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**JOHN F. KENNEDY SPACE CENTER**
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# EVALUATION OF SURLYN 8920 AS PHE VISOR MATERIAL AND EVALUATIONS OF NEW ADHESIVES FOR IMPROVING BONDING BETWEEN TEFLON AND STAINLESS STEEL AT CRYOGENIC TEMPERATURE


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# EVALUATION OF SURLYN 8920 AS PHE VISOR MATERIAL

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## ABSTRACT

Surlyn 8920 (an ionic and amorphous low density polyethylene made by Dupont) was evaluated as a possible replacement of Plexyglass G as PHE visor material. Four formulations of the polymer were made by adding different amounts of UV stabilizer, energy quencher, and antioxident in a Brabender plasticorder. The formulated polymers were molded in the form of sheets in a compression molder. Cut samples from the molded sheets were exposed in a weatherometer and tested on Instron Tensile Tester for strength and elongation. Specially molded samples of the formulated polymers were subjected to Charpy Impact test.

Data from the Instron Tensile test of samples showed some loss in strength and ductility of the formulated Surlyn polymers at 500 and 1000 hours of exposure in the weatherometer. The unformulated polymer had greater loss in strength and complete loss of ductility at 1000 hours of exposure. The plexyglass samples gave higher tensile strength but zero ductility (% elongation) at zero exposure.

Charpy impact tests of specially molded samples show Surlyn 8920 to have impact strength 30 - 40 times higher than Plexyglass G (current PHE visor material) and an order of magnitude higher than Lexan (polycarbonate made by G.E.). Formulated Surlyn gave 50% higher impact strength than unformulated Surlyn.

The formulated polymer giving the best balance of tensile and impact resistant properties was them molded in the form resembling a visor. These curved, molded samples successfully passed the ANSI Weight Drop Impact Test.

Based on the Instron and Impact test data, Surlyn 8920 indicated superior ductility and impact strength with adequate tensile strength compared to Plexyglass G, the current PHE visor material. On the basis of these results, it is recommended that Surlyn 8920 replace Plexyglass G as PHE visor material.

## 1.0 INTRODUCTION

### 1.1 Background Information

Current material used for making Propellant Handlers Ensembles (PHE) visor, Plexyglass G, has poor impact and scratch resistance. Because of its brittle nature the plexyglass PHE visor can be easily damaged during the process of handling solid propellants and endanger the health and life of a handler due to exposure to highly toxic hypergolic chemicals.

Surlyn 8920, an ionic and amorphous polyethylene made by Dupont Co. was chosen by Coleman Bryan because of its excellent mechanical and optical properties and resistances to toxic chemicals including the hypergols. This polymer should possess excellent impact resistance because of its ethenic and noncrystalline nature. Low cost of the polymer ($1.60/lb.) is an additional bonus.

Resistance to UV and oxidation degradation were to be improved by adding optimum quantities of UV stabilizer, energy quencher, and antioxidants.

### 2.1 Scope of the Project

This project involves evaluation of the formulated polymer encompassing the following four steps:

a. Formulation of the polymer.

b. Molding of the formulated polymer to make samples (exposed or unexposed in the weatherometer) for testing on the Instron Tensile Testing machine.

c. Molding of formulated polymers to make special samples for Charpy impact testing.

d. Evaluation of the tensile and impact properties of these samples.

e. Molding of the polymer formulation giving the best balance of tensile and impact resistant properties in the form of visor and subject these to ANSI Weight Drop Impact Test.

f. Make final recommendation regarding suitability of Surlyn 8920 as a replacement for current PHE visor material.

