or flexographic inks for which the smallest particle size possible should be obtained to reduce sedimentation. Tests show that Fluon® FL1700 (in liquid media) can be ground down to 0.3 micron on a triple roll mill, thus enabling the processor to control the particle size to suit his requirements. For dispersion, without particle size reduction, a paddle mixer or equivalent may be used. The proportion of Fluon® FL1700 required is 1 to 3% by weight of the non-volatile constituents of the ink.

The fine particle size resulting from using FL1700 minimises the potential for "piling "or build up on the printing press equipment which can lead to defects in the printed surface.

Fluon® FL1710

Fluon® FL1710 has a very fine particle size and is a very robust, versatile lubricant powder. It has been developed to disperse easily in inks using high or low shear mixers, without a change in either the particle size of the powders and with minimum viscosity modification of the ink. The addition of Fluon® FL1710 to an ink ensures the maximum retention of gloss and the maximum reduction in coefficient of friction. The proportion of Fluon® FL1710 required is 1 to 3% by weight of the non-volatile constituents of the ink.

2. METAL DECORATION COATINGS

2.1 Advantage of Using Fluon® Lubricant Powders

Fluon® lubricant powders are ideal additives for use with metal decoration coatings, often referred to as "can coatings". The cans themselves may be produced in a number of different ways ie:-

"Two piece" beverage cans made from uncoated metal blanks which are drawn into shape, spray coated on the inside and baked followed by roller coating on the outside and stoved.

"Two piece" food cans made from coated coil or coated sheet which is drawn into shape. These cans are thicker than beverage cans and may be either aluminium or tin free steel.

"Three piece" cans are made from pre-coated sheet since an uncoated stripe has to be left on the can to allow welding of the body join. The body is then completely coated with varnish. The can ends may be fabricated from either sheet or coil.

Fluon® lubricant powders are principally used on the external coating of the can to give improved frictional and rub resistance properties to the coating to facilitate easy sliding and movement of the cans on the production line. The Fluon® lubricant also acts as a processing aid during the drawing and neck forming operations of the can production.

Virgin Fluon® lubricant powders are preferred for can coatings rather than other materials (such as polyethylene blends) since they can withstand the relatively high stoving (drying) temperatures of up to 250°C without "burn-out" problems.

The base resins used for coatings are typically epoxy/phenolics containing between 0.5 to 2% Fluon® lubricant powder. Typical masterbatch compositions may be mixed together using high shear blending equipment such as triple roll mills or stirred media mills (eg. bead mills, sand mills and Attritor mills). Coating thicknesses are typically 6 to 10 microns so the need for a Fluon® lubricant powder which can be broken down to a fine particle size is paramount.

FL1700H is the preferred choice of lubricant for such applications since, under the correct high shear milling conditions, it can be broken down to sub-micron particle size and has excellent dispersion characteristics.

Fluon® lubricants have low surface energies which makes them difficult to wet-out in anything but certain solvent or surfactant systems. However, this feature can be used to an advantage in can coatings since solvent removal during the drying of the coating allows the Fluon® powder to become non-wetted and thus migrates to the surface resulting in a lubricant rich coating.

Food and Drug Administration (FDA) approved Fluon® lubricants may also be used for internal can coatings. These are usually water based epoxy materials which are applied to protect the inside of the can from certain aggressive chemicals.

2.2 Recommended Fluon® Lubricants and Processing Information

Fluon® FL1700H

Fluon® FL1700H is a friable PTFE powder which can be broken down to a very fine particle size by the application of high shear during mixing in liquid media. The extent of particle size reduction depends largely upon the degree of shear but sub-micron (0.3 uM) particle dispersions are possible.

The ability to achieve this fine particle size reduces PTFE sedimentation in the formulation and minimises the build up of material on the transfer blanket used in applying external can coatings.

Fluon® lubricants are typically added at between 0.5 to 2%, by weight, of the non-volatile content of the coating.

Fluon® FL1710H

When high shear mixing equipment is unavailable, Fluon® FL1710H may be used as a pre-milled lubricant powder for metal coating applications.

