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TRW MATERIALS COMPATIBILITY STUDY WITH ETHYLENE OXIDE/FREON 12 DECONTAMINATION PROCESSES

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1. INTRODUCTION

This report contains the results of a materials compatibility study conducted during the TRW Voyager Spacecraft Engine Demonstration Program. The purpose of this program is to demonstrate the capabilities of the basic TRW Lunar Module Descent Engine (LMDE) for the Voyager application. The primary objective of this particular study was to provide quantitative information on the compatibility of the materials currently used in the TRW LMDE with the type approval (TA) and flight approval (FA) ethylene oxide (ETO) decontamination process as defined in JPL Specification VOL-50503-ETS.

The study was divided into two parts. First, an extensive literature search was conducted to categorize the various materials with respect to compatibility with the ETO decontamination process. The second part of the study consisted of actual decontamination tests on selected material samples. The materials used for these tests were mainly those critical LMDE items to be used for Voyager plus various other materials of general interest. All of the test results are contained in this report.

2. SUMMARY

The literature search revealed that all of the metallics used on LMDE had an established history of compatibility with the ETO decontamination environment whereas the compatibility of many of the organic materials with this process was either unknown or doubtful. Based on this investigation, twenty-one different materials were selected for compatibility verification by decontamination tests. Of these materials, all but the aluminide coating were organic in nature.

The decontamination tests consisted of seven cycles, twenty-eight hours each in duration, of exposure to the ETO/Freon 12 decontamination environment specified in JPL Specification VOL-50503-ETS, "Environmental Specification Voyager Capsule Flight Equipment Type Approval and Flight Acceptance Test Procedures for the Heat Sterilization and Ethylene Oxide Decontamination Environments".The ETO concentration was maintained at 600mg/liter at a gas temperature of 122°F. The gas mixture was maintained at nominal 12 percent ETO and 88 percent Freon 12 (by weight) concentration with a relative humidity of 50 percent.

Of the LMDE materials used in the TRW Voyager Spacecraft Engine, only the Sylgard 182 showed a marked change in physical characteristics at the conclusion of the tests. This material is used as a filler between the ablative material and the titanium combustion chamber case. The 87 percent decrease in tensile strength that resulted from the exposure to the decontamination media is not considered detrimental because the material is not used for structural purposes, and in this particular application, less than one percent of the total volume of material used in the combustion chamber would be exposed to the decontamination fluid. Decontamination tests will be conducted on the engine assembly during Phase II of the demonstration program tests (to be followed by a nine-month vacuum storage test and a duty cycle firing) to confirm that the effects of this process on the Sylgard material at the engine assembly level are not significant.

Minor changes in tensile strength were noted in the MX2600 Phenolic Silica Laminate. However, these results are suspect due mainly to the wide variation in control specimen and test specimen tensile test values. This condition was probably caused by improper curing of the specimens.

It was determined that two materials are definitely not compatible with the decontamination process: Nitroso Rubber and Alkanex (a varnish used for sealing the electrical harness connectors). It was not planned, however, to use these materials on the Voyager Spacecraft Engine.

3. RESULTS OF LITERATURE SEARCH

A literature search was conducted on the materials listed in Table 3-1 to determine the degree of compatibility with the ETO/Freon 12 decontamination process. The materials were divided into the following categories:

1.) Established compatibility (C).

2.) Fairly compatible (Fairly C), but margins should be established by testing.

3.) Likely to be compatible (T), but should be tested before using.

4.) Not likely to be compatible (X), but should be tested if use is considered.

5. Not compatible (NC).

TABLE 3-1

Components	Compatibility with ETO/Freon 12
COMBUSTION CHAMBER ASSEMBLY	
Titanium Shell	C
Epoxy Phenolic Adhesives	T
Epon Adhesive 934	T
Sylgard Bonding	T
Phenolic Silica Laminate	C
Rubber Modified Phenolic Silica Laminate	T
Nozzle Extension	C
INJECTOR ASSEMBLY	
Titanium	C
Stainless Steel	C
Aluminum	C
Aluminide Coating	C
Lubco Dry Lube	C
Microseal Dry Lube	C
Loctite Sealing Compound	C
Columbium	C

SHUT OFF VALVE

Aluminum	C
Stainless Steel	C
Teflon Seals	C'
Kynar Seals	C
RTV Silicone Foam	T
Butyl O-Rings	Fairly C
EPR O-Rings	Fairly C
Electroless Nickel	C
Glass Filled Teflon (Rulon A)	C
Microseal Dry Lube	C
GE Silicone Primer	T
PR 5-9 (RTV)	T

PRE VALVE

Aluminum	C
Stainless Steel	C
Teflon Seals	C
Kynar Seals	C
Butyl O-Rings	Fairly C
DuPont 240 AC Lube	NC
EPR O-Rings	Fairly C
Microseal Dry Lube	C
GE Silicone Primer	T
Glass Filled Teflon	T
PR 5-9 (RTV)	T

EXIT CONE & SEAL

Aluminum	C
Stainless Steel	C
Teflon	C

GIMBAL ASSEMBLY

Aluminum	C
Steel	C
Titanium	C
Gimbal Bearing (Fabroid)	C

LINES & DUCTING

Aluminum	C
Stainless Steel	C
Titanium	C

HEAT SHIELD INSULATION

Quartz	C
Fiberfrax (No organic binder)	C

ELECTRICAL COMPONENT MATERIALS

Aluminum Connectors	C
Teflon Sealing Plugs	C
Gold Plated Copper Contracts	C
Polyethylene Boots	NC
Polyethylene Tubing	NC

ELECTRICAL COMPONENT MATERIALS (Continued)

Tin Plated Brass Ferrules	C
Black Anodized Aluminum Adapters	C
Chlorinated Polyether Ident. Strap	X
Chlorinated Polyether Cable Strap	X
RTV Silicone Rubber Potting Compound (601/11)	T
Polyimide Coated Teflon Insulated Wire	T
GE Silicone Primer	T
Glass Epoxy Terminal Board	C
Polyethylene Identification Sleeve	NC
Aluminum Chassis Assembly	C
Steel Shunt	C
Butyl Cover Gasket	Fairly C
"J" Box - Aluminum	C
Aluminum Protective Cup	C
Butyl Connector Seal	Fairly C
Copper Termal Lug	C
Solder	C
Aluminum Ring	C
Aluminum Plates	C
Glass Epoxy Wafer	C
Nylon Screws	C
Aluminum Plugs	C
Glass Cloth Tape	C
Steel Lockwire	C
Steel Washer	C
Steel Nut	C
Steel Screw	C
Aluminum Clamps	C
Teflon Clamps	C
Steel Flexure Shim	C
Titanium Flexure	C
Titanium Bracket Assembly	C
Aluminum Bracket Assembly	C
Torque Paint, Cat-a-lac	T

MISCELLANEOUS MATERIALS

Tubing and Sleeving Polyvinyldene Fluride (Kynar) AMS 3632	C
Tubing and Sleeving Polyolefin MIL-I-23053	NC
Tubing and Sleeving Teflon MIL-I-22129	C
Tubing and Sleeving Silicone Rubber over Fiberglass MIL-I-3190	T
Tubing and Sleeving Polyvinyl Chloride and its Co-polymers MIL-I-631	T
Tubing and Sleeving Polyethylene MIL-I-631	NC
Tubing and Sleeving Siliflex (Braided Fiberglass w/silicone resin)	C
Tubing and Sleeving Fiberglass w/fungicide Dowcide #7 added to varnish	C
Tubing and Sleeving Extruded Vinyl Plastic MIL-I-7444	C
Tubing and Sleeving Triple Saturated Cotton	C

MISCELLANEOUS MATERIALS (Continued)

Wire Insulation Hi Temp Teflon MIL-W-583 Type K	C
Wire Insulation Enamel MIL-W-583 Type F	NC
Wire Insulation Formvar or Farmex MIL-W-583 Type T	C
Wire Insulation Cotton MIL-W-583 Type C	C
Wire Insulation Silk MIL-W-583 Type S	C
Wire Insulation Glass MIL-W-583 Type G	C
Wire Insulation Thermaleze "F" MIL-W-583 Type L	C
Wire Insulation Silicone Enamel MIL-W-583 Type H	T
Wire Insulation Alkanex MIL-W-583 Type B	NC
Cord Nylon w/synthetic rubber finish	C
Non-metallic Washer Thermoplastic MIL-P-22242	C
Conductive Gasket Flurosilicone Chomerico Powder No. 8000	T
Insulating Tape Crepe Taper	X
Insulating Tape Acetate Cloth MIL-I-15126	T
Insulating Tape Paper	X
Insulating Tape Teflon Film/Silicone Adhesive	T
Insulating Tape Elastic Vinyl MIL-I-7798	T
Insulating Tape Polyester Film MIL-I-1526	C
Insulating Tape Acetate Film Cloth, Thermo-setting Adhesive	T
Insulating Tape Glass Cloth/Silicone MIL-I-19166	T
Insulating Tape Cambric, Varnished	X
Insulating Tape Epoxy Impregnated Glass Fabric	T
Epoxy	C
Hardware Parts Various Alloys of Steel, Aluminum and Brass	C
Wire Shields Silver Plated or Tinned Copper	C
Magnet Wire Soft Annealed Copper MIL-W-583	C
Receptacle Cu, Au, or Ni Finish	C
Wire Nickel	C
Nut Steel w/Molybdenum Disulphide Finish	C
Gear Sinite D-10	C
Leak Detector Inconel MIL-N-6840	C
Ball Bearing Steel, Phenolic "Synthane"	C
Name Plate Metal Foil	C
Ball Screw Assembly Steel Temp. Range of (Design Guide)	C
Receptacle Carbon Steel, Vitreous Material, Au, Ni	C
Washer, Beryllium Oxide	C
Receptacle Brass, Be, Cu, Glass Filled Diallyl Phthalate	C
Washer Indium	C
Spacer Delrin 500	C

4. DECONTAMINATION TESTS

4.1 Materials

The following table lists the materials and test specimen types subjected to the seven cycle ETO-Freon 12 decontamination tests. The choice of these materials was based largely on the results of the literature search and also on the general need for knowledge on the behavior of materials exposed to this environment.

Discussion of Materials Tested and Test Conditions

After evaluating the literature compatibility table, the following materials were selected for test:

TABLE 4-1

"MATERIALS FOR DECONTAMINATION TESTS"

	Material	Manufacturer	Specimen Type
1.	Ethylene Propylene Rubber O-Rings	Parker	As is
2.	Teflon O-Rings	Parker	As is
3.	Butyl Rubber O-Rings	Parker	As is
4.	Samples of Carboxy Nitroso Rubber	Thiokol	1 pc. 1/8" thick x 1/2" x 3 1/2 " 1 button 1/2"L x 3/8"D Micro Dumbell Tensile Specimen
5.	DuPont Krytox 240-AC Lube	DuPont	Applied to a Sov Ball Valve & Seal
6.	Lubco 2023 Dry Lube MIL-M-7866A	Lubco, Inc.	On Bearing
7.	Gimbal Bearing Material (Fabroid)	Nylo-Seals	Gimbal Bearing
8.	MX2600 Phenolic Silica Laminate	Fiberite	Tensile Specimens
9.	MX SE 57 Rubber Modified Phenolic Silica Laminate	Fiberite	Tensile Specimens
10.	WB 7208 Insulation Overwrap	Fiberite	Tensile Specimens
11.	RTV 601	Dow Corning	Micro Dumbell Tensile Specimen
12.	RTV S-5370	Dow Corning	Micro Dumbell Tensile Specimen

13.	RTV 8111	General Electric	Micro Dumbell Tensile Specimen
14.	Sylgard 182	Dow Corning	Micro Dumbell Tensile Specimen
15.	Epon Adhesive 934	Shell	Lap Shear Specimen
16.	HT 427 Phenolic Adhesive	American Cyanamid	Lap Shear Specimen
17.	Silicone Primer MT 3-17 with PR 5-9	Chem Seal Corp.	Painted on piece of aluminum
18.	Aluminide Coating	TRW	On Columbium coupons
19.	J-Box O-Ring (Butyl)	Parker	J-Box Cover and O-Ring
20.	Nitrile O-Ring	Parker	As is
21.	Electrical Harness Sample	Deutsch	2 connectors with wires

The preparation of all tensile and lap shear specimens were based on TRW and ASTM Specifications.

Material	TRW Preparation Specification	Test Specification
MX 2600 Phenolic Silica Laminate	MT 3-10	ASTM 0638
WB 7208 Insulation Overwrap	MT 3-31 PR 10-21	ASTM 0638
MX SE-57 Elastomer Modified Silica-Phenolic	MT 3-32 PR 10-20	ASTM 0638
Sylgard 182	PR 4-17	ASTM D412
HT 427 Phenolic Adhesive	PR 4-18 Type VIII	Fed. Test Method Standard 175 Method 1033.17
Epon 934	PR 4-18	"
RTV 601	PR 4-17	ASTM D412
RTV S-5370	PR 4-17	ASTM D412
RTV GE 8111	PR 4-17	ASTM D412
Nitroso	PR 4-17	ASTM D412

4.2 Decontamination Test Environment

The decontamination test conditions simulated those specified in JPL Specification VOL-50503-ETS for the TA testing. A total of seven cycles were performed in order to simulate both the TA and FA requirements. The purpose of these tests was only to provide exposure of the materials to the ETO/Freon 12 decontamination environment to determine compatibility, and no attempt was made to ascertain if the process was effective in actually decontaminating the test specimens.

The test chamber conditions were maintained at the following levels for the full duration of each of the seven 28-hour cycles:

Gas Composition:	12% ETO/88% Freon 12 (by weight)
ETO Concentration:	600 mg/liter
Gas Temperature:	122°F. (± 2°F.)
Relative Humidity:	50% (± 5%)

All external surfaces of the test specimens were exposed to the gas.

The test chamber pressure required to maintain the correct ETO concentration was originally calculated to be 20 psia at the required temperature (122°F.). After the tests began, the gas composition was verified by gas sample analyses. (See Table 1)

A detailed test procedure and a description of the test setup are included in the appendix.

5. TEST RESULTS AND DISCUSSION

5.1 O-Rings

The changes occurring in the O-Rings that are most commonly used, i.e., Butyl Rubber, Ethylene Propylene Rubber, and Teflon, show very little degradation, if any. There were no color changes noted. (Figures 2, 3, and 4.) The weight changes were minute and dimensional changes were insignificant (See Table 2). However, in view of the fact that Butyl Rubber is temperature sensitive above about 225°F., other materials should be considered if thermal conditioning for an extended period is anticipated.

Nitrile Rubber O-Rings showed gains in weight of 16 percent to 41 percent during the seven decontamination cycles, and increases in thickness of 4.3 percent to 12.7 percent. Therefore, Nitrile O-Rings are considered unsuitable for use in engines which would be subjected to ETO/Freon 12 decontamination.

Carboxy Nitroso Rubber is definitely not suitable when decontamination cycles are required. This rubber showed gains in weight ranging from 76.5 percent to 271 percent and dimensional increases from 30.9 percent to 81.3 percent. The tensile strength decreased 80 percent, and the elongation was reduced by 51 percent. Visual changes were apparent as early as the first 28-hour cycle. The Nitroso Rubber, which was originally dark green in color, changed to light green, and displayed significant swelling and increase in volume. This phenomena continued throughout the seven decontamination cycles, and after completion, the specimens continuously oozed beads of liquid even when the rubber was wiped dry (See Tables 2 and 12, and Figures 2, 5, 6, and 7.)

5.2 Aluminide Coatings

The Aluminide Coatings (See Table 3 and Figures 8 and 9), which are utilized on the injector pintle tip and nozzle extension, showed practically no change in weight during the decontamination. Very slight visual changes were apparent, which were confirmed by microscopic examination. There is no evidence to indicate that difficulty will be encountered with this material.

5.3 Elastomers

The RTV Compounds (Tables 4, 13, 14, and 15, and Figures 5 and 6), in general, showed good resistance to the ETO/Freon 12 environment. Of the three RTV compounds tested, only one, RTV S-5370, a silicone foam used as a potting compound in the Shut-Off Valve showed large weight and dimensional gains (about 19.5 percent). At room temperature, tensile strength and elongation tests with RTV S-5370 showed increases of 17.3 percent and 13.1 percent.

RTV 601 displayed a loss of 9.1 percent in tensile strength and a gain of 5 percent in elongation, and RTV GE 8111 showed a loss of 17.3 percent in tensile strength and 6 percent in elongation. RTV 601 is used as a sealant between the head end assembly and the ablative faceplate. (Minor exposure to ETO/Freon 12 in actual use). RTV GE 8111 is used in electrical applications for insulation. It, therefore, appears that all three RTV compounds tested are compatible with ETO/Freon 12 where physical strength is not a requirement.

Sylgard 182 (Table 16 and Figures 5 and 6), which is used between the combustion chamber case and ablative materials, showed significant changes in ETO/Freon 12. Losses of 87 percent in tensile strength and 4.4 percent in elongation were recorded. Weight and dimensional measurements were inadvertently missed. Photographs were taken before and after ETO/Freon 12 exposure and showed some swelling. Although significant changes occurred in this material, a simple conclusion of incompatibility cannot be drawn since in the application (Fill material between combustion chamber case and ablative material), a surface of only 0.060 inch thickness is exposed to the ETO mixture.