## 2.0 MATERIALS AND METHODS

### 2.1 Formulation of Polymer

Four formulations of Surlyn 8920 were made in a Brabender Plasticorder by adding different amounts of UV stabilizer (Tinuvin 328, 0.7%), energy quencher (Tinuvin 770, 0.5 or 1.0%), antioxidant (Irganox, 0.1 or .3%) and color masking agent (Monastal Blue, 2-10 ppm). The plasticorder was run at 165°C with mixing time of 10 minutes at 120 RPM with 1 minute of melting time for the polymer. The hygroscopic polymer was stored in a dessicant and dried periodically by pulling vacuum. Weight of each batch was 40 gms of dry polymer plus the ingredients listed above. Presence of moisture in the polymer necessitates the use of higher temperature in the plasticorder (145°C vs 165°C). The plasticorder was fitted with Branbury mixer containing sigma type mixing blades.

### 2.2 Molding of the Formulated Polymer

The formulated and unformulated polymer batches ( 38 gms) were then molded into 6-inch x 6-inch x 0.07-inch sheets in a Dake Compression molder at 270°F (132°C) at a force of 30,000 pounds (833 psi) using Mylar film on both sides as mold releasing agent. A molding cycle of five minutes was used. The sheets had some defects caused by air bubbles formed during thermoforming. No further experimentation was made to solve this problem because of the shortness of this summer program. The 6-inch x 6-inch molded sheets were molded to 10-inch x 10-inch sheets to improve product uniformity. Dogbone shaped samples were cut according to ASTM D 638-86 (Type V) specifications taking care to exclude molding defects. These were then mounted in the ATLAS Wetherometer at 50°C, energy density = 0.35 Watt/$m^2$ at 340 nm, humidity = 30% for 500, 1000, and 1500 hours exposures. A total of 60 samples were mounted for four formulated polymers and unformulated polymer (3 samples per polymer type per type of exposure). The samples exposed and unexposed were tested on the Instron Tensile Testing machine for strength and elongation (ductility).

### 2.3 Charpy Impact Test

Notched samples (ASTM D 256-84) of the formulated and unformulated polymers were molded using the Dake Compression molder (temperature 130°C, cycle time 5 minutes, force 10,000 pounds (600 psi) using a special mold fabricated by the Prototype Shop. The samples molded had defects caused by air bubbles formed during the thermoforming. No further effort was made to correct this. Similar samples of dexan (polycarbonate) and Plexyglass G were also made from flat sheets of materials made industrially. These samples were tested on the Charpy Impact tester for plastics according to ASTM method.

2.4 Instron Tensile Test

The tensile tests of the polymer samples (Surlyn 8920 and Plexyglass G) were completed using an Instron Tensile Testing Machine (Model 1125) at a pulling speed of 20 inch/min. and having a computerized data handling facility. The testing procedures followed specification according to ASTM standard (D412).

2.5 ANSI Weight Drop Impact Test

The polymer formulation giving the best balance of tensile and impact resistant properties were then molded into the form of visor (duplicating its curved surface) using a mold designed by Coleman Bryan and fabricated by the Prototype Shop. These samples were tested for impact strength using ANSI Weight Drop Test (Z87.1). Where 2.5 ounce, one inch diameter weight steel ball was dropped from a height of 50 inches on the curved sample.

## 3.0 RESULTS

3.1 Charpy Impact Test

The results of the Charpy Impact tests on unformulated, formulated Surlyn 8920, Plexyglass G, and Lexan (polycarbonate) are shown on Table 1. All the Surlyn 9020 samples had 30 to 40 times higher impact strength than that of Plexyglass G and one order of magnitude higher impact strength than Lexan (Polycarbonate made by G.E.). The unformulated samples gave lower impact strength compared with those of the formulated ones. The formulated polymer $M_3$ gave slightly lower impact strength than the other three formulated polymers ($M_1$, $M_2$, and $M_4$) and this can be ascribed to higher defect level of the samples caused during the compression molding process.

