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**3M**

RJC004796

**Exhibit  
1370**

State of Minnesota v. 3M Co.,  
Court File No. 27-CV-10-28862

STATE\_07543941

1370.0001

The function of most organic coatings is to protect and/or decorate substrates. Surface defects such as craters, sags and thick edges mar appearance and create weak spots which decrease protection.

Many surface defects arise from resin or pigment flow in the paint film after it is applied. Such movement is caused primarily by surface tension forces with the main force opposing it being viscosity. Preventing defects will allow the coating formulator additional time to spend on the more productive tasks of creating functional coatings with improved profitability.

This brochure discusses how to eliminate or reduce surface defects by the control of surface tension.

#### **BENEFITS OF FLUORAD FLUORO-CHEMICAL SURFACTANTS**

Curing surface defects is never easy. Ideally, solutions are developed from a knowledge of the cause of the defect. Unfortunately, diagnosis is often difficult since the coating supplier is seldom on site when the defect is observed and substrate cleanliness can be inadequate and/or irregular.

The maintenance of coating surface tension values at low levels with Fluorad fluorochemical surfactants can help produce coatings capable of being used in "less than perfect" industrial applications. The formulator will benefit by maintaining a quality "trouble free" image and reducing unproductive problem solving.

The use of additives in the paint and coating industry has been gaining greater acceptance as their benefits become increasingly difficult to reproduce with modifications of the base resins or solvent system. Much development time is still spent in solvent and resin permutation (to reduce surface tension values) when the use of Fluorad fluorochemical surfactants could achieve the desired effect. The use of lower cost solvents and resins frequently offsets the increase in cost of the surfactant.

Ingredient mischarge can happen in the best run factory; a Fluorad fluorochemical surfactant has been used on more than one occasion to reduce scrap costs by rescuing a paint overcharged with silicone defoamer.

#### **FLUORAD FLUORO-CHEMICAL SURFACTANTS IN COATINGS**

Fluorad fluorochemical surfactants were first used in a major coating application in 1958. A patent awarded to H.C. Geen of the Simoniz Company claimed that 3M company's fluorosurfactants conferred superior leveling to dry bright aqueous emulsion floor wax systems. Since that time, fluorosurfactants have been universally adopted in both household and institutional floor polish systems. They provide the necessary leveling and wetting performance over floors covered with "old" polish, or surfaces contaminated with low energy films such as grease or silicone resins. The low concentration of Fluorad fluorochemical surfactant needed for good performance significantly reduces detrimental effects, such as "black heel" marks, frequently seen with high levels of conventional surfactants.

Just as the hydrophobic moieties in Fluorad surfactants enable them to function as highly efficient additives in aqueous coatings, it was soon recognized that fluorochemicals should be capable of modifying surface tension in organic systems by virtue of the oleophobicity of their fluorochemical moiety. By careful choice of the solubilizing group in the molecule, 3M chemists have been able to design Fluorad products to function as surface active agents in many solvents and resins.

Surface tension control in organic systems is now possible, not only during the application of a solvent based coating, but also during the dynamic phase of drying and resin polymerization. The maintenance of low surface tension values throughout the drying phase will eliminate, or reduce, steep surface tension gradients which are frequently responsible for the formation of many coating defects such as floating, orange peeling, and fish eyes.

In an industrial situation it is not uncommon for surface preparation to be erratic. Low surface tension values will help considerably in minimizing the effect of such variation on coating appearance by improving the ability of the coating to wet and spread on the substrate. These surfactants are used extensively to reduce the surface tension of both organic and aqueous based coatings. Spot contamination in the form of fingerprints, roller grease, condensation drip, and even gross contamination from a mischarge of a silicone defoamer, can be overcome by the use of fluorochemical surfactants.

Consistent product performance is one step closer when Fluorad surfactants are used.

**FLUOROCARBON AND HYDROCARBON SURFACTANTS**

A surfactant (surface active agent) can be defined as:

**A material which concentrates at the surface of the liquid in which it is dissolved, or at the interface of a liquid and another immiscible liquid or solid.**

Since many polymers and oligomers are themselves surface active, they compete for space at an interface. Their presence can make it difficult to predict the behavior of any surfactant in specific resin systems.

Another definition of a surfactant is:

**A chemical comprised of two parts of widely differing polarity and solubility in liquid media.**

In general, surface active agents have limited solubility in the liquids in which they are used.