3. COATINGS AND INDUSTRIAL FINISHES

3.1 Advantages of Using Fluon® Lubricant Powders

Fluon® lubricant powders can be added to many industrial finishes to improve surface lubrication, reduce blocking and promote scuff resistance. They may be used to provide excellent non-stick surfaces in hollow-ware products such as bakeware and cookware for improved abrasion resistance, anti-friction properties and good corrosion resistance.

Most hollow-ware products are made from coated strips of steel or aluminium which have been treated with a Fluon® lubricant coating prior to fabrication into the finished product. Not only does the inclusion of a Fluon® lubricant improve non-stick properties in the fabricated component but it also acts as a processing aid during the actual drawing, stamping, folding and cutting manufacturing processes.

3.2 Recommended Fluon® Lubricants and Processing Information

Although a wide range of Fluon® lubricant powders may be used in industrial finishes, the preferred grades are FL1690, FL1710, and FL1710H.

Fluon® FL1710, and FL1710H

FL1710 and FL1710H may be readily dispersed using high or low shear mixers with minimal change in the particle size of the powder or the viscosity of the formulation. This is particularly important if the formulated coating resin is to be applied by automatic spray equipment.

For aerosol sprays, Fluon® FL1710 is the preferred choice due to its ease of dispersion and minimal effect on modifying the viscosity of the resulting formulation.
Coatings containing Fluon® lubricants may also be applied using conventional spray guns using a high sheared slurry of typically 1 part (by weight) FL 1710 and 5 parts (by weight) resin/solvent base.

Such a concentration will help to break down any agglomerates which may have formed with the Fluon® powder during storage and transportation. This slurry can be further let-down as required to approximately 2% by weight of "Fluon "lubricant.

A common dispersant used in the resin base of Fluon® coating systems is NMP (N-methyl-pyrrolidone) since Fluon® lubricants are frequently mixed in solutions of other high performance polymers, such as Polyethersulphone (PES), which can only be dissolved in such aggressive solvents. Alternative hydrocarbon solvents, such as methylene chloride, may be used for aerosol based formulations. Typically, the make up of a formulation would be:

-	2%	(by weight)	Fluon® lubricant powder
-	25%	(by weight)	solvent (eg. methylene chloride)
-	73%	(by weight)	propellant (eg. "Arcton" 11 / 12)

Some spray formulations can use both solvents and air drying acrylic lacquers can produce a dry, hard film coating. This film forming "binding" agent helps to retain the fine Fluon® particles on the substrate. If a film forming agent were to be used, this would be added at approximately 1% by weight and the solvent phase reduced to 24%.

For industrial coatings requiring excellent surface finish, Fluon® FL1710H would be the recommended grade.

Liquid resin coatings benefit most from the addition of Fluon® FL1710 or FL1710H which ensures good gloss and surface hardness whilst, at the same time, giving the maximum reduction in coefficient of friction.

Fluon® FL1690

Fluon® FL1690 can be tumble-blended or melt-mixed with a number of dry-powder coatings which are subsequently applied by electrostatic spray or fluidised bed techniques.

4. PAINTS

4.1 Advantages of Using Fluon® Lubricant Powders

Fluon® lubricant powders may be added to a number of decorative, masonary, aircraft and marine paint formulations to improve hardness, toughness, scuff, wear and abrasion resistance, water repellancy, ease of cleaning, and anti-fouling properties. "Fluon " lubricant powders can also reduce flammability and help prevent dripping in fire hazard situations and aids spreading properties in industrial paints.

As more paint manufacturers develop water based rather than solvent based formulations, the use of Fluon® lubricant powders increases the paints ability to withstand higher abrasion and wear resistance as measured via a combined ball indentation and scratch resistance test.

Matt based paints, which are traditionally more difficult to clean, also benefit from the addition of Fluon® lubricant powders.

Gloss coatings also gain from the addition of Fluon® powders but a small particle size is important to ensure that no imperfections in the smooth surface finish result.

Fluon® powders used in marine coatings provide excellent anti-fouling, marine growth and lubricating properties due to the "non-stick"nature of the PTFE. This results in improved surface finish on boat hulls allowing for higher surface speeds and fuel efficiency. Due to the inertness and low toxicity of "Fluon "lubricants, these advantages are achieved with minimal ecological and environmental effects.