PR 5-9 (Figure 12), a silicone rubber material used for masking dissimilar materials from vapor and consequent galvanic corrosion, was unaffected by ETO/Freon 12 either visually or dimensionally.

5.4 Gimbal Bearing Material

The fabroid material in the Gimbal Bearing held up quite well in the decontaminant. (See Figures 10 and 11). No changes were observed, although the bearing friction seemed to increase slightly.

5.5 Lubricants

DuPont Krytox 240-AC (Figures 11 and 13) lubrication material showed excellent resistance to the ETO/Freon 12 environment. Literature search compatibility studies conducted by the writer had indicated that 240-AC grease would not be compatible with ETO/Freon 12. It was predicted that the grease would lose its viscosity and thereby become useless for lubrication purposes However, contrary to this prediction, the grease became heavier, if anything, maintaining its viscosity, thus retaining its lubrication value.

As expected, there was no effect on the Lubco Dry Lube. The material retained its lubricating properties and withstood the ETO/Freon 12 environment with no evidence of degradation.

5.6 Electrical Materials

The Butyl Rubber J-Box O-Ring (Figures 14 and 15) retained normal size and indications are that there were no deleterious effects from ETO/ Freon 12. Little damage was noted on the electrical harness samples, (Figures 16, 17, and 18). The insulation, probably irradiated polyolefin, became a little tacky, but was still serviceable. The RTV potting compounds were unaffected both visually and dimensionally. The insulation materials were undamaged. The sealing material, alkanex, which is used to hold the insulation to the connector, was damaged, but the seal was not broken.

5.7 Ablative Materials

The ablative materials for the combustion chamber, MX 2600 Phenolic Silica Laminate, MX-SE 57 Rubber Modified Phenolic Silica Laminate, and WB 7208 Insulation Overwrap, exhibited some change after ETO/Freon 12. Visually, all specimens showed some bleaching after ETO/Freon 12 (Figures 19, 20, 21, 22, and 23). MX 2600 and WB 7208 showed weight increases from 3.4 percent to 7.6 percent (Table 5.) No changes in hardness were noted (Table 6). There was a drop in tensile strength of 17.8 percent in MX 2600; 7.1 percent in MX SE 57; but an increase of 6.9 percent for WB 7208 (Tables 7, 8, and 9). There was a drop in Modulus of 32.8 percent in MX 2600; of 7.5 percent in MX SE 57; and 16 percent in WB 7208. All ablative materials tested appear to be compatible with ETO/Freon 12.

5.8 Adhesives

The Lap Shear specimens of Epon 934 and Adhesive HT 427 were both compatible with ETO/Freon 12. Both adhesives are utilized in various components of the Voyager Engine (Tables 10, 11, and Figures 24 and 25).

6. CONCLUSIONS

6.1 The O-Rings proposed for usage in the TRW Voyager Engine are compatible in seven cycles of ETO/Freon 12 environment (See Appendix A for the Conditions). The O-Rings are namely, Ethylene Propylene Rubber, Teflon, and Butyl Rubber. Some of the other rubbers tested, Carboxy-Nitroso, and Nitrile, are definitely unsuitable for use in engines which could be subjected to the ETO/Freon 12 environment.

6.2 The Aluminide Coatings which are utilized on the injector pintle tips and nozzle extension are compatible with the ETO/Freon 12 environment. No problems are anticipated with these coatings.

6.3 The three RTV compounds, RTV S-5370, RTV 601, and RTV GE 8111, utilized in the TRW Voyager Engine, appear to be compatible with ETO/Freon 12. RTV S-5370 which is utilized as a potting compound in the Shut-Off Valve, though showing increases in weight and dimensional measurements, had increased tensile strength and elongation. RTV 601, which is used as a sealant between the head end assembly and ablative faceplate, and RTV GE 8111, utilized in electrical applications as insulation material, were both compatible with ETO/Freon 12.

Sylgard 182, which is utilized as a filler compound between the combustion chamber case and the ablative material, showed significant change in ETO/Freon 12. However, it is not believed that this would cause a problem as only a small fraction of the material is exposed to the ETO/Freon 12 gas in the engine assembly. It is not felt that the loss of tensile strength and the swelling would create a problem with the material sandwiched between titanium and the phenolic silica laminates.

PR 5-9, a silicone rubber material used for protecting various dissimilar materials from galvanic corrosion, appears to be compatible with ETO/Freon 12 gas.

6.4 The Gimbal Bearing material, a composite of Teflon and glass, is compatible in ETO/Freon 12.

6.5 DuPont Krytox AC Lube which is used in the Shut-Off Valve showed no effects from ETO/Freon 12, and contrary to literature search results, is compatible with ETO/Freon 12.

As expected, Lubco Dry Lube was compatible with ETO/Freon 12.

6.6 The J-Box Butyl Rubber O-Ring retained normal size and appears to be compatible with ETO/Freon 12, although some of the Alkanex type varnish peeled off the connector. This is not expected to be of serious impact, as the seal has not broken between the connector and the insulation.

6.7 MX 2600 Phenolic Silica Laminate, MX SE 57 Rubber Modified Phenolic Silica Laminate, and WB 7208 Insulation Overwrap, the ablative material for the combustion chamber, though showing some possible changes resulting from the ETO/Freon 12, are not expected to be a problem.

6.8 Epon 934 and the adhesive HT 427, which are used throughout the engine as adhesives, were quite compatible with ETO/Freon 12.

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APPENDIX

A. Test Equipment

The compatibility studies were conducted in 2 pressure cooker type sterilizers commercially available in 24 liter capacities. These sterilizers are capable of withstanding at least 100 psi (burst pressure) and are equipped with automatic safety relief valves when pressures greater than 30 psia are experienced.

Calculations based on the ETO/Freon 12 mixture, and the concentration of ETO of 600 mg/liter called out in the specifications, indicated that the test should be conducted at 20 psia ETO/Freon 12 pressure. Other conditions to be met were:

1. 122°F. ± 2°F., Constant Temperature
2. 50% Relative Humidity ± 5%
3. All material external surfaces were exposed to the gas
4. 28 hours of constant exposure

To meet these conditions, the following steps were taken:

1. To meet the temperature requirements, heating tapes were wrapped around both sterilizers.

2. The temperature was monitored in both sterilizers with the use of thermo couples measuring the gaseous temperatures. The thermocouples were wired to a pyrometer.

3. The relative humidity requirement was met by drawing a vacuum of 70 mm Mercury on the test sterilizer and adding 5 mm Mercury water vapor. 5 mm of water vapor brought the relative humidity to about 50%.

4. ETO/Freon 12 was added to the first sterilizer, which was utilized as an expansion chamber. 20 Psia was heated to a temperature of 122°F., then passed into the sample tank. The first sterilizer was maintained at 20 psia by adding ETO/Freon 12 gas to it from time to time.

5. The vent line was connected to 2 water scrubbers. The gas was disposed of by passing the gas slowly through these scrubbers. ETO reacts with water to form ethylene glycol thus removing ETO before the gas is vented to the atmosphere.

6. The concentration of ETO was monitored by evaluating one liter gas samples in a gas bomb. Gas Chromatography and Infra Red Spectrometry methods were used to analyze the gas.

A typical test setup is shown in Figure A-1.

B. Test Procedure

1. Place materials on screens in test sterilizers.

2. Seal both sterilizers.

3. Purge both sterilizers with Argon.

4. Turn on heating tapes on both sterilizers.

5. Turn on vacuum pump to both sterilizers.

6. Pump down both sterilizers to approximately 70 mm of Hg. Turn off valve interconnecting sterilizer #1 and test sterilizer.

7. Let sterilizers stand and check for leaks.

8. Turn on ETO/Freon 12 to sterilizer #1. As soon as pressure of 20 psia is reached, turn off ETO/Freon 12.

9. Add 5 mm of water vapor to test sterilizer, lowering manometer pressure from 70 mm to 65 mm of Mg.

10. As soon as the gas in sterilizer #1 is stabilized at 122°F. ± 2°F., pass gas to test sterilizer. Close valve interconnecting the two sterilizers.

11. Add more ETO/Freon 12 to sterilizer #1 to maintain pressure at 20 psia.

12. Remove gas sample from test sterilizer.

13. Adjust gas pressure to reach concentration of 600 mg/liter of ETO. (Approximately 20 psia)

14. Maintain gas pressure at 20 psia temperature at 122°F. ± 2°F. for 28 hours. (Lack of instrumentation prevented the constant monitoring of relative humidity in the test chamber).

15. After 28 hours, open outlet valve of test sterilizer allowing gas to go through scrubbers very slowly before venting through the hood.

16. After gas is all disposed, purge test sterilizer with Argon.

TABLE 1.

GAS ANALYSIS

Cycle No.	MOLES % ETO	Mg ETO/Liter
1	16.59	355
2.	22.12	473
4.	22.18	475
5.	25.63	549
6.	25.70	551

Gas Analysis for cycles 3 and 7 were inadvertently omitted.

TABLE 2.

O-RINGS

WEIGHT (GRAMS)/DIMENSIONAL MEASUREMENT (INCHES)

Material	Part No.	0 Cycle	1 Cycle	2 Cycles	3 Cycles	4 Cycles	5 Cycles	6 Cycles	7 Cycles	Δ Change
Butyl	SP 7032-037	.639/.068	.659/.068	.661/.068	.673/.070	.674/.070	.682/.070	.675/.070	.680/.069	+6%/+1.5%
	SP 7032-033	.461/.068	.467/.068	.470/.068	.473/.069	.480/.069	.477/.069	.476/.069	.478/.069	+4%/+1.5%
	SP 7032-031	.416/.071	.421/.071	.424/.071	.428/.071	.433/.071	.428/.071	.428/.071	.429/.071	+3%/0%
Nitrile	2-45	1.007/.070	1.051/.070	1.053/.070	1.091/.071	1.121/.071	1.161/.071	1.177/.074	1.209/.073	+16%/+4.3%
	2-142	1.325/.102	1.393/.103	1.435/.105	1.511/.108	1.606/.108	1.734/.108	1.781/.113	1.866/.115	+41%/+12.7%
EPR	No Part No.	.268/.070	.271/.070	.273/.071	.273/.071	.275/.071	.275/.071	.273/.071	.273/.070	+1.9%/0%
	No Part No.	.176/.065	.177/.067	.177/.067	.180/.068	.180/.068	.180/.068	.180/.068	.181/.067	+2.9%/3%
Teflon	SP 7028-230	4.394/	4.399/	4.334/	4.409/	4.414/	4.414/	4.412/	4.414/	+4%/
	SP 7028-230	.114x.138	.115x.139	.116x.140	.116x.139	.116x.139	.116x.139	.116x.139	.116x.139	+1.7%x+0.7%
	SP 7028-238	1.141/	1.142/	1.145/	1.145/	1.148/	1.148/	1.147/	1.147/	+.5%/+1.7% x1.4%
		.060x.070	.060x.071	.061x.072	.061x.072	.061x.072	.061x.072	.061x.071	.061x.071	
Nitroso (No O-Ring)	Button Sample	2.629/ (O.D.xL)	2.951/	3.354/	3.737/	3.953/	4.279/	4.403/	4.640/	+76.5%/ +36.1%+30.0%
		.474x.474	.504x.500	.530x.532	.565x.577	.580x.600	.625x.610	.650x.615	.645x.620	
	Coupon	1.360/	1.914/	2.534/	3.502/	3.958/	4.908/	4.902/	5.043/	+271%+60%x 81.3%x77.5%
		.025x.480x 3.685	-x610x 4.365	-x.610x 4.957	-x.740x 5.630	.044x.752x 5.950	.045x.827 x6.440	.046x.850 x6.50	.040x.870 x6.540	

TABLE 3.

ALUMINIDE COATINGS

Weight (Grams)

Sample	0 Cycle	1 Cycle	2 Cycles	3 Cycles	4 Cycles	5 Cycles	6 Cycles	7 Cycles	Δ Cycles
1	6.015	6.015	6.035	6.022	6.019	6.018	6.027	6.025	0.1%
2	2.322	2.322	2.335	2.325	2.324	2.324	2.332	2.326	<0.1%
3	4.308	4.320	4.335	4.310	4.310	4.312	4.326	4.312	<0.1%
4	4.379		4.378	4.379	4.379	4.380	4.383	4.388	<0.1%
5	6.023	6.030	6.037	6.023	6.024	6.024	6.025	6.045	<0.1%
6	2.309	2.309	2.395	2.310	2.310	2.310	2.310	2.313	<0.1%

TABLE 4.

WEIGHT (GRAMS)/DIMENSIONAL MEASUREMENT - THICKNESS (INCHES)

Material	0 Cycle	1 Cycle	2 Cycles	3 Cycles	4 Cycles	5 Cycles	6 Cycles	7 Cycles	Change
RTV S-5370 #1	.231/.075	.226/-	.227/.072	.241/.077	.238/.077	.263/.077	.262/.075	.276/.075	+19.5%/0%
#2	.221/.075	.217/-	.217/.076	.231/.076	.226/.076	.247/.076	.251/.075	.264/.075	+19.5%/0%
RTV 601 #1	.666/.075	.665/-	.665/.073	.666/.075	.666/.075	.667/.075	.667/.075	.667/.076	.1%/1.3%
#2	.614/.075	.614/-	.614/.073	.615/.077	.615/.077	.616/.077	.617/.076	.616/.076	.3%/1.3%
RTV GE 8111 #1	.526/.075	.526/-	.527/.073	.528/.075	.528/.075	.528/.075	.528/.077	.527/.077	.2%/2.7%
	.562/.075	.562/-	.562/.075	.565/.077	.563/.077	.564/.077	-/.076	.563/.076	.2%/1.3%

TABLE 5.

PHENOLIC SILICA LAMINATES

Weight (Grams)

Material	0 Cycle	1 Cycle	2 Cycles	3 Cycles	4 Cycles	5 Cycles	6 Cycles	7 Cycles	Δ Change
MX 2600	58.778	59.043	59.080	59.240	59.267	59.381	59.656	60.806	+3.4%
WB 7208	43.976	44.458	44.566	44.803	44.809	44.941	45.053	47.308	+7.6%

TABLE 6.

HARDNESS - BARCOL ON TENSILE SPECIMEN #12

	0 Cycle	1 Cycle	2 Cycles	3 Cycles	4 Cycles	5 Cycles	6 Cycles	7 Cycles
MXSE 57	70, 70	70, 70	70, 70	70, 70	70, 70	70, 70	69, 70	68, 68
MX 2600	73, 73	73, 73	73, 73	72, 72	72, 72	72, 72	71, 72	70, 71

TABLE 7.

TEST METHOD ASTM D638

Room Temperature Tensile Strength and Modulus - Laminate Phenolic Silica MX 2600

I.D. NUMBER	STRESSED DIMENSION	STRESSED AREA	ACTUAL LOAD LBS.	TENSILE STRENGTH POUNDS PER SQ. IN.	MODULUS PSI x 10^6
1 Control	.498/.120	.05976	460	7700	1.44
2 Control	.499/.120	.05988	540	9020	1.90
3 Control	.501/.122	.06112	616	10100	2.01
4 Control	.501/.122	.06112	690	11300	2.01
5 Control	.501/.120	.06012	444	7390	1.51 *
6 Control	.500/.121	.06050	652	10800	1.97
			AVERAGE =	9390	1.80
7 ETO/F12	.510/.131	.06681	570	8530	1.39
8 ETO/F12	.505/.127	.06414	464	7230	1.20
9 ETO/F12	.505/.126	.06363	530	8330	1.19
10 ETO/F12	.503/.128	.06438	484	7520	1.18
11 ETO/F12	.503/.129	.06489	474	7300	1.13
12 ETO/F12	.503/.132	.06640	488	7350	1.18
			Δ CHANGE =	-17.8%	-32.8%

SPEED OF TESTING: Crosshead Speed .05 in/min.

* Extensometer Malfunction

TABLE 8.

TEST METHOD ASTM D638

Room Temperature Tensile Strength and Modulus - Laminated Phenolic Silica MX SE 57

I.D. Number	STRESSED DIMENSION	STRESSED AREA	TENSILE STRENGTH ACTUAL LOAD LBS.	TENSILE STRENGTH POUNDS PER SQ. IN.	MODULUS PSI x 10^6
1 Control	.497/.111	.05517	298	5400	1.21
2 Control	.498/.113	.05627	306	5440	1.18
3 Control	.499/.112	.05589	290	5190	1.18
4 Control	.498/.113	.05627	294	5220	1.21
5 Control	.500/.113	.05650	300	5310	1.20
6 Control	.497/.112	.05566	302	5430	1.22
			AVERAGE =	5330	1.20
7 ETO/F12	.501/.116	.05812	290	4990	1.11
8 ETO/F12	.501/.116	.05812	290	4990	1.13
9 ETO/F12	.503/.115	.05785	296	5120	1.19
10 ETO/F12	.502/.116	.05823	290	4980	1.11
11 ETO/F12	.500/.118	.05900	284	4810	0.98
12 ETO/F12	.502/.118	.05924	284	4790	1.12
			AVERAGE	4950	1.11
			Δ CHANGE	-7.1%	-7.5%

SPEED OF TESTING: Crosshead Speed .05 in/min.