Both definitions are useful in highlighting the major differences between fluorochemical and hydrocarbon surfactants.

Both classes of surfactants act in a similar fashion in aqueous systems. The insoluble portion of the molecules—the hydrocarbon and the fluorocarbon hydrophobic chain—both orientate at the liquid surface with the hydrocarbon or fluorocarbon tail of the molecule in the gas phase and the more polar portion in the aqueous phase.

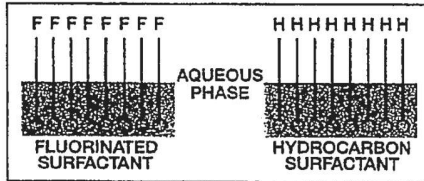


Figure 1. Surfactant orientation in aqueous coatings.

There is, however, a significant difference in efficacy due to the stronger electron withdrawing power of the fluorine atom. Surface tension values as low as 16 dynes/cm in aqueous systems are attainable with fluorocarbon surfactants at concentrations as low as .005%. This contrasts with a minimum value of about 25 dynes/cm at 1% with a typical hydrocarbon surfactant.

The small amount of Fluorad fluorochemical surfactant necessary in aqueous coatings reduces the tendency for floor coatings to develop "black heel" marks. In addition, the low use concentration in floor polish systems has only a small effect on manufacturing cost calculated on a per gallon basis.

The fluorocarbon and hydrocarbon tails on the molecules behave very differently in nonaqueous systems due primarily to the major differences in the solubility of the tails in the organic components in the coating. Typically, the hydrocarbon tails of conventional surfactants have sufficient solubility in organic paint systems whereby the chemical will not migrate to a liquid/gas interface to function as an efficient surface active agent. The reverse is the case with molecules having fluorocarbon tails. These moieties are not miscible with organic liquids, such as solvents or resins. By using the correct solubilizing group, 3M chemists have designed fluorochemicals which orientate at an organic interface to act as a surfactant (see Table 1 on page 10).

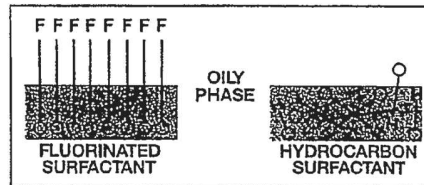


Figure 2. Surfactant orientation in organic coatings.

The surface defects described below are typically due to unwanted or excessive flow of pigment and/or resin.

A coating consists of two interfaces—the coating/air interface, and the coating/substrate interface. Surface tension gradients are the main cause of surface defects in the former, whereas defects at the latter are due to contamination at the interface, or to poor wetting of a low energy surface with a coating having too high a surface tension.

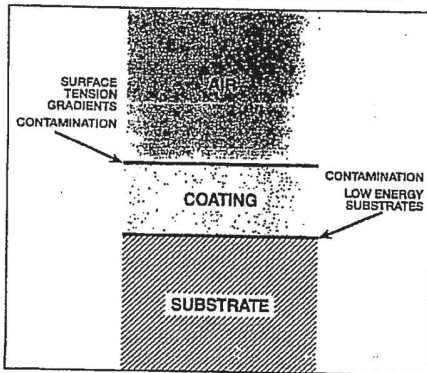


Figure 3. Location of surface defects.

#### DEFECTS AT THE COATING/AIR INTERFACE

Defects at the coating air interface can be caused by solvent popping, pigment flocculation, shear and gravity effects, phase separation, poor leveling and surface tension effects. This brochure is aimed at those defects which can be alleviated by surface tension modification.

#### SURFACE TENSION GRADIENTS

Many types of surface defects seen in coatings can be attributed to the presence of surface tension differences at the air/coating interface. Such differences can be generated by surface irregularities—produced during coating application, contamination from oil mists, dust, overspray, or differential evaporation of solvents.

Surface tension values (?) of coatings can drift upwards (+) or downwards (–) as solvents evaporate from the system. If the drift varies across the surface of the coating, then certain characteristic coating patterns may be observed.

Figure 4 illustrates surface tension drift in a single drop of paint. Ideally, a drop should spread and dry evenly. However, as the drop exhibits a greater surface area at the edges, the solvent will evaporate faster at the perimeter. If, as a result of evaporation, the remaining paint at the edge of the drop has a higher surface tension, the paint resins will flow towards the perimeter of the drop—providing the viscous drag of the drying paint can be overcome. Conversely, if the surface tension decreases, the resins will flow towards the center of the drop.