Fluon® lubricant powders can be used in aircraft paint formulations where an abrasion resistant finish applied to the lower fuselage and underside of the wings provides protection from gravel and stones on unpaved runways. Additionally, Fluon® powders are used in paints used to treat the inside of aircraft holds to prevent corrosion from condensation or hydraulic fluid, and on sliding surfaces such as wing slats where good wear resistance is required.

Fluon® powders have also been used in industrial paint applications where the PTFE provides a thin coating for hopper, silo and general vessel lining in order to provide a non-stick surface, avoiding product "caking" and build-up. The typical Fluon® powder lubricant content is 20% by weight.

4.2 Recommended Fluon® Lubricants and Processing Information

Fluon® FL 1690 and FL 1710

Fluon® FL 1690 and FL 1710 may be added at up to 15% by weight to aircraft and marine paint formulations. Suitable dispersion of the PTFE can be achieved using low shear paddle mixers.

Fluon® FL 1700

Fluon® FL1700 requires to be processed using high shear mixing to achieve a fine, sub-micron particle size. In decorative inks, the PTFE may be first blended with the pigment to avoid duplicate high shear mixing. Typical loadings of Fluon® powders in domestic paints are 1 to 3% by weight.

5. THERMOPLASTICS

5.1 Advantages of Using Fluon® Lubricant Powders

Fluon® PTFE lubricant powders such as FL1690 (or possibly FL1700) predispersed into a thermoplastic base resin greatly improve the surface wear characteristics of the compound. The molecular weight and particle size of the PTFE lubricant used may be custom-tailored to yield optimum improvements, for the selected resin system in wear, friction and PV (pressure-velocity) rating.

During the initial "break-in" or "running in" period of the plastic component, the PTFE particles embedded in the thermoplastic matrix shear to form a high lubricity film over the mating surface. The PTFE serves to cushion asperities from shock and subsequent fatigue failure.

For each family of bearing materials there is an optimum ratio of polymer to PTFE content. Wear rate can be improved by modifying the level (w/w) of PTFE in a compound typically up to 15 to 20%.

The addition of PTFE beyond the optimum point, will result in increased wear but the coefficient of friction will continue to show improvement.

This critical loading is based on the ability to uniformly disperse the PTFE throughout the resin matrix.

While the optimum loading will vary slightly with each resin system, it approaches 20 wt% for crystalline polymers and 15 wt% for amorphous and elastomeric resins. The optimisation is clearly seen by observing the wear and frictional values for the various resin families shown in Table 1.

TABLE 1 : THERMOPLASTIC WEAR MODIFICATION DUE TO FLUON® INCLUSION

Polymer	% of FL1690 (w/w)	Coefficient of Friction (against Steel)	Wear Factor, K $10E^{-10}$ in^3 min/ft/lb/hr
Polyacetal	0	0.21	65
	5	0.18	40
	10	0.17	30
	15	0.16	20
	20	0.12	13
Polystyrene	0	0.32	3000
	15	0.14	175
Polycarbonate	0	0.38	2500
	5	0.20	125
	10	0.17	85
	15	0.15	75
	20	0.14	70
Nylon 6	0	0.26	200
	15	0.20	30
	20	0.19	15
Nylon 6/6	0	0.28	200
	5	0.20	80
	20	0.18	12

Compared with filled and unfilled grades of PTFE, Fluon® FL1690 filled thermoplastic resins offer greater hardness, tensile strength, ease of processing, freedom from creep and lower cost. For many applications which require low friction and good wear properties conventional PTFE grades cannot be used on economic grounds - either the raw material is too expensive or the fabrication techniques are too wasteful in time of material.

Fluon® FL1690 filled plastics can be processed by orthodox fabrication techniques and the cost can be controlled by monitoring the proportion of Fluon® FL1690 to give the optimum combination of cost and performance.

In addition to improving the friction and wear properties of thermoplastics, Fluon® FL1690 can also have useful effects on polymer melts. It has been observed that it improves the flow of polycarbonates and glass-filled nylon thus allowing intricate cavities to be filled more easily.

It also increases the swell ratio (as measured on polyethylene grades), indicating that it increases the elasticity of the melt.
This conclusion is supported by the occurrence of fewer voids and sink marks in thick-section mouldings and extrusions and by the fact that mould shrinkage is reduced.
Significant reductions in friction can be achieved with as little as 2% Fluon® FL1690 (w/w) allowing its use purely as a processing agent in applications such as masterbatch preparations.