TABLE 9.

TEST METHOD ASTM D638

Room Temperature Tensile Strength and Modulus - Laminated Phenolic Silica WB 7208

I.D. NUMBER	STRESSED DIMENSION	STRESSED AREA	TENSILE STRENGTH ACTUAL LOAD LBS.	TENSILE STRENGTH POUNDS PER SQ. IN.	MODULUS PSI x 10^6
1 Control	.496/.197	.09771	484	4950	1.28
2 Control	.495/.197	.09752	390	4000	1.22
3 Control	.498/.201	.1001	474	4740	1.36
4 Control	.498/.199	.09910	468	4722	1.24
5 Control	.499/.202	.1008	390	3870	1.16
			AVERAGE =	4356	1.25
6 ETO/F12	.503/.202	.1016	474	4670	1.00
7 ETO/F12	.503/.201	.1011	496	4910	1.08
8 ETO/F12	.503/.198	.09959	438	4400	1.07
9 ETO/F12	.505/.201	.1015	446	4390	1.07
10 ETO/F12	.504/.200	.1008	496	4920	1.06
			AVERAGE =	4658	1.05
			Δ CHANGE	+6.9%	16.0%

SPEED OF TESTING: Crosshead Speed .05 in/min.

TABLE 10.

METHOD - Federal Test Method Standard 175 - Method 1033.1T

Room Temperature Lap Shear Strength - EPON 934

I.D. NUMBER	STRESSED DIMENSION	STRESSED AREA		SHEAR STRENGTH ACTUAL LOAD LBS.	SHEAR STRENGTH POUNDS PER SQ. IN.
1 Control	.96/.51	.49		1350	2750
2 Control	.95/.50	.48		1330	2770
3 Control	.93/.51	.47		1305	2780
			AVERAGE	1328	2767
4 ETO/F12	.98/.50	.49		1280	2610
5 ETO/F12	.95/.51	.48		1280	2670
6 ETO/F12	.97/.52	.50		1250	2500
7 ETO/F12	.90/.51	.46		1250	2720
			AVERAGE	1265	2625
			Δ CHANGE	-2.1%	-5.1%

SPEED OF TESTING: Load Paced at 600 to 700 psi/min.

TABLE 11.

METHOD - Federal Test Method Standard 175 - Method 1033.1T

Room Temperature Lap Shear Strength - Adhesive HT 427

I.D. NUMBER	STRESSED DIMENSION	STRESSED AREA		SHEAR STRENGTH ACTUAL LOAD LBS.	SHEAR STRENGTH POUNDS PER SQ. IN.
1 Control	.92/.51	.47		680	1450
2 Control	.99/.51	.50		660	1320
3 Control	.96/.50	.48		700	1460
			AVERAGE=	680	1410
4 ETO/F12	1.04/.50	.52		680	1310
5 ETO/F12	.96/.50	.48		710	1480
6 ETO/F12	.93/.50	.47		640	1360
7 ETO/F12	.97/.51	.49		690	1410
			AVERAGE=	680	1390
			Δ CHANGE	0%	-1.4%

SPEED OF TESTING: Load Paced at 600 to 700 psi/min.

TABLE 12.

METHOD - ASTM D 412

Room Temperature Tensile & Elongation - NT-5 Nitroso Rubber

I.D. NUMBER	STRESSED DIMENSION	STRESSED AREA	YIELD STRENGTH ACTUAL LOAD POUNDS	YIELD STRENGTH POUNDS PER SQ. IN.	TENSILE STRENGTH ACTUAL LOAD POUNDS	TENSILE STRENGTH POUNDS PER SQ. IN.	IN IN / 0.876	PERCENT
NT-5 CONTROL								
1	.187/.021	.003927	---	---	4.9	1250	1.900	217
2	.187/.022	.004114	---	---	6.6	1600	2.735	312
3	.187/.027	.005049	---	---	8.8	1740	3.332	380
4	.187/.027	.004675	---	---	6.8	1450	2.490	284
5	.187/.025	.004675	---	---	7.6	1630	3.035	346
				AVERAGE =		1530		308
NT-5 TEST SPECIMENS								
6	.316/.030	.009480	---	---	3.0	316	* 2.230	149
7	.313/.035	.01096	---	---	3.5	287	2.380	159
8	.312/.025	.007825	---	---	3.1	396	2.125	142
9	.314/.033	.01036	---	---	2.8	270	2.240	149
10	.315/.031	.009765	---	---	2.9	297	2.335	156
				AVERAGE =		313		151
				Δ CHANGE		-80%		-51%

Apparent Average Gage Length - 1.5

SPEED OF TESTING: Crosshead Speed 20 in/min.

TABLE 13.

METHOD - ASTM D 412

ROOM TEMPERATURE TENSILE & ELONGATION - RTV GE 8111

I.D. NUMBER	STRESSED DIMENSION	STRESSED AREA	YIELD STRENGTH ACTUAL LOAD POUNDS	YIELD STRENGTH POUNDS PER SQ. IN.	TENSILE STRENGTH ACTUAL LOAD POUNDS	TENSILE STRENGTH POUNDS PER SQ. IN.	IN--IN 0.876	PERCENT
RTV GE 8111	Silicone Rubber							
1	.187/.070	.01309	---	---	6.50	497	2.182	249
2	.187/.071	.01328	---	---	6.80	512	2.110	241
3	.187/.070	.01309	---	---	7.52	574	2.425	277
4	.187/.065	.01216	---	---	7.20	510	2.110	241
5	.187/.070	.01309	---	---	7.32	559	2.140	244
				AVERAGE =		530		250
RTV GE 8111	Test Specimens							
6	.187/.070	.01309	---	---	6.60	504	2.360	269
7	.187/.071	.01328	---	---	5.26	396	1.825	208
8	.187/.070	.01309	---	---	5.20	397	1.888	216
9	.187/.070	.01309	---	---	5.84	446	2.062	235
10	.187/.072	.01346	---	---	5.96	443	2.150	245
				AVERAGE (of 5)		437		235
				(of 3)				250
				Δ CHANGE		-17.3%		-6%

SPEED OF TESTING: Crosshead Speed 20 in/min.

TABLE 14.

METHOD - ASTM D 412

Room Temperature Tensile and Elongation - RTV 5-5370

I.D. NUMBER	STRESSED DIMENSION	STRESSED AREA	YIELD STRENGTH ACTUAL LOAD POUNDS	YIELD STRENGTH POUNDS PER SQ. IN.	TENSILE STRENGTH ACTUAL LOAD POUNDS	TENSILE STRENGTH POUNDS PER SQ. IN.	IN--IN 0.876	PERCENT
RTV Silicone Foam S-5370								
1	.187/.072	.01346	---	---	0.82	61	.458	52
2.	.187/.067	.01253	---	---	0.78	62	.490	55
3	.187/.063	.01178	---	---	0.72	61	.455	52
4	.187/.065	.01216	---	---	0.70	58	.431	49
5	.187/.065	.01216	---	---	0.84	69	.504	58
				AVERAGE=		62		53
RTV S-5370 Test Specimens								
6	.187/.068	.01272	---	---	0.96	76	.540	62
7	.187/.068	.01272	---	---	0.94	74	.525	60
8	.187/.067	.01253	---	---	0.80	64	.527	60
9	.187/.068	.01272	---	---	1.00	79	.520	59
10	.187/.065	.01216	---	---	0.97	80	.552	63
				AVERAGE		75		61
				Δ CHANGE		+17.3%		+13.1%

SPEED OF TESTING: Crosshead Speed 20 in/min.

TABLE 15.

METHOD - ASTM D 412

Room Temperature Tensile and Elongation - RTV 601

I.D. NUMBER	STRESSED DIMENSION	STRESSED AREA	YIELD STRENGTH ACTUAL LOAD POUNDS	YIELD STRENGTH POUNDS PER SQ. IN.	TENSILE STRENGTH ACTUAL LOAD POUNDS	TENSILE STRENGTH POUNDS PER SQ. IN.	IN--IN 0.876	PERCENT
RTV 601 Silastic Silicone Rubber								
1.	.187/.072	.01346	---	---	6.06	451	1.769	202
2.	.187/.072	.01346	---	---	5.74	426	1.750	200
3.	.187/.071	.01328	---	---	6.16	464	1.925	220
4.	.187/.071	.01328	---	---	6.00	452	1.815	207
5.	.187/.072	.01346	---	---	6.44	478	1.975	225
				AVERAGE =		454		210
RTV 601 Test Specimens								
6.	.187/.072	.01346	---	---	4.96	368	1.644	188
7.	.187/.072	.01346	---	---	5.68	422	2.028	232
8.	.187/.072	.01346	---	---	5.68	422	1.940	221
9.	.187/.071	.01328	---	---	5.50	414	1.940	221
10.	.187/.071	.01328	---	---	5.80	437	2.145	245
				AVERAGE =		413		221
				Δ CHANGE		-9%		+5%

SPEED OF TESTING: Crosshead Speed 20 in/min.

TABLE 16.

METHOD - ASTM D 412

Room Temperature Tensile of Elongation - Sylcard 182

I.D. NUMBER	STRESSED DIMENSION	STRESSED AREA	YIELD STRENGTH ACTUAL LOAD POUNDS	YIELD STRENGTH POUNDS PER SQ. IN.	TENSILE STRENGTH ACTUAL LOAD POUNDS	TENSILE STRENGTH POUNDS PER SQ. IN.	IN--IN 0.876	PERCENT	GAGE LENGTH
Sylgard 182 Microballon Eccosphere									
1	.187/.055	.01029	---	---	3.8	369	1.057	120	
2	.187/.055	.01029	---	---	3.8	369	1.205	138	
3	.187/.053	.009911	---	---	3.7	373	.875	100	
4	.187/.053	.009911	---	---	3.7	373	.904	103	
5	.187/.055	.01029	---	---	3.7	360	.880	100	
				AVERAGE		369		112	
Sylgard 182 Test Specimens									
6	.220/.162	.03564	---	---	1.50	42	1.110	111	1.0
7	.220/.163	.03586	---	---	1.75	49	1.155	116	1.0
8	.205/.157	.03219	---	---	1.80	56	1.087	99	1.1
9	.222/.160	.03552	---	---	1.75	49	1.085	99	1.1
10	.220/.100	.03520	---	---	1.50	43	1.110	111	1.0
				AVERAGE		48		107	
				Δ CHANGE		-87%		-4.4%	

SPEED OF TESTING: Crosshead Speed 20 in/min.

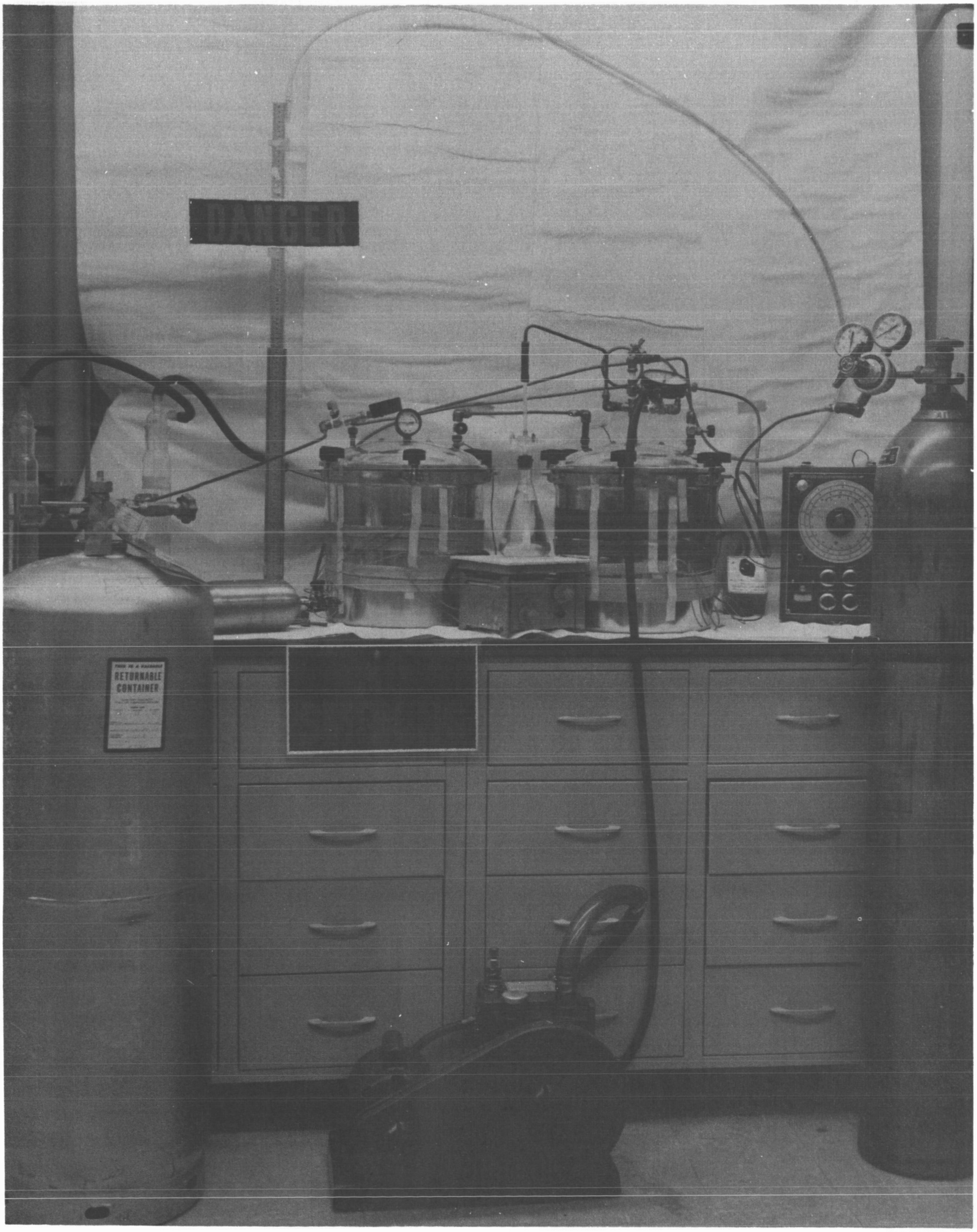

FIGURE 1. Decontamination Set-Up Color Photo.

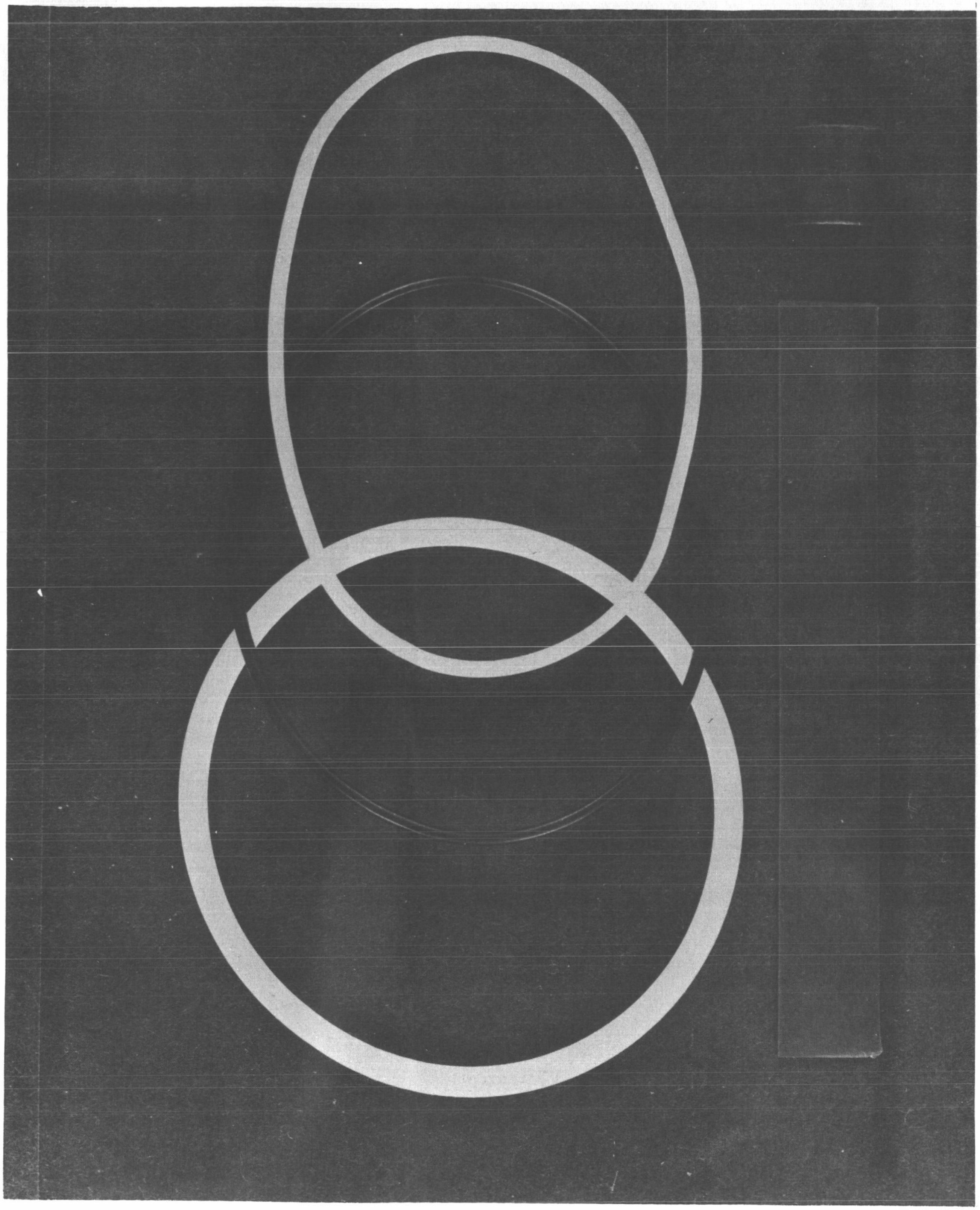

FIGURE 2. O-Rings - Teflon and Butyl - Sheet and Button pieces of Nitroso Rubber, all before ETO/Freon 12. Color Photo (Neg. #32618-67)