3.2 Instron Tensile Test

The results of the tensile tests are given in Table 2 for Surlyn 8920 at zero, 500, and 1000 hours of exposure in the Atlas Weatherometer and for Plexyglass G at zero hour exposure. Also, the literature data of Surlyn 8920 and Plexyglass G are presented. The formulated polymer samples show some loss of strength and ductility at 500 hours of exposure. The unformulated polymer samples show greater loss in strength and ductility. At 1000 hours exposure the formulated polymer samples showed no further loss in tensile properties. But the unformulated polymer samples showed further loss in strength and total loss in ductility (percent elongation). At 1000 hours of exposure, samples of polymer $M_4$ show an increase in strength and ductility over these values at zero or 500 hours of exposure, which is unexpected. One explanation is that the samples, used for the 1000 hours of exposure were of better quality, having a lower defect level. The Plexyglass G samples at zero exposure gave higher strength but zero percent elongation. The Surlyn (formulated and unformulated) samples gave higher strength and about equal elongation compared to data supplied by Dupont Co. Exposures up to 1500 hours of the Surlyn 8920 samples and up to 500 hours for Plexyglass G samples are under way.

### 3.3 ANSI Weight Drop Impact Test

The polymer formulations $M_1$ and $M_2$ gave the best balance of tensile and impact resistance properties. Curved samples made using these polymers successfully passed the ANSI Impact test where a steel ball weighing 2.5 ounce was dropped from the height of 50 inches.

## 4.0 CONCLUSIONS

4.1 The Brabender Plasticorder with mixing head proved adequate mixing of the Surlyn 8920 polymer beads with UV stabilizer, energy quencher, antioxidant, and color masking agent. The Dake Compression Molder gave adequate samples; however, some defects that occurred during molding operation caused variations in the tensile and impact strength data.

4.2 The formulated Surlyn polymer samples successfully withstood (some loss in strength and ductility) the exposure to UV light and moisture at 1000 hours of exposure in the Weatherometer. Where as the unformulated polymer samples did not. The unexposed plexyglass samples having UV stabilizer gave higher strength but zero percent elongation (ductility).

4.3 Formulated Surlyn samples gave 30 to 40 times higher Charpy Impact strength than Plexyglass G samples and greater than 10 times higher impact strength than Lexan (polycarbonate). Formulation of Surlyn by addition of ingredients mentioned in Section 4.1 improved its impact strength by 50% over the unformulated polymer, an unexpected bonus.

4.4 Special molded samples made from the best formulated polymer (based on tensile and impact test data) easily passed the ANSI Weight Drop Impact Test.

## 5.0 RECOMMENDATIONS

Based on the tensile and impact test data, formulated Surlyn 8920 samples show strength comparable to that of Plexyglass G at zero exposure in the Weatherometer; however, ductility was far superior (350% to 0% elongation). These formulated polymer samples maintained most of its optical clarity, strength, and ductility at 1000 hours of exposure in the Weatherometer.

Based on these results, it is recommended that Surlyn 8920, modified according to formulation $M_1$ or superior, replace Plexyglass G, the current materials for PHE visor.

TABLE 1

CHARPY IMPACT TEST DATA OF SURLYN 8920
LEXAN AND PLEXYGLASS

| | | IMPACT STRENGTH (INCH-POUND) | | | | | |
|---|---|---|---|---|---|---|---|
| POLYMER | TYPE | SAMPLE #1 | SAMPLE #2 | SAMPLE #3 | SAMPLE #4 | SAMPLE #5 | AVERAGE |
| SURLYN ($M_1$) | FORMULATED | 164 | 146 | 150 | 144 | 168 | 154.4 |
| SURLYN ($M_2$) | FORMULATED | 128 | 150 | 164 | 168 | 156 | 153.2 |
| SURLYN ($M_3$) | FORMULATED | 130 | 122 | 130 | 128 | 162 | 134.4 |
| SURLYN ($M_4$) | FORMULATED | 160 | 144 | 148 | 140 | 152 | 148.8 |
| SURLYN (P) | UNFORMULATED | 110 | 106 | 90 | 90 | 80 | 95.2 |
| *SURLYN (P) | UNFORMULATED | 88 | 100 | 94 | 100 | - | 95.5 |
| PLEXYGLASS | UNFORMULATED | 4.5 | 4.0 | 4.0 | 4.5 | 4.0 | 4.2 |
| LEXAN (POLYCARBONATE) | UNFORMULATED | 14 | 14 | 12 | 12 | 14 | 13.2 |