Used at these low levels, Fluon® powders provide improved mould release, internal lubrication, increased processing rates, and shorter moulding cycles.

They also reduce the adiabatic heat which causes unintentional and uncontrolled curing in thermoset compounds and allow greater extrusion rates in thermoplastics.
However, for optimum PV values and resistance to wear, 10% to 20% (w/w) of FL1690 should be used in the finished product.

PTFE filled thermoplastics are recommended for applications requiring low friction losses, freedom from "stick-slip" and maximum wear resistance.

Typical examples are :

Gears, cams, bearings, guides, wear plates, business equipment, components for instruments, liners for control cables, sliding contact applications for quantity production in domestic appliances and automotive areas.

5.2 Recommended Fluon® Lubricants and Processing Information

Fluon® FL1690

In general Fluon® FL1690 should be mixed by the same techniques as those used for mixing pigments or masterbatches.

Fluon® FL1690 can be tumble mixed with thermoplastics in powder form to give dry blends which can then be extruded or moulded. To ensure an acceptable dispersion of the PTFE the particle size of thermoplastic powder should not exceed 150 microns.

It is also possible to obtain a good dispersion by mixing Fluon® FL1690 with thermoplastics in granule form, using high shear mixers. These mixers may also be used to prepare a masterbatch containing about 40% Fluon® FL1690 which can then be blended with the bulk of the thermoplastic, still in granular form, to produce a composition of the required PTFE content.

The processing conditions for Fluon® FL1690-filled thermoplastics are identical to those of the host material.

Fluon® FL1700

Fluon® FL1700 may be used as a replacement for FL1690 for applications where good powder flow and low dust levels are required. Although this material is somewhat coarser in its original state, the shear forces provided by single or twin screw extruders is sufficient to break down the powder to an acceptable particle size.

6. THERMOSET RESINS

6.1 Advantages of Using Fluon® Lubricant Powders

Fluon® FL1690 and FL1710 filled thermosets are recommended for applications which require low friction losses, freedom from ' stick-slip ' and maximum wear resistance, such as slides, gears, cams, bushes, components for instruments and low-power motors, and liners for control cables. They are particularly suitable for sliding contact applications in domestic appliances and automobiles.

6.2 Recommended Fluon® Lubricants and Processing Information

Fluon® FL1690 and FL1710

Fluon® lubricant powders can be dry mixed with thermosetting moulding powders using similar processing techniques as for thermoplastics. Ideally Fluon® FL1690 and FL1710 should be incorporated during the manufacture of the resin but dry mixing before moulding also gives good results.

In the case of thermosetting laminating resins (eg, for the production of phenolic/cotton laminates), the "Fluoroglide" lubricant powder should be mixed with the liquid resin by gentle stirring.

Good dispersion should be achieved without the need for vigorous mixing. Any tendency for the Fluon® FL1690 or FL1710 to settle to the bottom during the course of a long production run can be overcome by using a stirred tank.

Fluon® lubricant powders may be added at typical levels of between 10 to 15% by weight.

7. ELASTOMERS

7.1 Advantage of Using Fluon® Lubricant Powders

In many elastomeric applications, various lubricants have been added to formulations to improve the coefficient of friction. Waxes, stearates, soaps, plasticisers and oils have been found useful under certain limited conditions, but these materials are normally extracted by lubricating oils, hydraulic fluids and aqueous solutions. Solid lubricants such as graphite and molybdenum disulphide have also been used, but the large amounts which are necessary to provide good lubricating properties may have a detrimental effect on strength and wear resistance.

For most mechanical applications, the outstanding lubricating qualities of Fluon® lubricant powders, when coupled with the various elastomeric matrices, offer improved wear and frictional properties.

The addition of Fluon® lubricant powders to natural rubbers and synthetic elastomers (e.g. Aflas®) during processing imparts to the finished moulding many of the surface slip characteristics of PTFE, such as:-

1. Improved mould release
2. Lower static and dynamic coefficients of surface friction
3. Increased abrasion resistance
4. Elimination of stick slip
5. Improved tear strength

Fluon® lubricants in rubbers are used where improved release or reduced wear are required. In general the improvement in surface properties is more marked with hard rubbers, i.e. those with Shore A hardness greater than 60. In the automotive and consumer durable industries the use of Fluon® filled nitrile rubber for dynamic seals has eliminated stick-slip, improved wear resistance and reduced noise. Fluon® lubricant powder filled nitrile rubber cab also be used to replace silicone rubber on laminating rollers used with adhesives because of improved releases and better tear strength at lower cost.