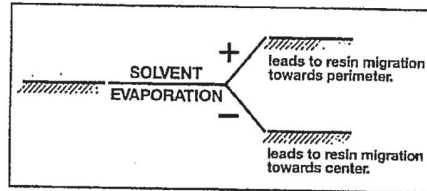


Figure 4. Effect of surface tension gradient.

Typical use levels for Fluorad fluorochemical surfactants FC-430 and FC-431 to effect solvents and resins are reported in Table 1 shown on page 10.

The classical way to avoid such migration is to eliminate the surface tension gradient by maintaining surface tension at a fixed (low) value. This can be accomplished by Fluorad fluorochemical surfactants in either aqueous or organic systems.

An example of how FC-430 can be used to stop resin migration caused by thermal gradients is illustrated in Figure 5.

Control with  
no surfactant

Coating with  
FC-430 @ 0.5%

Fluorad fluorochemical surfactants will effectively reduce surface tension values in most systems so that the surface tension gradients are eliminated, or at least reduced. Not only are these surfactants effective in overcoming spot contamination, but they have also been used to rescue batches of paint accidentally contaminated with excess silicone defoamer.

### BÉNARD CELLS

Bénard cells appear during solvent evaporation (see Figure 7). They arise from circulatory flow within the coating film. These eddy currents are caused by differences in temperature, surface tension and density.

Figure 5. Resin migration due to heat (surface tension) gradient.

Panels were coated with epoxy resin and cured in an oven for 10 minutes at 240°F on a metal shelf formed in a diamond pattern.

### CRATERING

The main cause of cratering is foreign matter appearing on the surface of the paint during its fluid stage. Contamination such as dust, gel particles, overspray and oil, is usually found at the center of the crater. In the case of a silicone oil droplet, the low surface tension oil creates a surrounding area of reduced surface tension. Coating resins flow away from this area to the higher surface tension areas in the bulk of the solution. The result is a crater (see Figure 6).

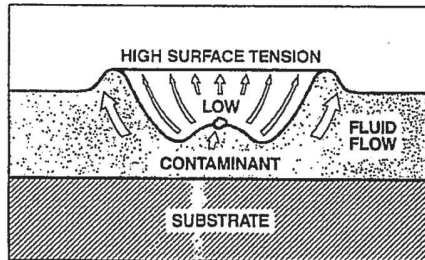


Figure 6. Crater formation due to surface tension gradients.

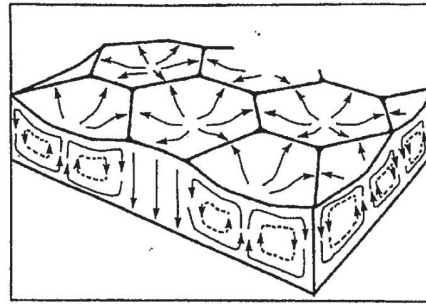
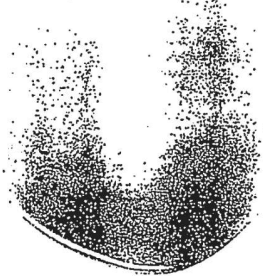


Figure 7. Fluid flow in Bénard cells due to surface tension gradients.

Pigmented systems can exhibit color changes (floating) due to separation of the pigments as they are carried in the eddy currents of Bénard cells. The effect can be reduced if the rate of change in surface tension with temperature or concentration is minimized, the viscosity increased, or the applied coating thickness reduced.



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### ORANGE PEELING

Localized surface tension variations across the coating surface create slight mounds and dimples in the surface of the coating. Similar irregularities can also be observed when dewetting occurs. This effect, described as "orange peel," is sometimes desirable to hide substrate roughness in large objects. If orange peeling is undesirable, the effect can be reduced by the use of Fluorad surfactants to control the surface tension variation and improve substrate wetting. Increased viscosity to lower coating mobility will also reduce the problem.

### PICTURE FRAMING

This common coating effect appears as a build up of paint at the edges of coated articles. It should not be confused with sagging, which occurs at the lower edges of vertical substrates. Picture framing (see Figure 8) is the result of surface tension gradients occurring at the edges of a substrate due to a faster rate of evaporation of the coating solvents at the extended surface. Since the coating resins are generally higher in surface tension than the solvents, the resins will tend to flow towards the edges and create the picture frame or, "fat edge" effect.