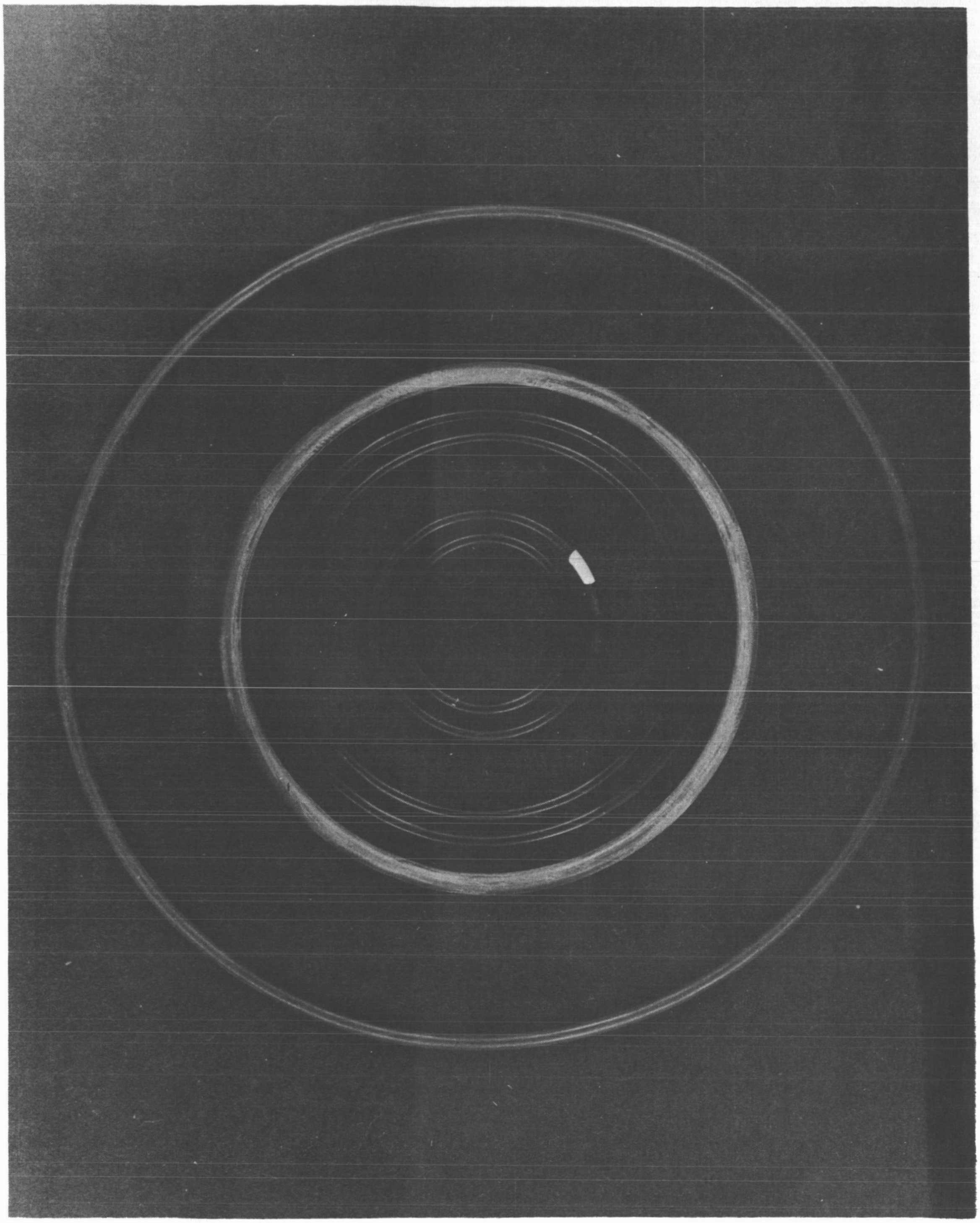

FIGURE 3. O-Rings before ETO/Freon 12. Going from the largest to the smallest - Nitrile 2-45; Nitrile 2-142; Butyl 7032-031; Butyl 7032-037; EPR (No #); EPR (No #). Color Photo (Neg. #32611-67).

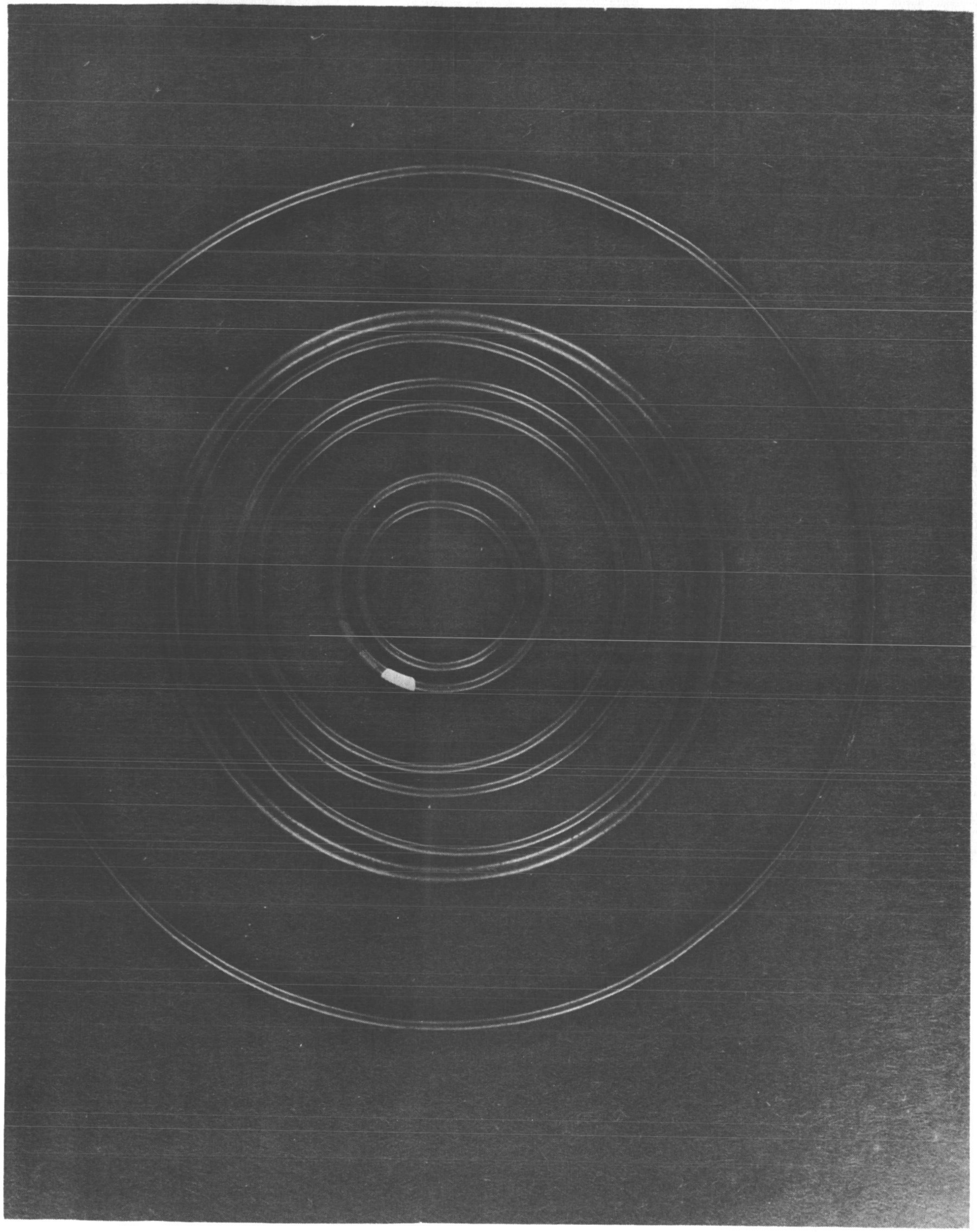

FIGURE 4. O-Rings after 7 cycles ETO/Freon 12. Going from the largest to the smallest - Nitrile 2-45; Nitrile 2-142; Butyl 7032-033; Butyl 7032-031; Butyl 7032-037; EPR (No #); EPR (No #). Color Photo (Neg. #33015-67).

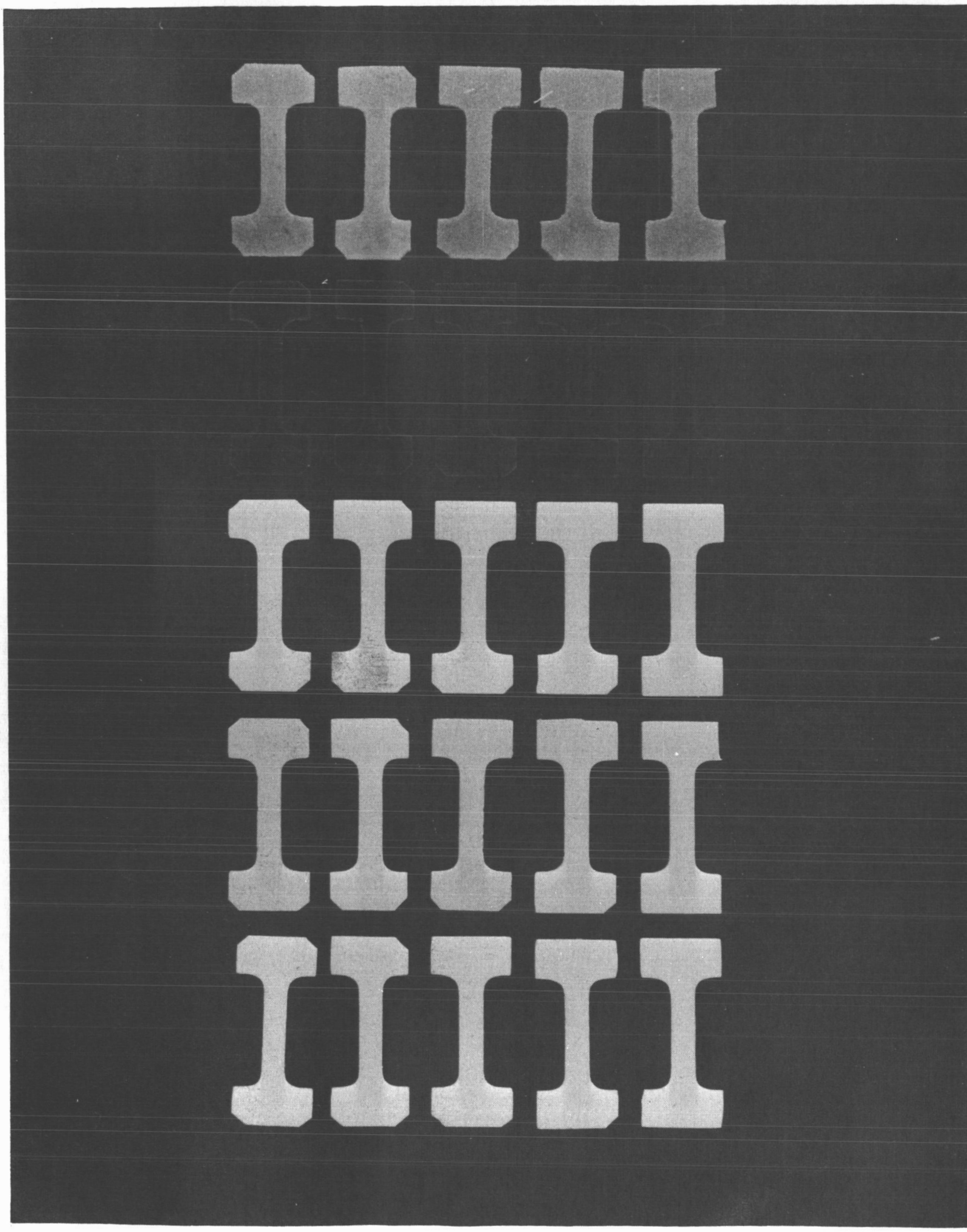

FIGURE 5. Top to Bottom - Sylgard 182 Dumbell Samples; RTV 601 Dumbell Samples; RTV GE 8111 Dumbell Samples; NT-5 Nitroso Rubber Dumbell Samples; RTV S-5370 Dumbell Samples. All before ETO/Freon 12. Color Photo (Neg. #32614-67).

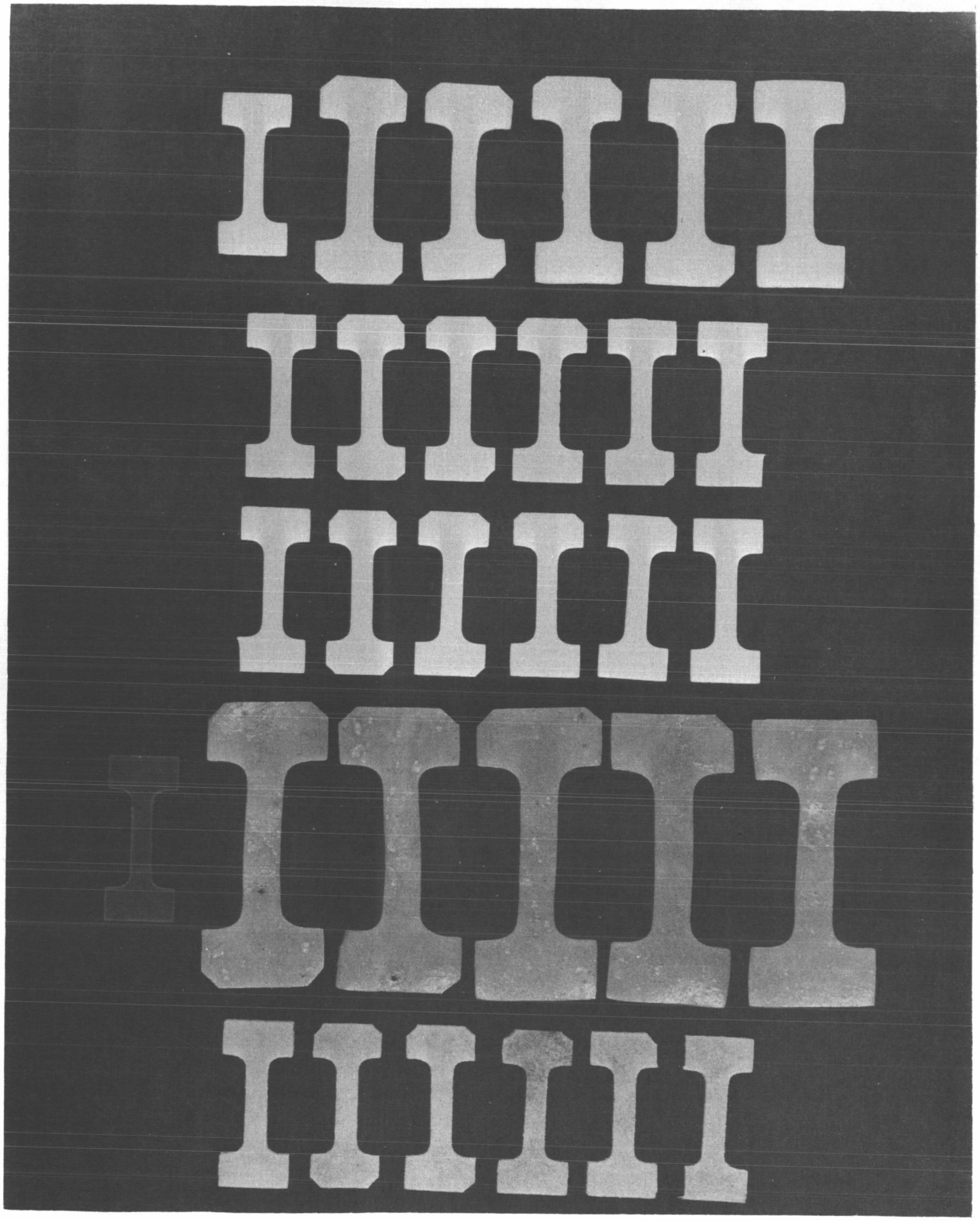

FIGURE 6. From top to bottom - Sylgard 182 Dumbell Samples; RTV 601 Dumbell Samples; RTV GE 8111 Dumbell Samples; NT-5 Nitroso Rubber Dumbell Samples; RTV S-5370 Dumbell Samples. All after 7 cycles ETO/Freon 12. Note increase in size of Sylgard 182 and Nitroso Rubber specimens from the original. Color Photo (Neg. #33012-67).