Similar improvements in properties have been experienced with styrene butadiene rubber, silicone and nitrile rubbers, polyurethane and fluoroelastomers blended with Fluon® lubricants.

Fluon® lubricant powders may be used in such typical elastomeric applications such as "0"-rings, hoses, fan belts and gaskets.

Fluon® lubricants may also be added in smaller amounts (typically 2 to 5%) to rubbers to provide a low friction surface for window and door seals in the automotive industry.

7.2 Recommended Fluon® Lubricants and Processing Information

Fluon® FL1690, and FL1700

Fluon® lubricant powders can be blended into rubber compositions by dry mixing with the fillers and subsequently compounding in the normal manner. When this compound is moulded the finished component can be easily removed from the mould due to the improved release properties. This can lead to a reduction in rejection rates, particularly on intricate mouldings.

During processing, a thin skin of rubber can form over the Fluon® powder on the surface of the moulding and it may be necessary to lightly abrade or machine the surface before the optimum improvement in ' slip ' characteristics can be achieved.

Fluon® lubricant powders are inert to all chemicals used during processing and will neither interact with nor absorb any of the formulation ingredients.

Fluon® FL1690, and FL1700 can be added at a 15-25% concentration by weight of the elastomer to reduce surface friction and wear rate, and to eliminate 'stick-slip'. The lower percentage addition will provide most of the advantages listed, but the higher percentages are required to give improved release properties.

Fluon® lubricant powders should be mixed thoroughly with the fillers before blending with the elastomer. The resulting rubber composition can then be processed under normal conditions. At these levels of addition, there is some reduction in the mechanical properties of the moulded rubber as PTFE acts as an inert filler and has no reinforcing properties. For this reason "Fluoroglide" FL1700, with its smaller median particle size, and its capability of being reduced in particle size to as little as 0.3 micron by high-shear mixing, is the preferred grade.

Satisfactory results have been obtained with, for example, butadiene-acrylonitrile, styrene-butadiene, polyurethane, polychloroprene rubbers and fluoroelastomers.

8. OILS, GREASES AND SEALING PASTES

8.1 Advantages of Using Fluon® Lubricant Powders.

There are number of applications where extremes of pressure and temperature and environment are experienced where "Fluoroglide" lubricant powders may be used for improved lubrication.

Fluon® FL1690, FL1700, FL1700H, FL1710, and FL710H are excellent lubricant additives for specialised oils and greases designed for conditions where conventional additives such as graphite and molybdenum disulphide are unsuitable. The lubricating performance of these additives under various conditions is summarised in Table 2.

Fluon® lubricant powders offer cleanliness, an important factor in greases intended for machinery in the food, confectionery, pharmaceutical and dairy industries. Also important for many engineering applications is the freedom from 'stick-slip' movement from which it is obtained as a result of the equal coefficients of static and dynamic friction of PTFE.

Greases incorporating Fluon® lubricant powders are particularly well suited for applications which require low starting torques and where regular smooth sliding action is essential, for example miniaturised equipment and other mechanisms actuated by low power motors.

Table 2 : SUMMARY OF LUBRICATING PERFORMANCE OF GRAPHITE, MOLYBDENUM DISULPHIDE AND PTFE UNDER VARIOUS CONDITIONS

Condition	Graphite	MoS2	PTFE
Dry oxygen	Poor	Moderate	Good
Dry nitrogen	Very Poor	Good	Good
Damp Air	Good	Poor	Good
Cryogenic temperatures	Poor	Poor	Good
High temperatures > 300°C	Good	Good	Poor
Vacuum	Poor	Poor	Good
Radiation	Poor	Good	Poor
Very high load, high speed	Good	Good	Poor
Low load, high speed	Good	Good	Moderate
Low load, low speed	Good	Good	Good
High load, low speed	Moderate	Moderate	Good
Corrosive environment	Good	Poor	Good

Additionally, extreme environmental demands on greases, such as those experienced in the aerospace industry where wide temperature ranges, high vacuum conditions at high speeds and heavy loads, can be accommodated by the inclusion of Fluon® lubricant powders.