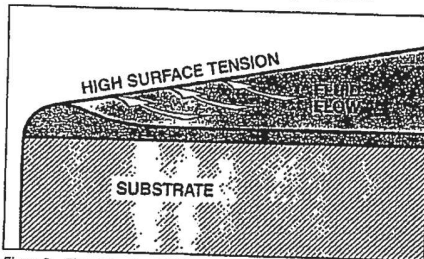


Figure 8. Picture framing. Solids move to areas of higher surface tension.

Fluorad surfactants are particularly effective in reducing the surface tension gradient which is the driving force of this defect.

### LEVELING

Paradoxically, the leveling capability of a coating should be improved with high surface tension which tends to minimize the surface area (and hence smooth the surface) of the applied coating. Leveling defects caused by application methods such as brush marks and roller striations should be reduced if the system surface tension can be increased.

However, the presence of a surface tension gradient—exaggerated by a high surface tension value—can also produce a leveling problem similar to those mentioned earlier.

In a freshly applied non-level coating, surface tension gradients can be caused if the coating components have differing evaporation rates and different surface tension values. Less volatile components will evaporate slower in the valleys of the applied coating, and the converse for the coating at the peaks. The surface tension gradient will cause a flow of coating solids to the peaks—resulting in poor leveling (see Figure 9).

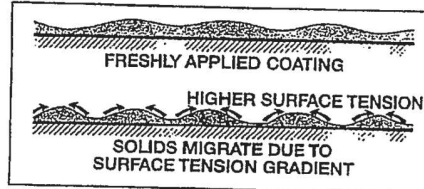


Figure 9. Movement of solids in a non-level coating.

In most cases it is wiser to avoid surface tension gradients (particularly on large areas). Fluorad surfactants are used extensively to control leveling by depressing surface tension values throughout the drying and curing cycles of a wide variety of coating systems.

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**DEFECTS AT THE COATING/SUBSTRATE INTERFACE**

All substrates have a surface energy (tension). The pioneering work of Zisman established values for the surface energy of solids and although Zisman's work did not take into account the variations seen in surface energy due to surface roughness, the values never-the-less provide a foundation for the ranking of the difficulty of wetting various substrates.

**TABLE 2. TYPICAL SURFACE ENERGY VALUES OF VARIOUS SURFACES**

|                         | Dynes/cm<br>mN/m |
|-------------------------|------------------|
| <b>LIQUIDS</b>          |                  |
| Water                   | 73               |
| Lube Oil                | 29               |
| Silicone Oil            | 20               |
| <b>RESINS</b>           |                  |
| Liquid Epoxy            | 48               |
| Liquid Polyester        | 35               |
| Alkyd                   | 25               |
| Polydimethylsiloxane    | 20               |
| <b>SOLIDS</b>           |                  |
| Phosphated Steel        | 43-56            |
| Aluminum                | 37-45            |
| Tin Plate               | 35-45            |
| Polyester               | 43               |
| Polyvinyl Chloride      | 39               |
| Polystyrene             | 33               |
| Polyethylene            | 31               |
| Polytetrafluoroethylene | 18               |

A liquid will only wet and spread over a surface if the forces of attraction between the liquid and the substrate are greater than the cohesive forces within the liquid.

The concept of the "spreading coefficient" has been used to predict the ability of a liquid to spontaneously wet and spread on a substrate.

If  $\gamma_{\text{Liquid}}$  is the surface tension of the coating,  $\gamma_{\text{Solid}}$  is the surface energy of the substrate, and  $\gamma_{\text{LS}}$  is the interfacial tension between the coating and the substrate, then the spreading coefficient SC is defined as:

$$SC = \gamma_{\text{Solid}} - (\gamma_{\text{Liquid}} + \gamma_{\text{LS}})$$

Spreading will only occur if this coefficient is a positive number. Defects will be prevented or reduced if  $\gamma_{\text{Liquid}}$  and  $\gamma_{\text{LS}}$  are made as small as possible.

The minimum criteria for any coating to wet and spread on a solid is for the surface tension of the coating to be less than the surface energy of the substrate. Examination of Table 2 and comparison with Table 1 will provide an illustration of how Fluorad fluorochemical surfactants can assist in helping coatings wet and spread on challenging substrates.

Similar conclusions can be drawn if the substrate is covered with a contaminating film of hydrocarbon or silicone oil. Only in this instance, the surface tension values of the oil film can be substituted for that of the solid substrate.