*REPLICATED

TABLE 2

STRENGTH AND DUCTILITY DATA OF SURLYN 8920 FORMULATED POLYMER

| SAMPLE | TYPE | TENSILE STRENGTH (PSI) | ELONGATION (PER CENT) |
|---|---|---|---|
| $P_0$ | FORMULATED AND UNEXPOSED | 3492 | 315 |
| $M_{10}$ | FORMULATED AND UNEXPOSED | 3262 | 340 |
| $M_{20}$ | FORMULATED AND UNEXPOSED | 3249 | 345 |
| $M_{30}$ | FORMULATED AND UNEXPOSED | 3445 | 343 |
| $M_{40}$ | FORMULATED AND UNEXPOSED | 3111 | 283 |
| $PX_0$ (PLEXYGLASS) | FORMULATED AND UNEXPOSED | 7052 | 0 |
| $P_1$ | UNFORMULATED BUT EXPOSED 500 HOURS | 2966 | 285 |
| $M_{11}$ | FORMULATED AND EXPOSED 500 HOURS | 3047 | 300 |
| $M_{21}$ | FORMULATED AND EXPOSED 500 HOURS | 3181 | 280 |
| $M_{31}$ | FORMULATED AND EXPOSED 500 HOURS | 3250 | 243 |
| $M_{41}$ | FORMULATED AND EXPOSED 500 HOURS | 3183 | 220 |
| SURLYN 8920 | VENDOR DATA | 2200 | 350 |
| PLEXYGLASS G | LITERATURE DATA | 5500 | 35 |

| | | | | | |
|---|---|---|---|---|---|
| $M_1$ | ANTIOXIDANT<br>ENERGY QUENCHER | 0.3%<br>1.0% | $M_2$ | ANTIOXIDANT<br>ENERGY QUENCHER | 0.1%<br>1.0% |
| $M_3$ | ANTIOXIDANT<br>ENERGY QUENCHER | 0.3%<br>0.5% | $M_4$ | ANTIOXIDANT<br>ENERGY QUENCHER | 0.1%<br>0.5% |

ALL FORMULATIONS HAD 0.7% UV STABILIZER AND 2 - 10 PPM MONASTAL

BLUE AS COLOR MASKING AGENT.