The low surface energy of Fluon® lubricant powders means that little shear energy is required to form a soft, continuous film of lubricant.

Anti-stick properties are another advantage; the critical surface tension of fluoropolymers are below the surface tension of most liquids. An unusual consequence of this is that most lubricating greases in which Fluon® lubricant powders are incorporated exclude water from interface boundaries and thus reduce hydrolytic corrosion.

Work undertaken in the USA using perfluoroalkyl ether and trifluoropropylmethyl polysiloxane oils thickened by PTFE and FEP [1] has shown that the most stable greases are those produced from Fluon® lubricant powders having the smallest particle size, highest surface areas, high oil adsorption and the highest critical surface tension in relation to the surface tension of the oil.
Fluon® lubricant powders may also be suitable for applications involving exposure to gaseous, or in some cases, liquid oxygen where potential fire hazards need to be eliminated. products containing Fluon® lubricant powders should first be tested for oxygen rating acceptability via an organisation such as the German B.A.M. (Bundesanstalt fur Materialforschung und Prufung) [2].

Greases incorporating Fluon® lubricant powders in greases include lubrication at low temperatures in corrosive conditions, where cleanliness is demanded, and where judder-free movement is required.

Specific examples are: -

- Valves for chemical plant.
- Impregnated packing for safety valves which may be seldom used but which must not stick.
- Stop-cocks for laboratory ware and high vacuum equipment.
- General running-in of engineering equipment.

One of the more recent applications for PTFE lubricant powders has been the inclusion in internal combustion engine lubricating oils.

A considerable amount of literature has already been published on this application which has highlighted the role that PTFE particles may play in filling the irregularities in the metal counterface and providing a smooth, low friction surface between the moving metal parts.

Once the lubricant is in place, the oil base provides a barrier film which bonds the PTFE to the surface giving a very low boundary friction coefficient which reduced the total running friction of the engineer. Further developments are awaited in this expanding automotive applications area.

Alternative applications for oils and greases enriched with Fluon® lubricants are conveyor chain lubricants which do not decompose at modern paint stoving temperatures, machine tool lubricants for tapping operating and reduced die wear in die stamping operations and general lubricants for moving machine parts, bearings, compressors, pumps and some hydraulic systems.

8.2 Recommended Fluon® Lubricants and Processing Information

The choice of carrier for Fluon® lubricant based sealing compounds is not limited to oils and greases and any resin capable of withstanding the appropriate operating conditions is acceptable.

Fluon® FL1690

Dispersion is readily achieved in most pastes and greases by the use of low shear paddle mixer. Triple roll milling with a tight nip is not required, and generally not advised, as this may deform the particles. The proportion of Fluon® FL1690 added should be up to 15% by weight.

Fluon® FL1700 and FL1700H

Fluon® FL1700 disperses easily with high-shear mixing. The FL1700 particle is friable and when sheared in a liquid medium breaks down to submicron size; for instance after triple roll milling in a medium viscosity oil the particle size can be reduced to 0.3 micron. Ideally a masterbatch of 30-50% by weight of Fluon® FL1700 should be prepared, triple roll milled and subsequently diluted by the bulk of the medium to the required percentage addition.

This makes Fluon® FL1700 particularly suitable for addition to low viscosity media such as oils where larger particles may sediment. Additional tabilization may be achieved using suitable surfactants and other additives.
The proportion of Fluon® FL1700 added should be up to 10% by weight although lower proportions (2 to 5%) may be acceptable for certain less demanding applications.

Suitable mills which may be used to achieve mixing of Fluon® powders into oils and grease (as well as paint and ink formulations), are shown below :-

- Triple roll mills
- Stirred media mills - Attritor mills
  - Bead mills
  - Sand mills
- Ball mills
- Paddle mixers (eg. "Silverson" type)
- Edge runner mills (eg. motorised mortar and pestle type)

Stirred media mills may be batch or continuous and are capable of producing fine dispersions of most materials.

Certain oil and grease formulations requiring excellent consistency and fine particle size may benefit from the high performance Fluon® grade FL1700H.