Additional steps which can be taken to improve wetting and spreading are the replacement of resins and solvents with those having lower surface tension values and higher viscosities.

The energy expended during coating application and the degree of surface roughness will both influence spread of a coating on a surface and, if a coating can be made to spread, even temporarily, it will be possible to maintain a continuous film if the viscosity is sufficiently high.

However, if the movement to higher solids systems frequently limits viscosity modification or the choice of resins, the necessity of incorporating an efficient surfactant becomes the only practical option.

Figure 10 illustrates three epoxy-phenolic formulations of similar viscosities, but increasing solids content, coated on "contaminated" oily tin plate and baked. With no flow control agent added, the "conventional" 40% solids formulation based on diglycidyl ether of Bisphenol A (DGEBA) with an epoxy equivalent weight (EEW) of 2000, shows good coverage with some pinholes. When a lower equivalent weight DGEBA of 500 is substituted to achieve 60% solids, severe cratering is obvious. Total retraction into droplets results when a liquid DGEBA of EEW = 190 is substituted to reach 80% solids. When Fluorad surfactant FC-430 is added to each system, good wetting and leveling is observed in all cases.

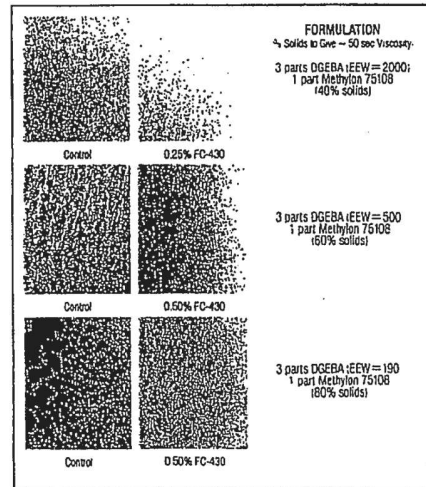


Figure 10. High solids epoxy coatings with identical solvent blends: with and without FC-430.

### DEWETTING

As mentioned in the previous section, spreading may occur with systems having negative spreading coefficients. But, if the viscosity of the coating is low, the coating will retract from the surface (dewet) over a period of time.

Dewetting will become evident when defects such as craters, islands, pinholes and the retraction of the coating to form beads occur.

From the equation of spreading, it is seen that the reduction of the surface tension of the liquid, and the interfacial tension between the liquid and the solid, to the lowest possible values will reduce this effect.

Surface contamination is one of the most frequent causes of dewetting. Inadequate substrate cleaning or control, careless handling (fingerprinting, conveyor oil), are prime suspects for this problem. Unfortunately, in an industrial environment it is often not possible to reliably remove these causes. The best course may be to assume problems will occur and design the paint system with a low surface tension.

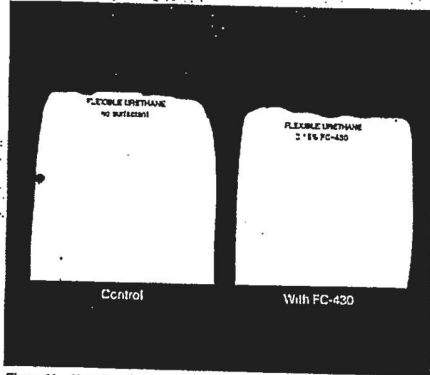


Figure 11. Urethane coating applied over surface contaminated with mineral oil palm print.

### RECOATABILITY

The comments on wetting and dewetting apply to recoatability—only the substrate in question is now a previously applied coating. Apart from incidental contamination between coating operations, recoatability problems are caused by the previously applied coating. Formation of a low energy surface from the use of certain resins, curing regimes, or additives migrating to the surface of the undercoat, are responsible for most of the problems.

Remedies are the same as those suggested above; adjustments to the formulation of the final coat using lower surface tension resins and solvents, or reducing the surface tension of the applied resins and solvents, or reducing the surface tension of the applied coating with surfactants. Higher viscosity coatings may also reduce the effect of the low energy substrate. When practical, solvent wiping or lower baking temperatures can sometimes help.



The capability of Fluorad fluorochemical surfactants to be used as surfactants in organic media allows the coating formulator to reduce defects caused by surface tension variations in organic coatings as well as aqueous systems. Coatings with fewer defects translate to infrequent interruptions of the coating line and higher productivity, less rework and lower rework costs, greater reliability and improved quality. All these factors imply savings and satisfied customers.