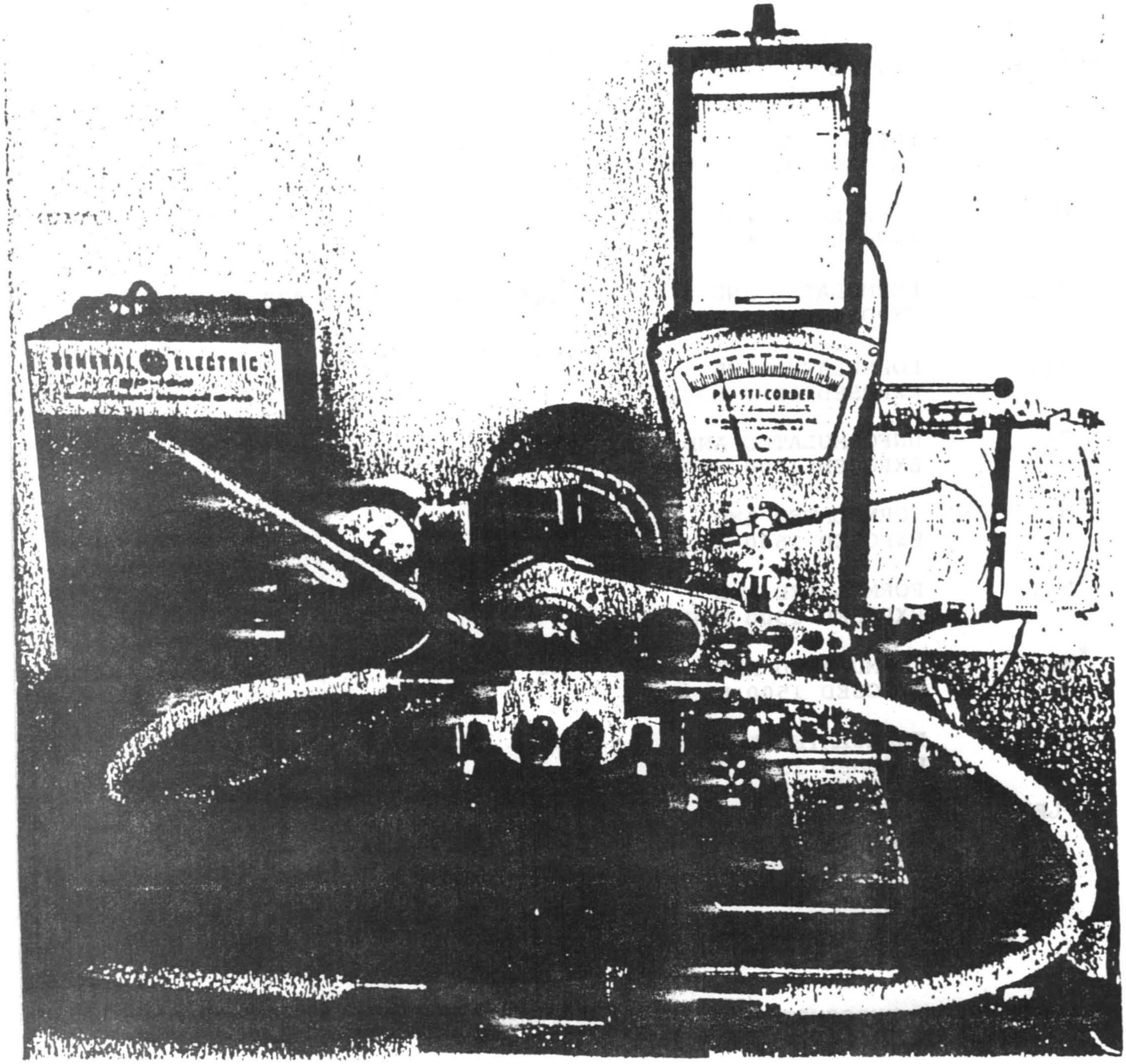
TABLE 2

STRENGTH AND DUCTILITY DATA OF SURLYN 8920 FORMULATED POLYMER

| SAMPLE | TYPE | TENSILE STRENGTH (PSI) | ELONGATION (PER CENT) |
|---|---|---|---|
| $M_{12}$ | FORMULATED AND EXPOSED 1000 HOURS | 3179 | 350 |
| $M_{22}$ | FORMULATED AND EXPOSED 1000 HOURS | 3180 | 353 |
| $M_{32}$ | FORMULATED AND EXPOSED 1000 HOURS | 3146 | 323 |
| $M_{42}$ | FORMULATED AND EXPOSED 1000 HOURS | 3285 | 367 |
| $P_2$ | UNFORMULATED AND EXPOSED 1000 HOURS | 2765 | 0 |
| *$M_{13}$ | FORMULATED AND EXPOSED 1500 HOURS | -- | -- |
| *$M_{23}$ | FORMULATED AND EXPOSED 1500 HOURS | -- | -- |
| *$M_{33}$ | FORMULATED AND EXPOSED 1500 HOURS | -- | -- |
| *$M_{43}$ | FORMULATED AND EXPOSED 1500 HOURS | -- | -- |
| *PLEXYGLASS G | FORMULATED AND EXPOSED 500 HOURS | -- | -- |

*UNDERGOING EXPOSURE IN THE WEATHEROMETER

BRABENDER PLASTICORDER WITH BRANBURY MIXER
EQUIPPED WITH SIGMA TYPE MIXING BLADE.

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