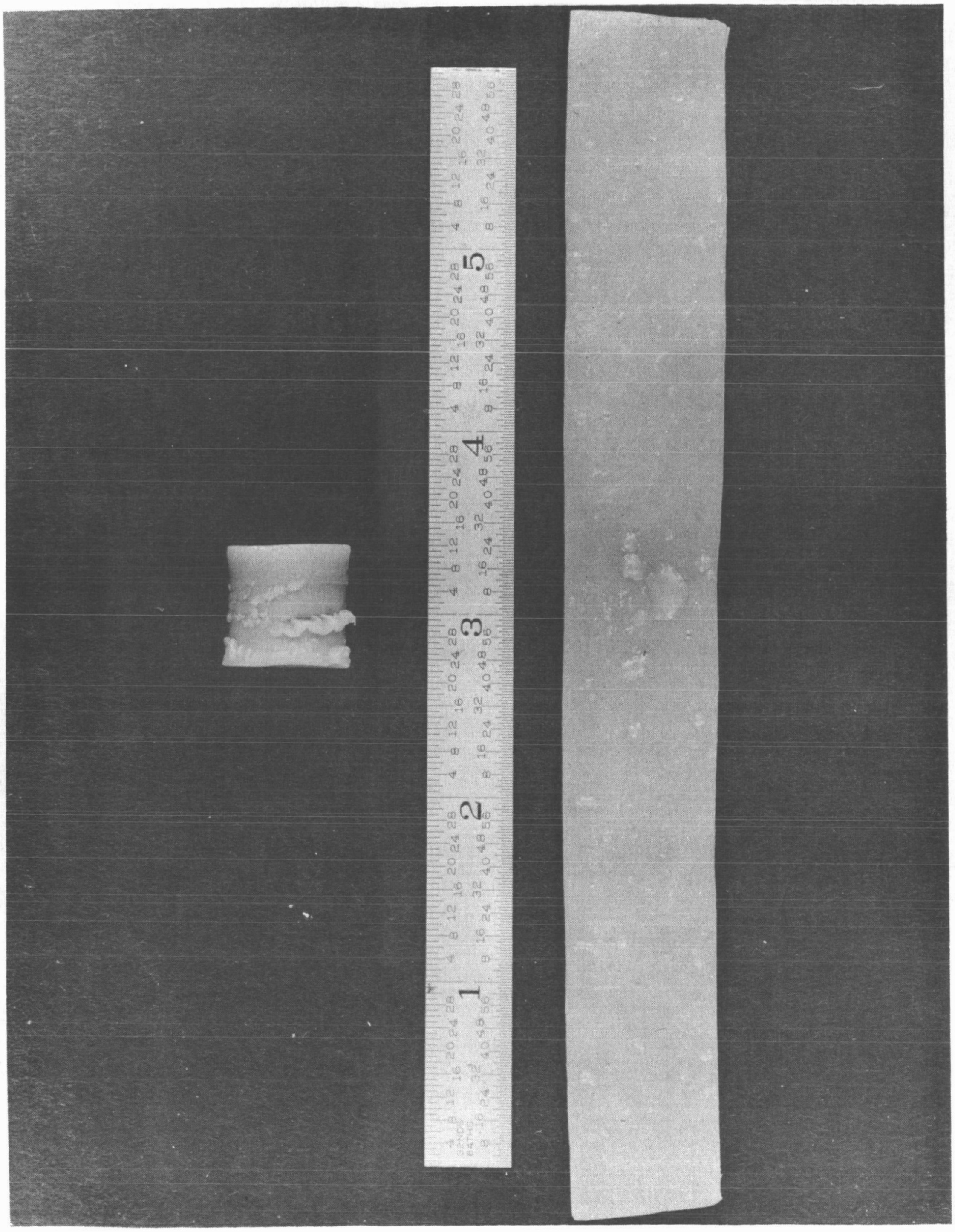

FIGURE 7. Nitroso Rubber after 7 cycles of ETO/Freon 12. The original size of the button was approximately 1/2" diameter X 1/2" Long. The sheet was approximately .025" thick X 1/2" wide X 3 3/4" Long originally. Note color change from dark green to light green. Color Photo (Neg. #33021-67).

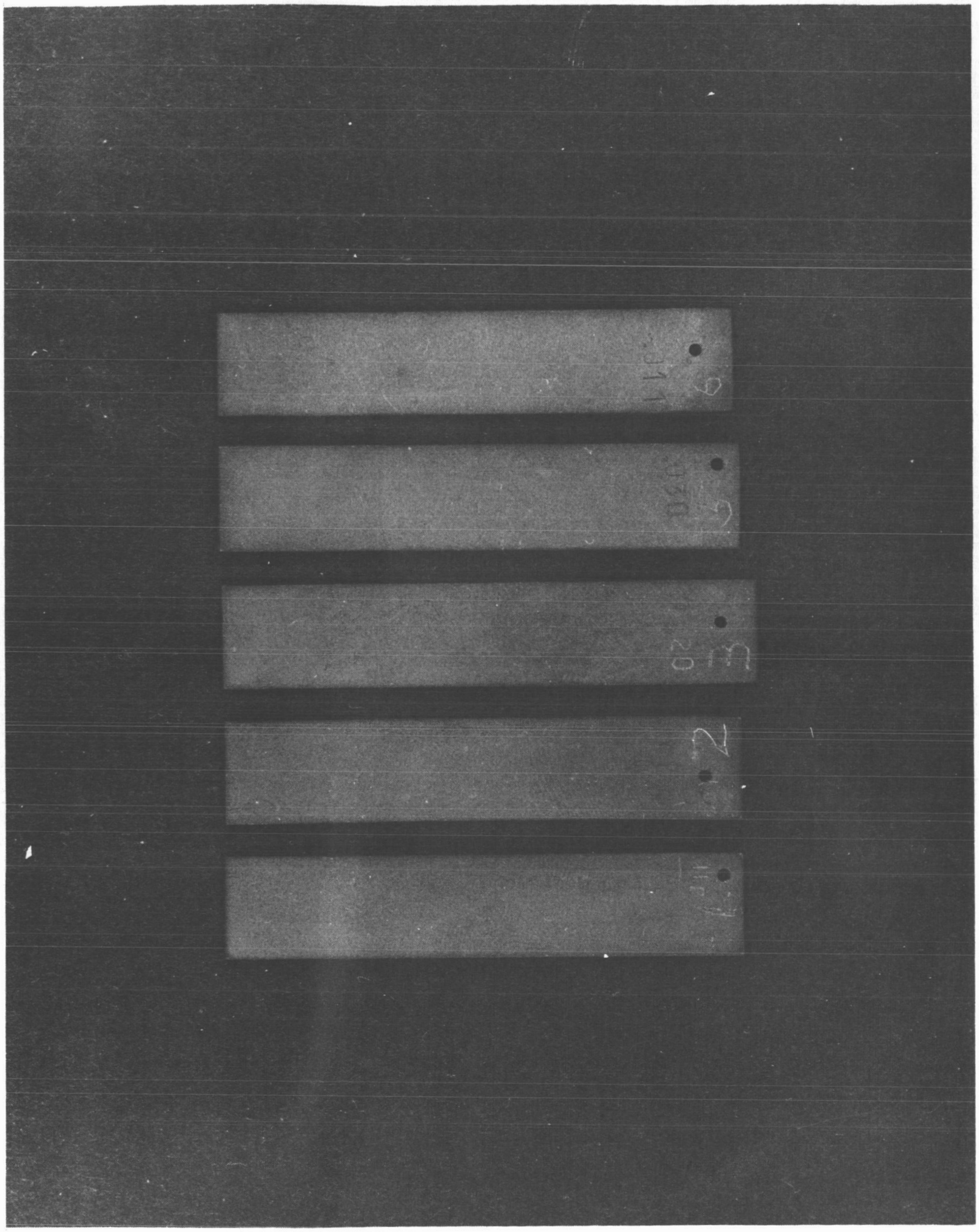

FIGURE 8. Aluminide Coatings before ETO/Freon 12. Color Photo (Neg. #32612-67)

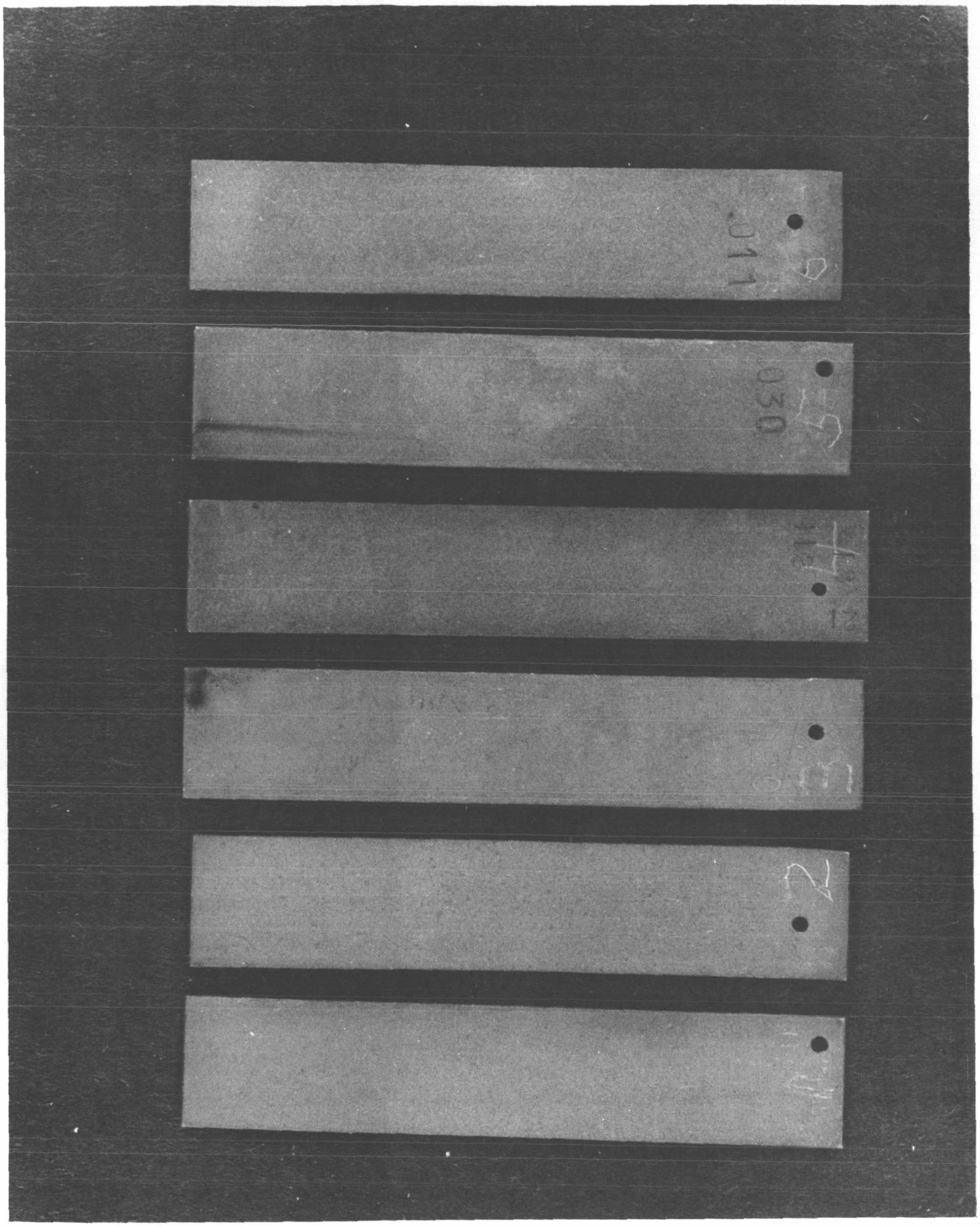

FIGURE 9. Aluminide Coatings after 7 cycles ETO/Freon 12. Note slight color changes from original in Figure 8. Color Photo (Neg. #33025-67).

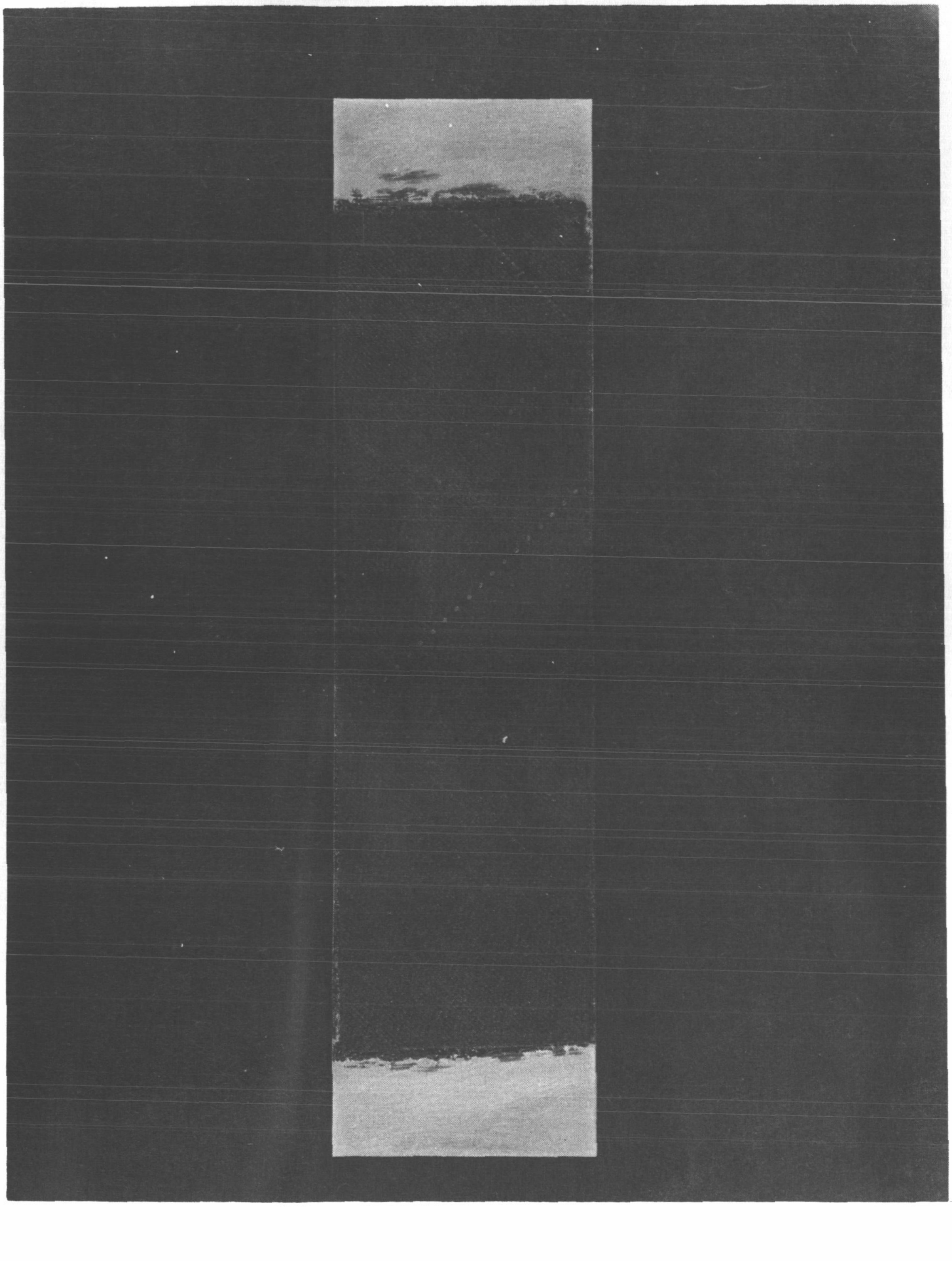

FIGURE 10. Fabroid Gimbal Bearing material before ETO/Freon 12. The material was bonded on to a piece of steel because its physical appearance could not be studied in a Gimbal Bearing. Color Photo (Neg. #33024-67).