A wide selection of Fluorad surfactants are available to assist the coating formulator (listed in Table 3, page 11). The effectiveness and choice of the best Fluorad surfactant in coatings is dependent on the degree of its solubility/insolubility in the coating media. The surfactant should be active at the surface the moment the defect is about to form. Thus it may be necessary to consider the solubility relationships of the surfactant at various pH, or in a solvent, a liquid resin, or any mixture of these at a variety of temperatures. With these variables, it is impossible to provide precise recommendations for the choice of a surfactant to cure each defect, but Table 4 (page 10) is an appropriate starting point.

Table 4 suggests starting concentrations for evaluation of these surfactants in the various coatings. The values in Table 4 are the percent concentration of surfactant, as supplied, taken on a weight basis.

An improvement in wetting and leveling has been observed in some water reducible coatings when Fluorad fluorochemical surfactant FC-171 has been blended with FC-430 or FC-431 in a 40/60 ratio and used at a level of 0.2% based on coating solids. Other blends of Fluorad surfactants may also prove useful in other systems.

Foaming can sometimes be reduced if FC-170-C and FC-171 can be used.

### USE LEVELS

The ranges of use concentration depend on the solvent vehicle used. Table 5 (page 11) assists in the selection of an appropriate solvent.

Typically, the use of Fluorad surfactants in aqueous media is between .005% and .02% based on resin solids. In water reducible coatings the level is between .05% and .3%, and in solvent coatings the level is between .1% and .7%, based on coating solids.

To ensure the most effective use of surfactant, it is recommended that a stock solution of the product be prepared prior to addition to the coating. Often, a 1%-10% solution is made. Instructions how to do this are given in the individual technical data sheets.

### 3M AND COATINGS

The 3M Company has had a long tradition of coating various substrates with a wide variety of varnishes, paints, adhesives, binders, sizes and resins. Programs are continually underway to improve coating performance and many of these will yield commercial products in the future.

Share your problems with us; 3M sales and technical service staff will work with you to solve them.

#### 3M Corporate Headquarters

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800/541-6752 (Ordering Product & Pricing)  
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519/451-2500

**TABLE 1. SURFACE ACTIVITY OF FLUORAD FLUORO-CHEMICAL SURFACTANTS IN SOLVENTS @ 25°C**

| Grams of solid/100 ml of solvent  | SURFACE TENSION (Dynes/cm) |      |      |       |        |      |      |
|-----------------------------------|----------------------------|------|------|-------|--------|------|------|
|                                   | FC-430                     |      |      |       | FC-431 |      |      |
|                                   | .5                         | .2   | .1   | Blank | .5     | .2   | .1   |
| Distilled Water                   | 27.6                       | 28.0 | 30.3 | 72.0  | 34.6   | 35.7 | 38.6 |
| Methyl Alcohol                    | 18.5                       | 18.5 | 20.3 | 23.4  | 19.2   | 19.3 | 19.9 |
| Butyl Cellosolve <sup>1</sup>     | 21.5                       | 21.7 | 23.0 | 29.2  | 19.9   | 20.2 | 21.1 |
| Cellosolve <sup>1</sup> Acetate   | 22.0                       | 22.9 | 23.7 | 28.7  | 20.5   | 20.7 | 21.2 |
| Cellosolve <sup>1</sup>           | 19.8                       | 20.4 | 21.4 | 29.5  | 19.6   | 19.6 | 20.6 |
| Methyl Ethyl Ketone               | 21.9                       | 22.5 | 22.7 | 24.4  | 21.5   | 22.1 | 22.8 |
| Toluene                           | 21.1                       | 22.9 | 23.7 | 28.8  | 20.2   | 20.2 | 20.2 |
| Solvesso <sup>2</sup> 100         | 21.9                       | 23.4 | 24.0 | 30.3  | 19.5   | 19.5 | 20.3 |
| Dimethylformamide                 | 20.3                       | 21.0 | 22.5 | 37.0  | 20.9   | 21.3 | 22.2 |
| NIAX <sup>3</sup> LG-56 Triol     | 18.9                       | 21.0 | 23.0 | 33.6  | 27.6   | 34.0 | 34.0 |
| Phanyl Glycidyl Ether             | 19.9                       | 20.1 | 20.6 | 43.8  | 19.8   | 20.2 | 21.1 |
| Dibutyl Phthalate                 | 20.8                       | 22.5 | 22.6 | 34.3  | 19.4   | 19.4 | 21.0 |
| Polymeric Isocyanate <sup>3</sup> | 19.2                       | 20.2 | 22.9 | 48.1  | 20.1   | 20.7 | 22.9 |