Fluon® FL 1710 and FL 1710H

Fluon® FL1710 disperses easily in oils and greases using either high or low shear mixers, with minimal change in the particle size of the powder of the viscosity of the compound. The proportion of FL1710 added should be up to 15% by weight.

As with FL1700H, certain oil and grease formulations may benefit from the proven consistency of FL1710H for even the most demanding lubricant powder applications.

9. GELCOATS FOR BUILT-IN MOULD RELEASE

9.1 Advantages of Using Fluon® Lubricant Powders

Fluon® lubricant powders may be used in the production of polyester and epoxy mould gelcoats for the production of ' self-releasing ' moulds which offer more efficient use of capital, space and labour in the glass-reinforced (GRP) and general plastics industry.

The addition of Fluon® lubricant powders should be undertaken during the manufacture of the gelcoat to ensure a workable viscosity and the required release properties.

Mould gelcoats containing Fluon® FL1690 or FL1700 offer the following advantages:

1. Built-in release properties - no mould release agent is required during the life of the mould.
2. Quicker production cycles - no time is wasted in cleaning the mould and applying mould release agent.
3. Reduced mould costs - less physical force is required to release mouldings, so moulds can last up to three times as long. A potential cause of mould damage, ie. incomplete coverage by conventional mould release agents, is eliminated.
4. Space saving - fewer moulds occupy less space.
5. Labour saving - the labour-intensive operation of mould preparation is eliminated.
6. Appearance - the absence of release agents ensures an attractive, consistent finish.

9.2 Recommended Fluon® Lubricants and Processing Information

Because of their different physical properties, Fluon® FL1690 and FL1700 should be added to the base resins in different proportions, and different compounding techniques are required.

Fluon® FL1690

Fluon® FL1690 should be added in the proportion of 25% to 30% by weight during the manufacture of the gelcoat. Thorough wetting of the Fluon® FL1690 is essential and this is best done by pre-mixing it with one of the solvents used in the gelcoat formulation before adding to the remainder of the ingredients. Fluon® FL1690 is a soft material and care should be taken to ensure that the particles are not damaged by mixing at too high a shear rate. A triple roll mill can be used for mixing but the setting should be such that it mixes rather than grinds. This form of mixing is particularly good because it also ensure that no air is introduced to the resin.

Fluon® FL 1700

Fluon® FL1700 is a friable powder which can be broken down by high shear mixing to optimise dispersion of the PTFE for gelcoat manufacture. This means that a smaller percentage addition is needed to achieve the required release properties. A 15% to 20% by weight addition should be made by wetting with solvent and then mixing with the other ingredients under conditions of high shear.

A triple roll mill set for grinding is ideal for this addition, but, if a planetary mixer is used, care should be taken to avoid air being entrapped.

The self-release gelcoat is then applied as a conventional mould gelcoat. For the best possible results the master mould should be prepared to a very fine surface finish so that the mould produced requires the minimum of attention. After production the surfaces of the mould should require no further preparation, but if necessary to can be lightly polished.

The absence of a conventional release agent means that any mould imperfections, such as those produced by abrasive polishes, will be visible on the mouldings produced. very bad abrasions can result in a mechanical key between mould and moulding and a possible stick-up.

The inclusion of Fluon® PTFE lubricant powder into a resin causes a rise in viscosity because of the thixotropic effect of its fine inert particles.
It is necessary, therefore, to adjust the viscosity during production to ensure a workable constituency in the final formulation; because of its finer particle size, and high surface area FL1700 causes a greater increase in viscosity than FL1690. For this reason the addition should be carried out by the resin producer during the gelcoat production rather than by the processor to a finished gelcoat.

The appearance of pinholes in the mould surface, or of similar sized lumps on the surface of the moulding, has two possible causes. One is that the individual Fluon® particles are not properly wetted and, as a result, carry air bubbles into the resin, and the other is that air is entrapped during mixing. In both cases the bubbles subsequently burst and become small undercut voids.
In extreme cases these voids will provide a mechanical key and can result in a stick-up.

To overcome this defect the Fluon® powder must be thoroughly wetted and no air entrapped during mixing. Delamination of the mould gelcoat from the back-up resin can take place if the latter is incorrectly applied.