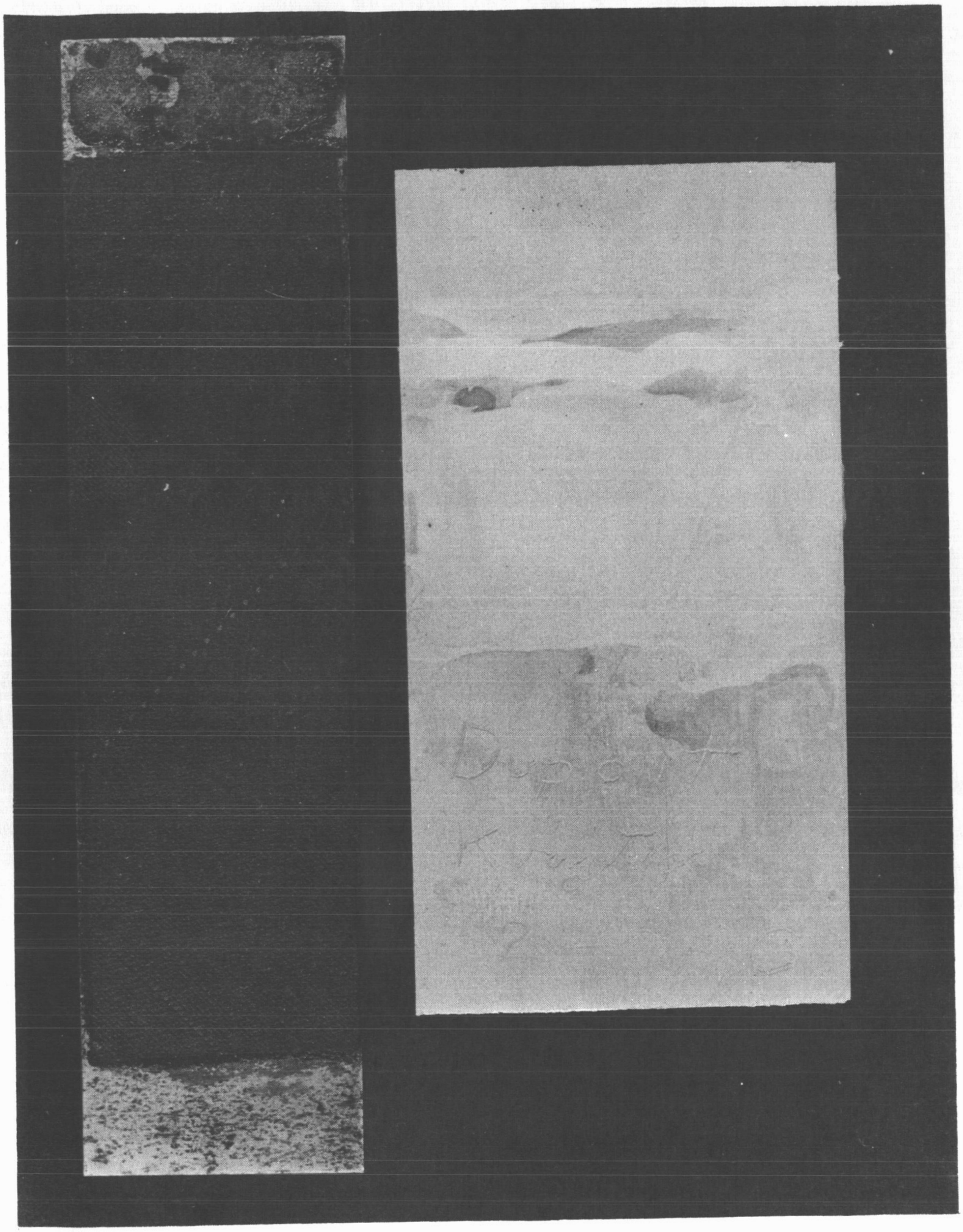

FIGURE 11. On the left, Fabroid Gimbal Bearing material after 7 cycles ETO/Freon 12. No change in the Fabroid material, although steel shows some corrosion. On the Right, DuPont Krytox 240-AC Grease after 7 cycles ETO/Freon 12. Material has become a little viscous but still maintains its lubricating properties. Color Photo (Neg. #33017-67).

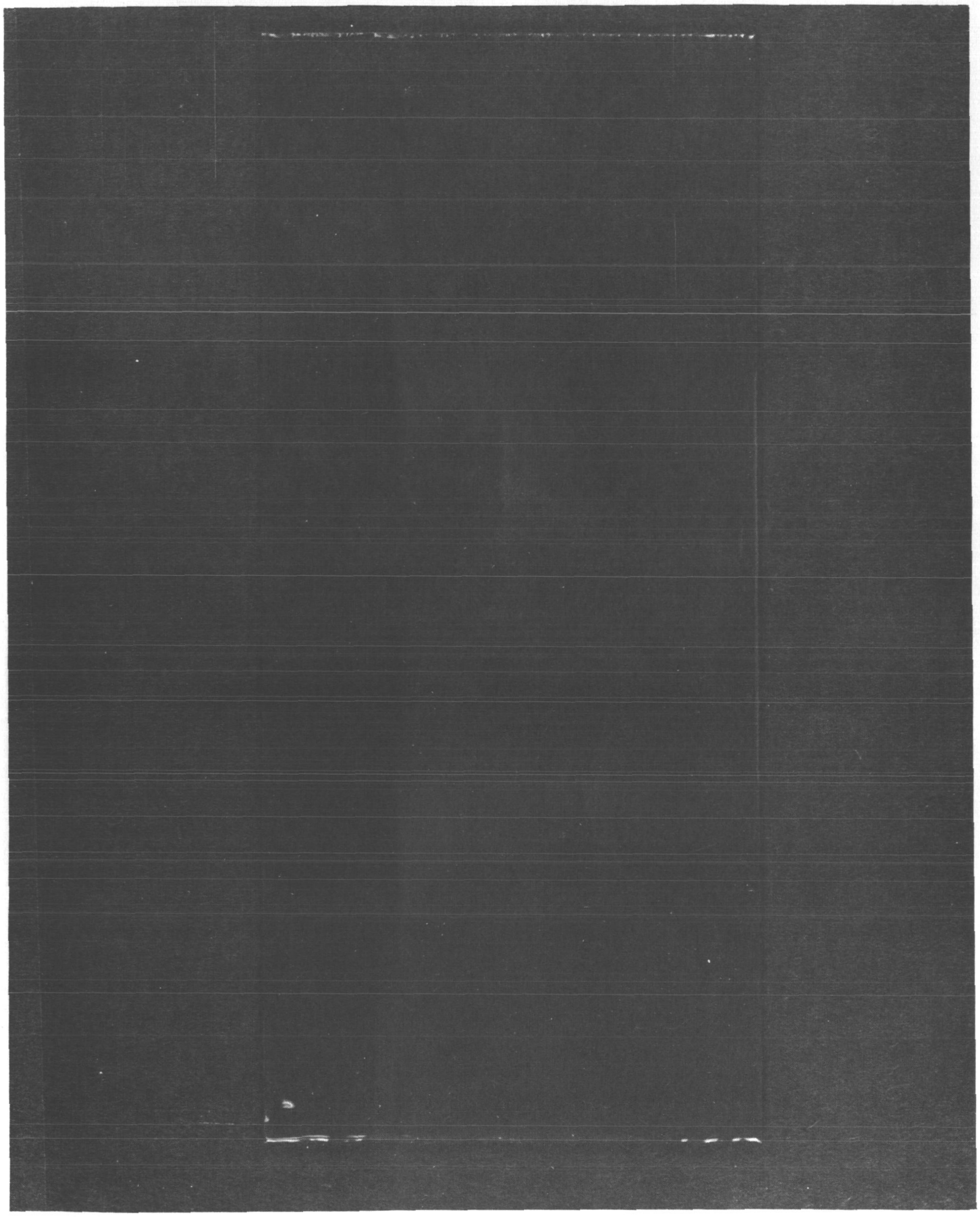

FIGURE 12. PR 5-9 before ETO/F12. A photo showing the material after ETO/F12 was not taken. The material showed no effects and physical changes. Color Photo (Neg. #32616-67).

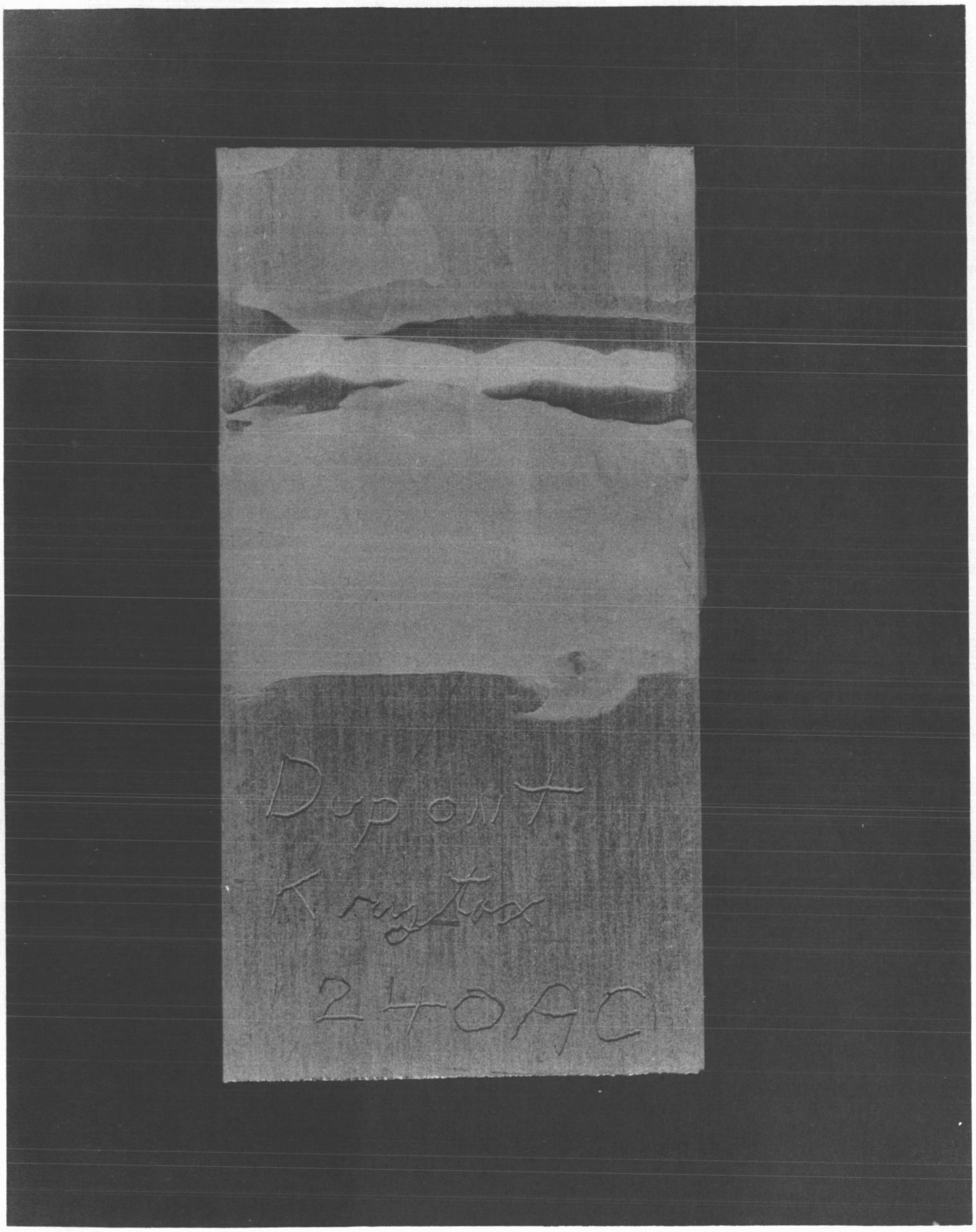

FIGURE 13. DuPont Krytox 240-AC Grease before ETO/Freon 12. Color Photo (Neg. #32890-67).

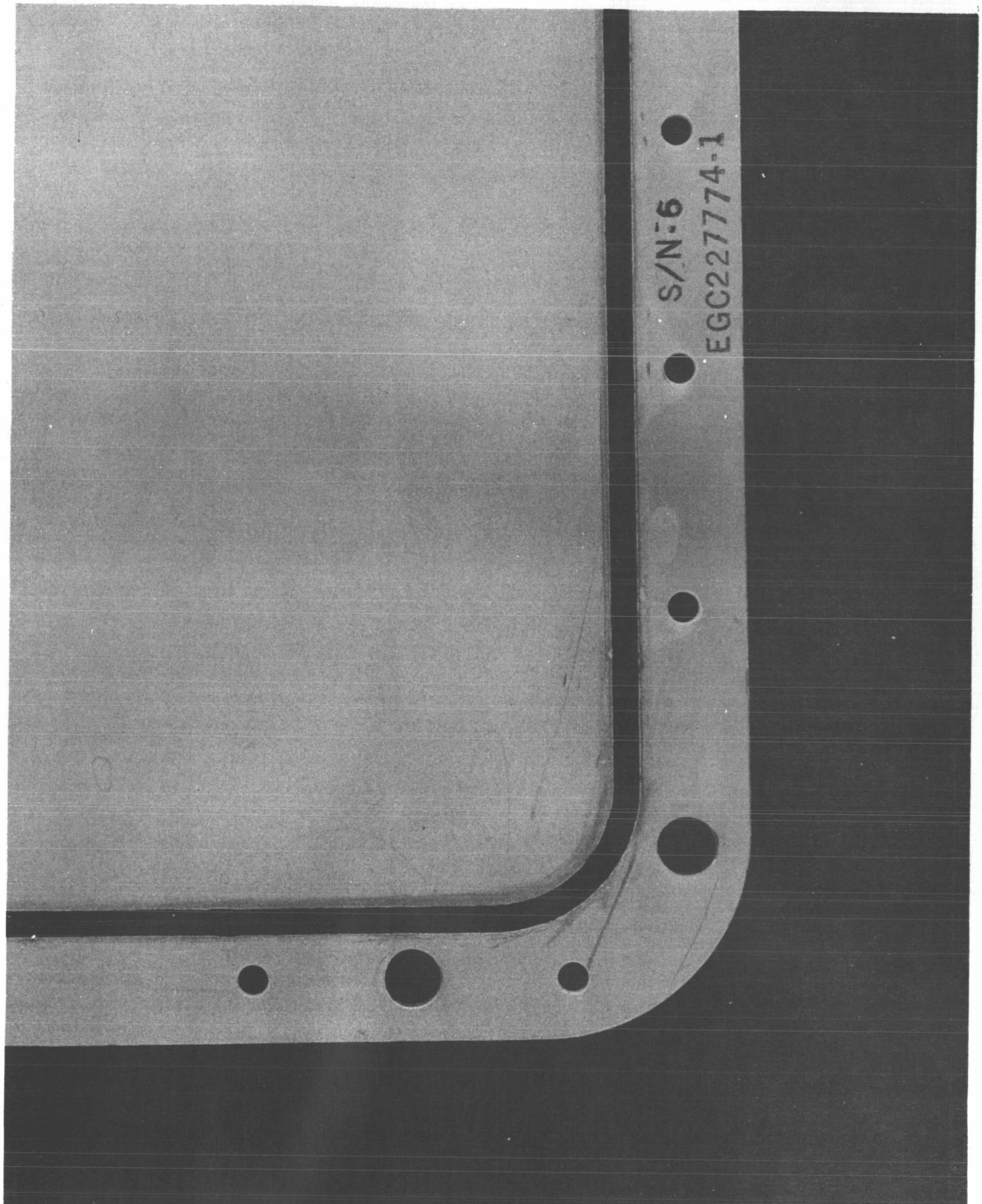

FIGURE 14. Electrical J-Box O-Ring (Butyl) before ETO/Freon 12. Color Photo (Neg. #32621-67)