<sup>1</sup>Trademark of Union Carbide Corporation  
<sup>2</sup>Trademark of Esso Corporation  
<sup>3</sup>Mondur MRS, Mobay Chemical Company

**TABLE 4. SUGGESTED FLUORAD FLUORO-CHEMICAL SURFACTANTS FOR VARIOUS COATING SYSTEMS**

| COATING SYSTEMS  | SURFACTANT CHOICES |        |        |         |         |        |        |        |
|--|--------------------|--------|--------|---------|---------|--------|--------|--------|
|  | FC-120             | FC-129 | FC-135 | FC-170C | FC-171  | FC-430 | FC-431 | FC-740 |
| (Values shown are starting point concentrations based on coating resin solids) |                    |        |        |         |         |        |        |        |
| <b>AQUEOUS</b>   |                    |        |        |         |         |        |        |        |
| Emulsion (Latex)   |                    |        |        |         |         |        |        |        |
| Acidic   |                    |        | 0.02%  | 0.01%   | 0.01%   |        |        |        |
| Neutral  |                    |        |        | 0.01%   | 0.01%   |        |        |        |
| Basic  | 0.04%              | 0.02%  |        | 0.01%   | 0.01%   |        |        |        |
| Colloidal Dispersion   |                    |        |        |         |         |        |        |        |
| Acidic   |                    |        | 0.02%  |         |         |        |        |        |
| Neutral  | 0.04%              | 0.02%  |        | 0.01%   | 0.01%   | 0.01%  |        |        |
| Basic  | 0.04%              | 0.02%  |        |         |         |        |        |        |
| <b>Water-Reducible</b>   |                    |        |        |         |         |        |        |        |
| Epoxy  |                    |        |        |         | 0.10%*  | 0.10%  |        |        |
| Polyester  |                    |        |        |         | 0.10%*  | 0.10%  |        |        |
| Urethane   |                    |        |        |         | 0.10%*  | 0.10%  |        |        |
| Alkyd  |                    |        |        |         | 0.10%** | 0.10%  |        |        |
| Cellulosic   |                    |        |        |         | 0.10%** |        | 0.20%  |        |
| Acrylic  |                    |        |        |         | 0.10%** |        | 0.20%  |        |
| <b>NONAQUEOUS</b>  |                    |        |        |         |         |        |        |        |
| Solvent-Free   |                    |        |        | 0.25%   | 0.25%   | 0.25%  | 0.50%  |        |
| <b>Hi-Solids or Solvent-Based</b>  |                    |        |        |         |         |        |        |        |
| Epoxy  |                    |        |        |         |         | 0.25%  |        |        |
| Polyester  |                    |        |        |         |         | 0.25%  |        |        |
| Urethane   |                    |        |        |         |         | 0.25%  |        |        |
| Alkyd  |                    |        |        |         |         | 0.25%  |        |        |
| Cellulosic   |                    |        |        |         |         |        | 0.50%  |        |
| Acrylic  |                    |        |        |         |         |        | 0.50%  |        |
| Oleoresinous   |                    |        |        |         |         |        |        | 0.50%  |