During the manufacture of a mould, care should be taken to ensure that the back-up laminates are applied before the self-release gelcoat has cured. The simple test of when the gelcoat is receptive, it to tough the gelcoat with a finger. When the gelcoat feels sticky but leaves no resin on the finger it is ready for the application of the back-up laminates.

Damage because of mishandling of a mould and faults such as star-cracks can be easily repaired. The damaged area of gelcoat should first be removed to expose the back-up laminate, ensuring that the good gelcoat around the area is left with an undercut edge. This undercutting, together with the exposed glass laminate, will provide a mechanical key for the repair gelcoat. Self-release gelcoat can then be applied and allowed to cure. The repaired area must then be rubbed down to the same level and surface finish as the rest of the mould. The materials recommended for lightly polishing the mould should be used as a final treatment for the repair.

10. DRY LUBRICANT

10.1 Advantages of Using Fluon® Lubricant Powders

There are available a number of powders which are used, by themselves, as lubricants in intricate or inaccessible mechanisms, or where conventional lubricants are unacceptable. Of these powders only PTFE offers cleanliness combined with the capability of working under the widest range of conditions. Table 2 again summarises the lubricating performance of PTFE in comparison with two other well-known dry lubricants, graphite and molybdenum sulphide.

Fluon® FL1690 has replaced graphite for the lubrication of lace machinery. The cleanliness of PTFE has ensured the production of clean lace and eliminated the lengthy scouring process previously necessary to remove residual graphite from the lace.

10.2 Recommended Fluon® Lubricants and Processing Information

Fluon® FL1690 and FL1710

Fluon® FL1690 and FL1710 can be applied by being shaken from a porous bag, blown by a 'puffer pack' or hand-operated spray gun or sprayed from an aerosol.

11. MISCELLANEOUS APPLICATIONS

Fluon® powders may also be used in a number of applications such as :-

Batteries (as an inert non-moisture adsorbing extrusion aid)
Pyrotechnics (Fireworks)
Machine cutting fluids
Tableting or processing fluids
Surface coatings (eg. bullets)

FOOD CONTACT APPROVAL (FDA COMPLIANCE)

All the Fluon® lubricant powders described in this document meet the compositional requirements of the United States of America Food and Drug Administration (FDA) regulation 21 CFR 177.1550

When incorporated into a composition containing other materials, then users must satisfy themselves that the total system satisfies the regulations.

STORAGE

Fluon® lubricant powders are supplied in 25 kg laminated fibreboard kegs and should be stored under cool, dry conditions. Fluon® FL1680 and FL1690 lubricant powders are contained within two polyethylene liners which are individually sealed. "Fluon FL1700 and FL1710 lubricants are packed in pre-lined fibreboard kegs" .

Each keg contains one silica gel desiccant bag to minimise moisture build-up during storage. This desiccant bag should be removed prior to subsequent Fluon® lubricant powder processing.

There will be no chemical deterioration of the Fluon® lubricant powder during storage.

HANDLING PRECAUTIONS

Within their working temperature range, Fluon® FL1680, FL1690, FL1700, and FL1710 lubricant powders are completely inert but when heated to higher temperatures they give rise to gaseous decomposition products or fumes which can produce unpleasant effects if inhaled. The inhalation of these decomposition products or fumes is easily prevented by applying local exhaust ventilation as near to the source of the fumes as possible.

Smoking should not be permitted in workshops where Fluon® lubricant powders are handled because smoking tobacco contaminated with PTFE will give rise to polymer fumes. It is therefore important to avoid contamination of clothing, especially the pockets, with PTFE and to maintain a reasonable standard of personal cleanliness by washing hands and removing any PTFE particles lodged under the finger nails.

Further information on the Health and Safety issues is included in the Material Safety Data Sheet for Fluon® Fluoropolymer Lubricant Powders which is obtainable from your local AGC Chemicals Europe, Ltd. Sales Office. Users of other materials mentioned in this publication but not produced by AGC Chemicals Europe, Ltd. Business Group are advised to obtain Health and Safety information from the suppliers.

Ref [1]

Polytetrafluoroethylene and Fluorinated Ethylene Propylene Grease Lubricants.
John B Christian & Barry Arkles (LNP), Malvern, Pennsylvania, USA.

Ref [2]

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