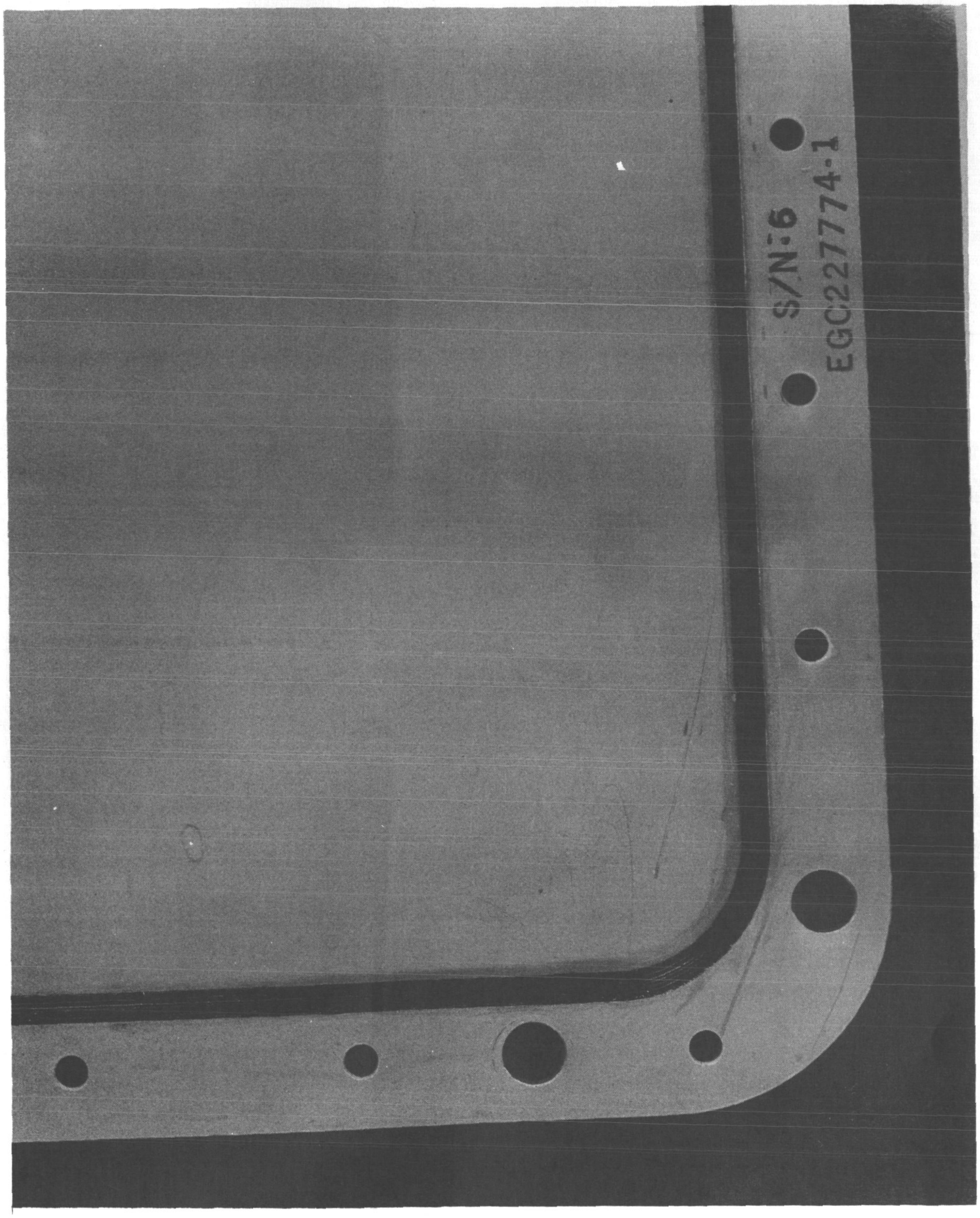

FIGURE 15. Electrical J-Box with Butyl O-Rings after 7 cycles ETO/Freon 12. No apparent visible changes noted. Color Photo (Neg. #33011-67)

FIGURE 16. Electrical Harness Samples (PT2-96-196, Removable Type Contacts) before ETO-Freon 12. Color Photo (Neg. #32615-67)

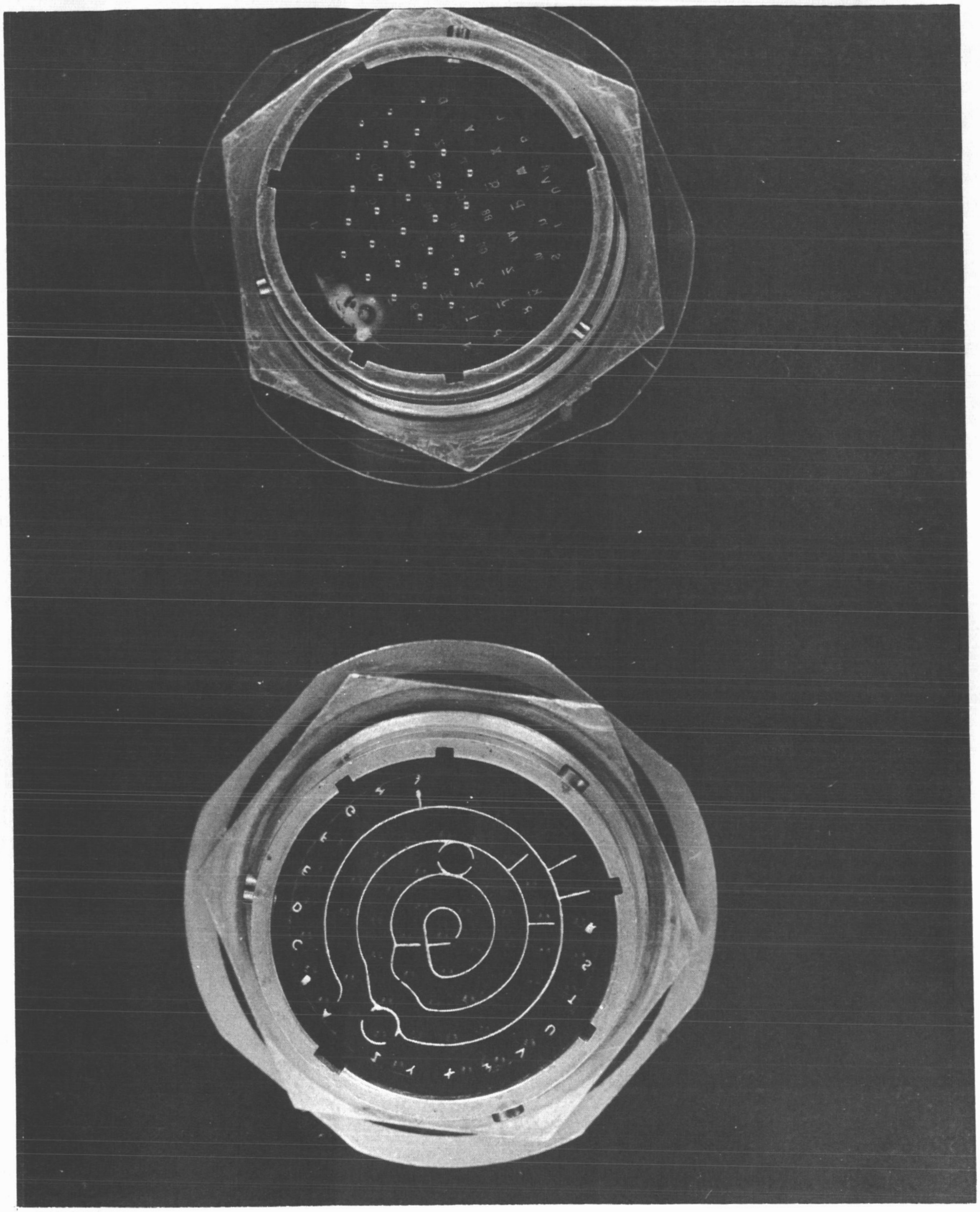

FIGURE 17. Looking into electrical connectors (PR 2-96-196) before ETO/Freon 12. A photo after ETO/Freon 12 was not taken as there were no visible changes. Color Photo (Neg. #32617-67).

FIGURE 18. Electrical Harness material after 7 cycles ETO/Freon 12. Note sealing material peeling off. Color Photo (Neg. #33019-67)

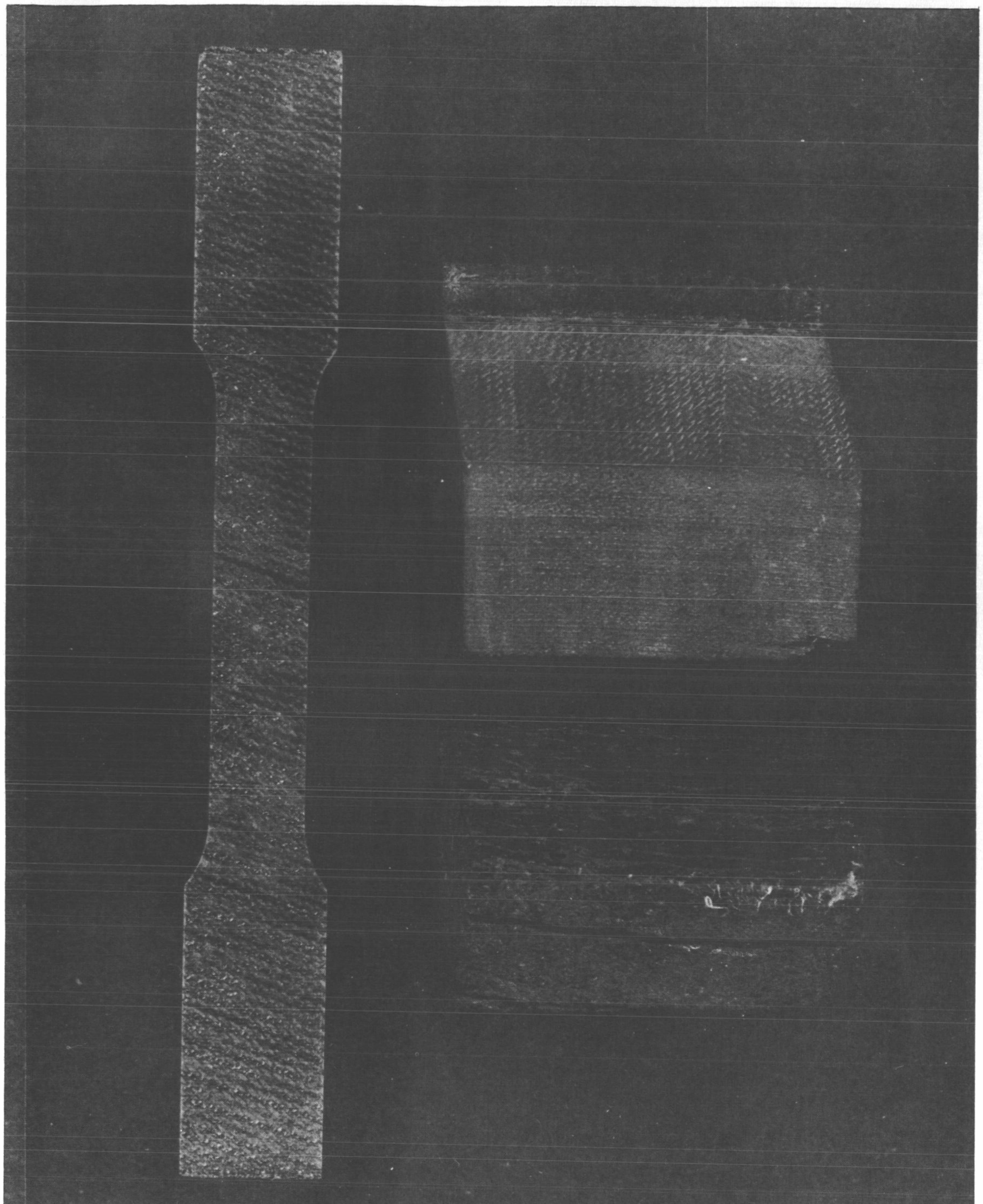

FIGURE 19. Right Top - MX 2600. All before ETO/Freon 12. Color Photo (Neg. #32619-67). Right Bottom - MX 7208 Insulation Overwrap. Left - MX 2600 Tensile Specimen.

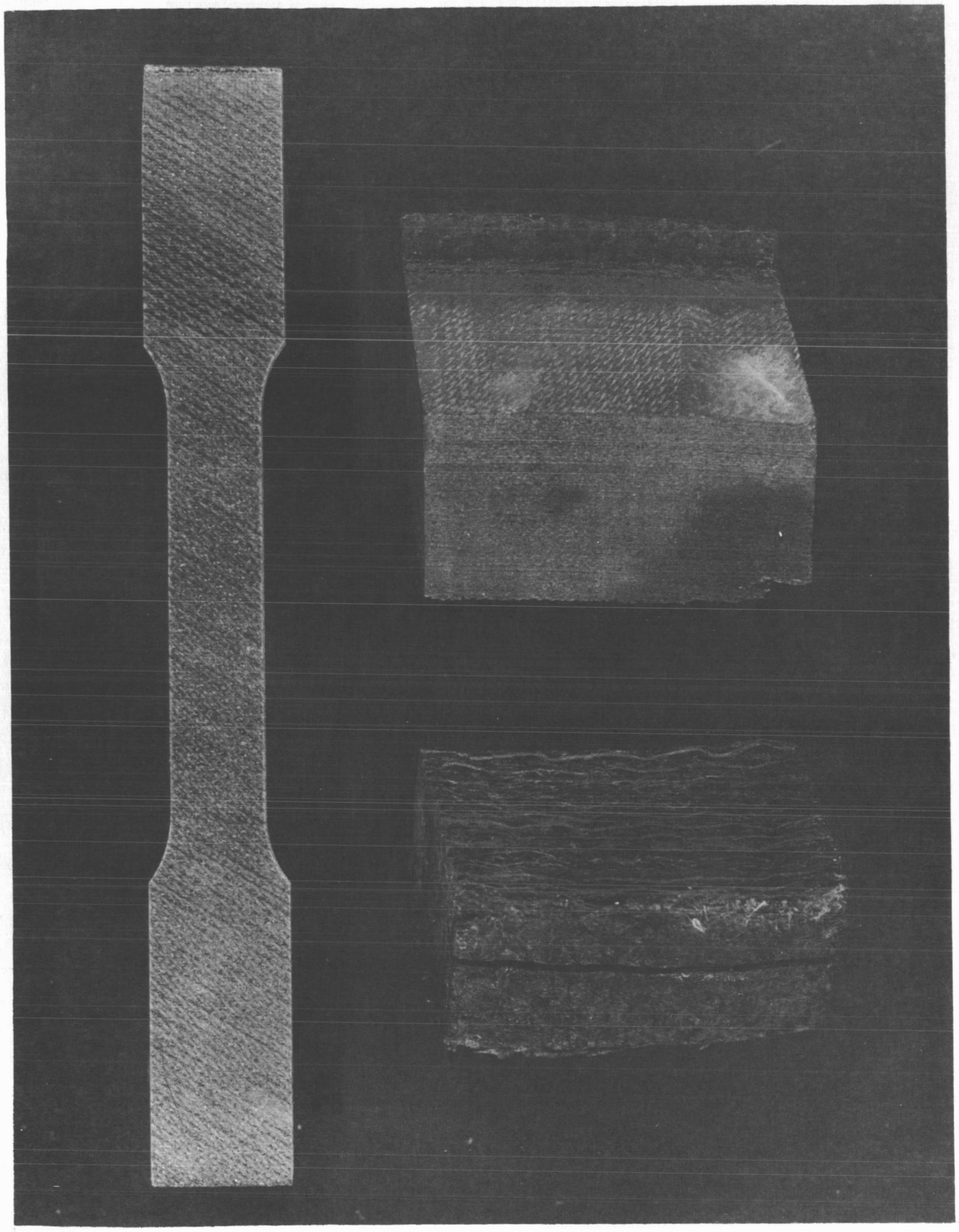

FIGURE 20. Right Top - MX 2600 after 7 cycles of ETO/Freon 12. Note slight bleaching effect on samples. Color Photo (Neg. #33016-67). Right Bottom - Insulation Overwrap. Left - MX 2600 Tensile Specimen.

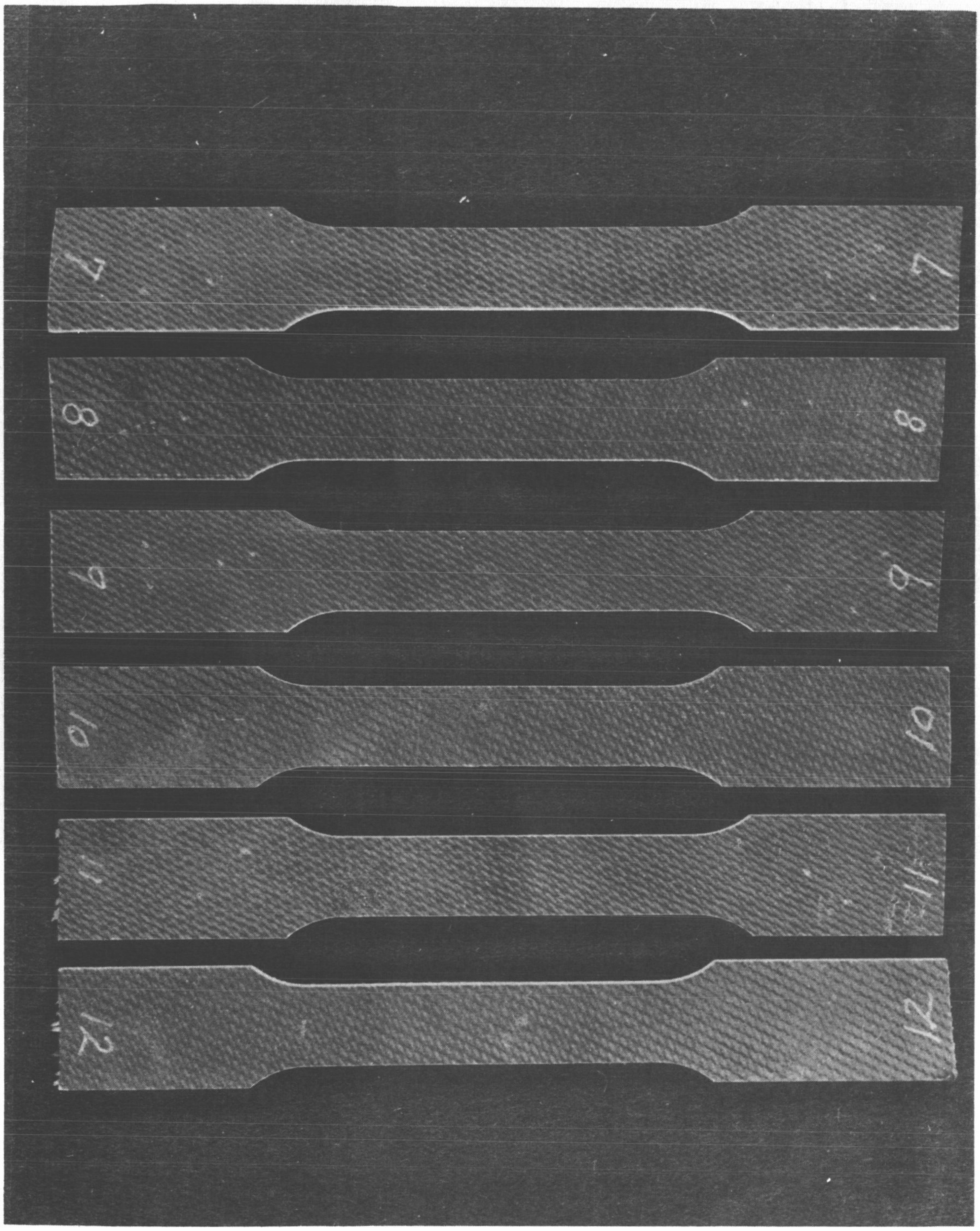

FIGURE 21. MX SE 57 Rubber Modified Phenolic Silica Laminate before ETO/Freon 12. Color Photo (Neg. #32620-67)