\*FC-171\* BLENDED WITH FC-430 \*\*FC-171 BLENDED WITH FC-431

**TABLE 3. TYPICAL PHYSICAL PROPERTIES OF FLUORAD FLUORO-CHEMICAL SURFACTANTS\***

| PRODUCT CODE | GENERAL STRUCTURE OR DESCRIPTION (R <sub>1</sub> = C <sub>n</sub> F <sub>2n-1</sub> )  | TYPE     | % ACTIVE | SPECIFIC GRAVITY | VISCOSITY @ 25C (cps) | FLASH POINT (closed cup) | pH      |
|--------------|--|----------|----------|------------------|-----------------------|--------------------------|---------|
| FC-120       | R <sub>1</sub> SO <sub>3</sub> <sup>-</sup> NH <sub>4</sub> <sup>+</sup> (n ~ 10)  | Anionic  | 25%      | 1.0              | 10                    | 139F (58C)               | 8.5-9.5 |
| FC-129       | R <sub>1</sub> SO <sub>2</sub> N(C <sub>2</sub> H <sub>5</sub> )C <sub>12</sub> CO <sub>2</sub> <sup>-</sup> K <sup>+</sup> (n ~ 8)      | Anionic  | 50%      | 1.3              | 30                    | 115F (46C)               | 8-11    |
| FC-135       | R <sub>1</sub> SO <sub>2</sub> NHC <sub>3</sub> H <sub>6</sub> N <sup>+</sup> ·CH <sub>3</sub> I <sup>-</sup> (n ~ 8)                    | Cationic | 50%      | 1.2              | 30                    | 53F (11C)                | 3-5**   |
| FC-170C      | R <sub>1</sub> SO <sub>2</sub> N(C <sub>2</sub> H <sub>5</sub> )(CH <sub>2</sub> CH <sub>2</sub> O) <sub>4</sub> H (n ~ 8)               | Nonionic | 80%      | 1.3              | 400                   | >300F (>148C)            | 6-8     |
| FC-171       | R <sub>1</sub> SO <sub>2</sub> N(C <sub>2</sub> H <sub>5</sub> )(CH <sub>2</sub> CH <sub>2</sub> O) <sub>4</sub> CH <sub>3</sub> (n ~ 8) | Nonionic | 100%     | 1.4              | 150                   | >300F (>148C)            | 6**     |
| FC-430       | Fluoroaliphatic Polymeric Esters   | Nonionic | 100%     | 1.1              | 7000                  | >200F (>93C)             | 7**     |
| FC-431       | Fluoroaliphatic Polymeric Esters   | Nonionic | 50%      | 1.0              | 50                    | 18F (-8C)                | 7**     |
| FC-740       | Fluoroaliphatic Polymeric Esters   | Nonionic | 50%      | 1.0              | 150                   | 132F (55C)               | NA      |

\*Not for specification purposes  
 \*\*1% Aqueous

**TABLE 5. SOLUBILITY OF FLUOROSURFACTANTS IN SOLVENTS (GRAMS OF SURFACTANT/100 GRAMS OF SOLVENT)**

| SOLVENT                                 | FC-120 | FC-129 | FC-135 | FC-170C | FC-171 | FC-430 | FC-431 | FC-740 |
|---|--------|--------|--------|---------|--------|--------|--------|--------|
| Distilled Water                         | <1     | >10    | <1     | ~0.1    | ~0.1   | >20    | <1     | <1     |
| Methyl Alcohol                          | >10    | <1     | >10    | 100     | 2-5    | 3      | >10    | <1     |
| Ethyl Alcohol                           | >10    | <1     | >20    | 100     | 100    | 100    | 100    | —      |
| Isopropyl Alcohol                       | >10    | <1     | 2      | 100     | >20    | >20    | 100    | <1     |
| Ethylene Glycol Monobutyl Ether         | —      | —      | —      | —       | >20    | >10    | >20    | —      |
| Dipropylene Glycol Monomethyl Ether     | <1     | <1     | —      | 100     | —      | —      | —      | <1     |
| Ethylene Glycol Monoethyl Ether Acetate | <1     | <1     | —      | 100     | >20    | >20    | >20    | <1     |
| Acetone                                 | <1     | <1     | 2      | >20     | 100    | 100    | 100    | 100    |
| Methyl Ethyl Ketone                     | <1     | <1     | —      | >5      | >20    | >20    | >20    | 100    |
| Niack Lg-56 Triol                       | —      | —      | —      | —       | —      | 1      | <1     | —      |
| Phenyl Glycidyl Ether                   | —      | —      | —      | —       | —      | 0.5    | 1      | —      |
| Dibutyl Phthalate                       | —      | —      | —      | —       | >20    | 1      | >20    | —      |
| Dimethylformamide                       | <1     | <1     | —      | >20     | >20    | >20    | >20    | <1     |
| Polymeric Isocyanate                    | —      | —      | —      | —       | —      | —      | 2      | —      |
| Toluene                                 | <1     | <1     | <1     | <1      | >20    | >20    | >20    | >80    |
| Solvesso 100                            | —      | —      | —      | —       | —      | >10    | >20    | —      |
| Kerosene                                | —      | —      | —      | —       | —      | —      | —      | >80    |
| Heptane                                 | —      | —      | <1     | <1      | <1     | <1     | <1     | >80    |



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