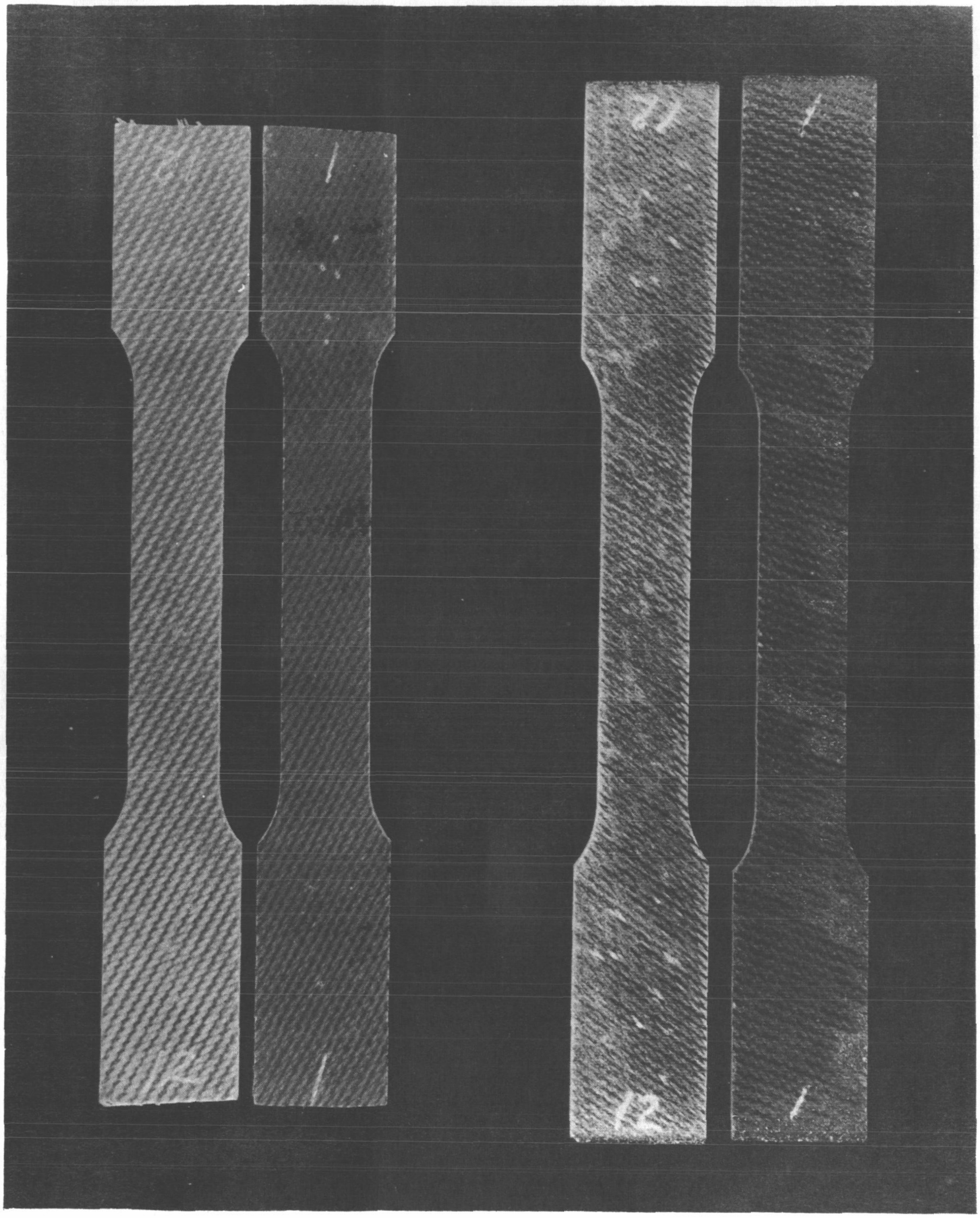

FIGURE 22. Extreme Left - MX SE 57 after ETO/Freon 12. Second from Left - MX SE 57 before ETO/Freon 12. Third from Left - MX 2600 after ETO/Freon 12. Fourth from left - MX 2600 before ETO/Freon 12. Note slight bleaching effects after ETO/Freon 12. Color Photo (Neg. #33023-67)

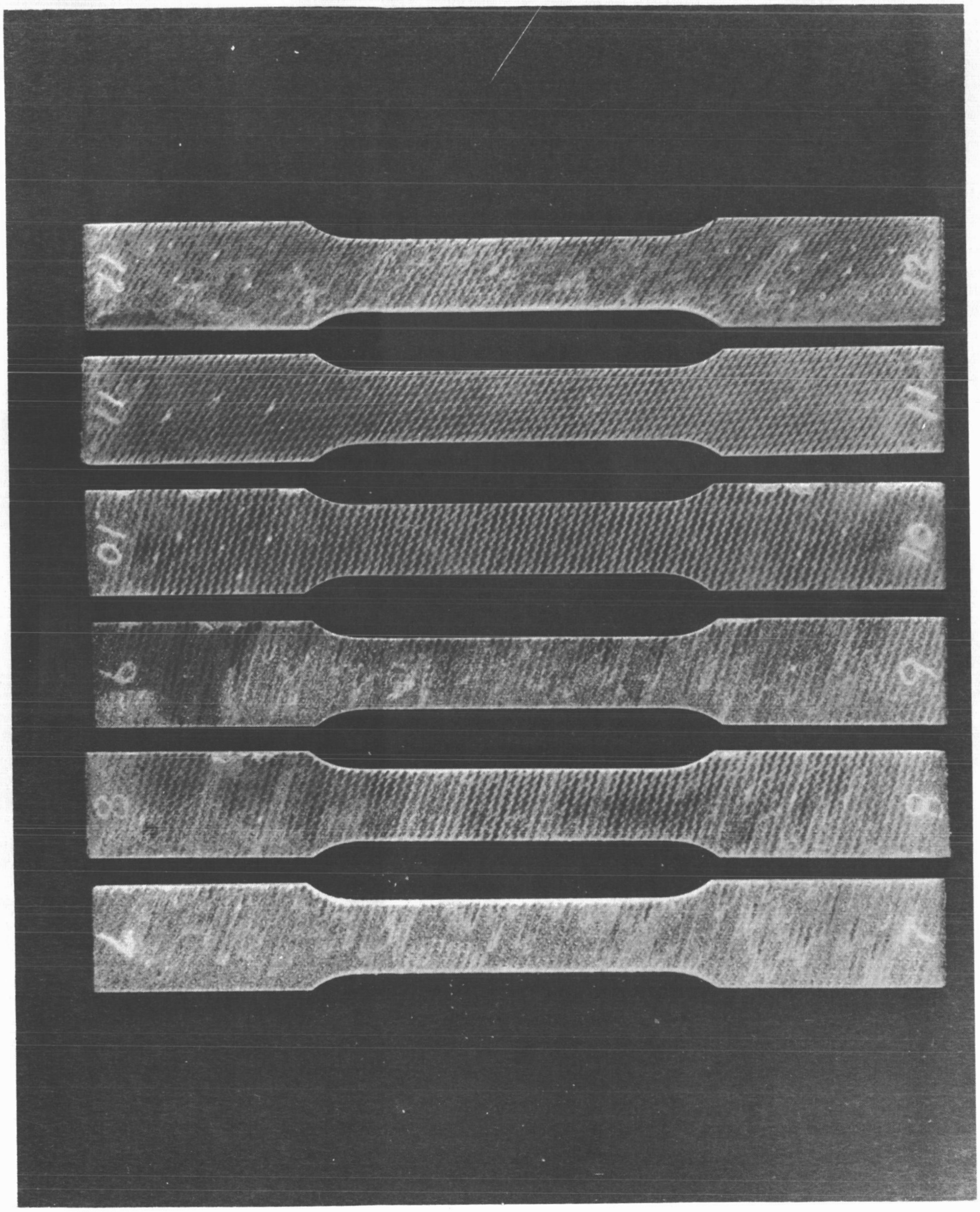

FIGURE 23 - MX 2600 Phenolic Silica Laminate after 7 cycles of ETO/Freon 12. Note bleaching effect of ETO/Freon 12. Color Photo (Neg. #33013-67)

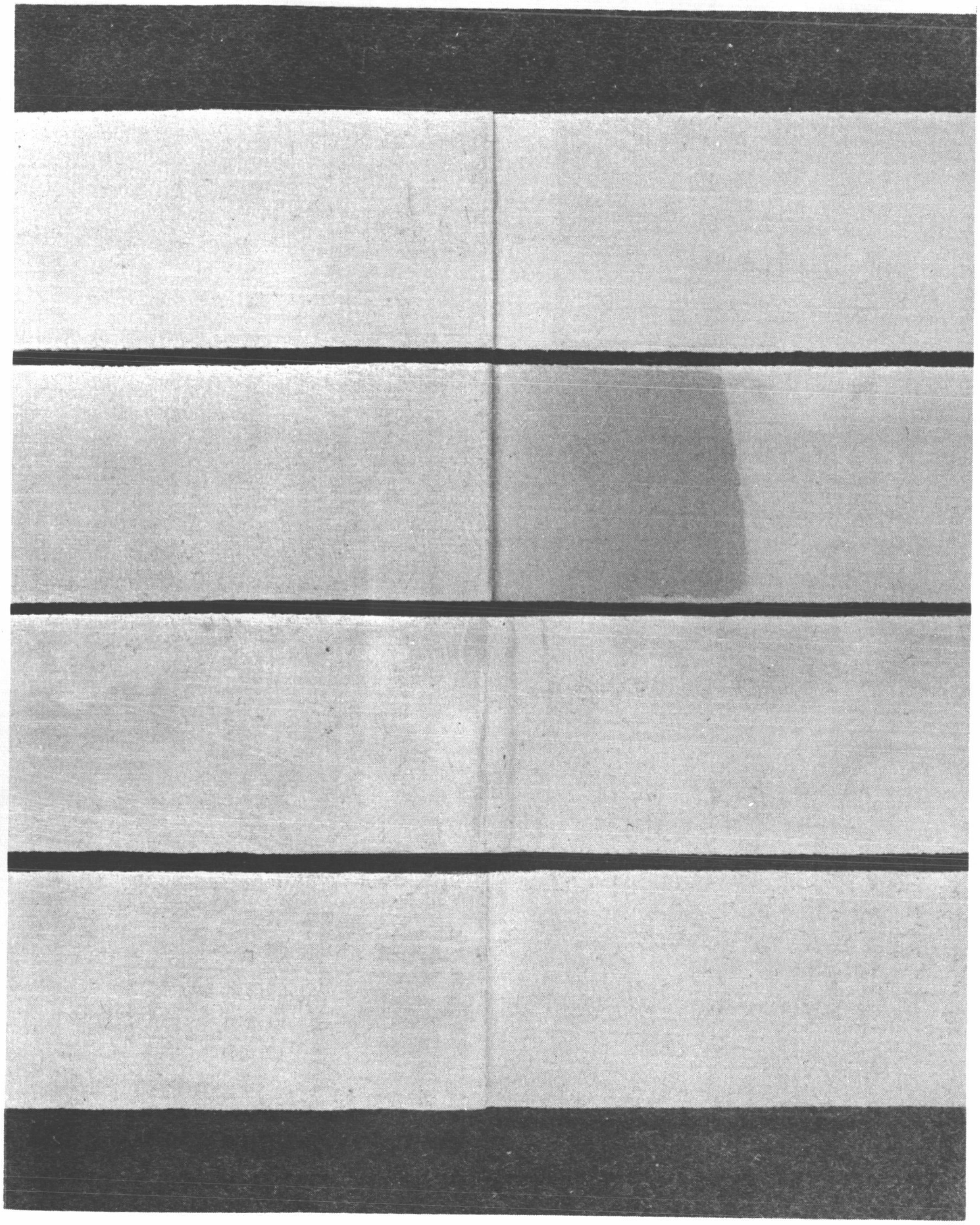

FIGURE 24. Two on Top - Epon 934 Adhesive Lap Shear Specimens. All before ETO/Freon 12. Color Photo (Neg. #32622-67).
Two on Bottom - HT 427 Phenolic Adhesive Lap Shear Specimens.

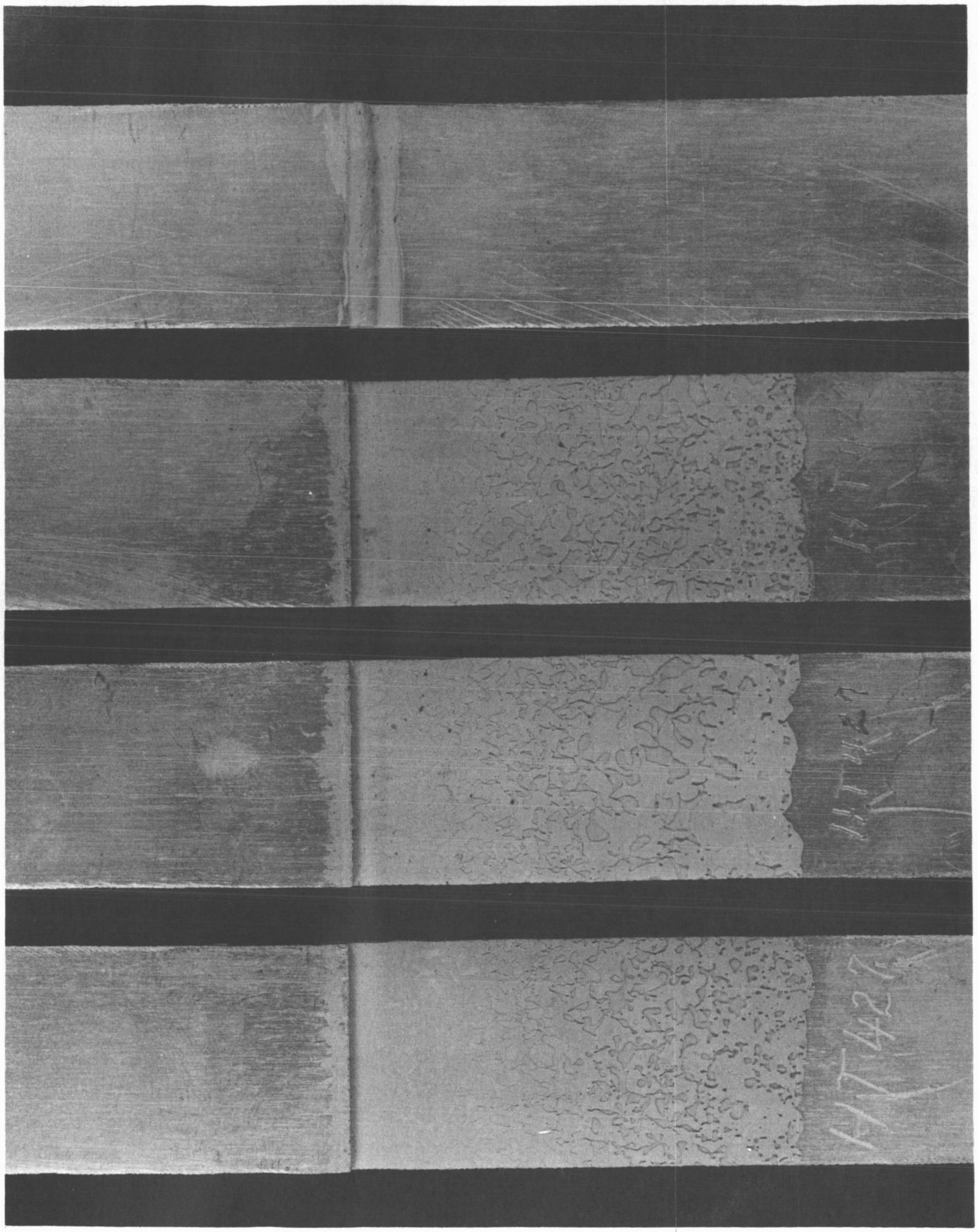

FIGURE 25. HT 427 Phenolic Adhesive Lap Shear Specimens after 7 cycles of ETO/Freon 12. Color Photo (Neg. #33014-67)