# APPENDIX A

## APPENDIX A

Summary of the N17105 Equipment Study

Since the probes and compensators from the mishap were so heavily damaged, MLSA requested examples of these devices from a TWA 747 of about the same age and service history to serve as a baseline. As a result of this request, six fuel probes and five compensators were removed from a TWA 747 (tail number N17105), and delivered for analysis. These probes were apparently working properly when removed from service.

It was determined that each probe and compensator could be uniquely identified by means of the model and serial numbers marked on a metal placard attached to each unit. These numbers were used in this report and associated figures.

Evaluation of fuel probes and compensators from N17105 established a baseline to aid the analysis of the same components from the mishap aircraft. Any evidence of, or conditions that might contribute to, an electrical short or an arc path was noted.

Upon receiving the components, each probe and compensator was inspected and the terminal block and attached wiring were photographed. Only the terminal blocks were photographed in detail, since these areas were of primary interest. The insulation resistance of each sample was measured using a Hewlett Packard HP 4339B high resistance meter. All were found to have a resistance in excess of $1X10^9$ ohms, with most exhibiting values between $1X10^{12}$ and $1X10^{13}$ ohms at 200 volts dc.

In both the mishap aircraft N93119 and N17105, polytetrafluoroethylene (PTFE) insulated wire was used to connect the fuel probes and compensators to the cockpit fuel indicator assemblies. The Low-Z wire was found to be a stranded, 20-gauge wire, while the Hi-Z connection was made by means of 20-gauge stranded wire with a shield. Both inner and outer insulation of the shielded wire were found to be PTFE using FTIR. Pigtail lead wires (20-gauge stranded PTFE insulated wire) were connected to the shielding braid so all shields could be tied together (Figure 31). This connection was made by means of a solder joint, covered with heat shrink tubing sealed at the ends with an elastomer (Figures 3 and 5).

Two types of strain relief clamps were found on terminal blocks of the N17105 probes and compensators. One was stainless steel, in a half clamshell shape. Clamps of this design compress the probe/compensator wiring against a surface composed of sharply pointed conical serrations (Figures 31, 32, and 33). The other type of clamp observed in the study was a nylon "P" clamp. This type wrapped around and compressed the wiring into a tight bundle (Figure 40). Probes and compensators from N17105, with date codes before November of 1969, were found to have the half clamshell steel strain relief clamps with serration on the opposing clamping surface of the terminal block. Units with date codes after this were found to have nylon "P" clamps. These did not have a serrated surface beneath these clamps.

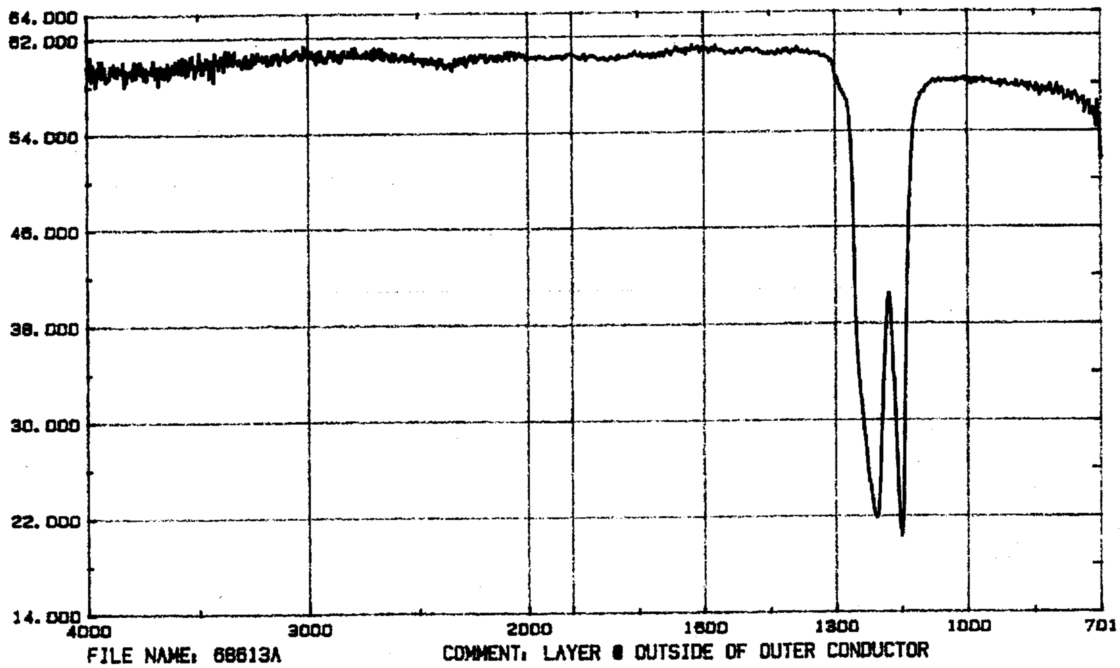
The compression from both types of strain relief clamps was found to cause mechanical degradation to the PTFE insulation. When PTFE is compressed, it can exhibit creep or cold flow. This mechanism causes the insulation material to be displaced and, over time, can result in the conductor being exposed (Figures 33, 34, and 35). Pressure caused by two wires laying in tight contact at points outside the clamp appeared to also cause cold flow (Figures 36 through 43). Insulation damage was found where a wire comes in contact with clamp edges. This edge-induced damage was found in several units on both sides of steel strain relief clamps. Damage was also observed where wires passed over, and were pressed against the ends of the heat shrink used to insulate the shield pigtails solder joints (Figures 48 and 49).

Cross-sectioning and optical microscopic inspection confirmed the presence of cold flow type damage and significant thinning at sites where the conductor was visible near the insulation surface (Figures 39, 43, and 47).

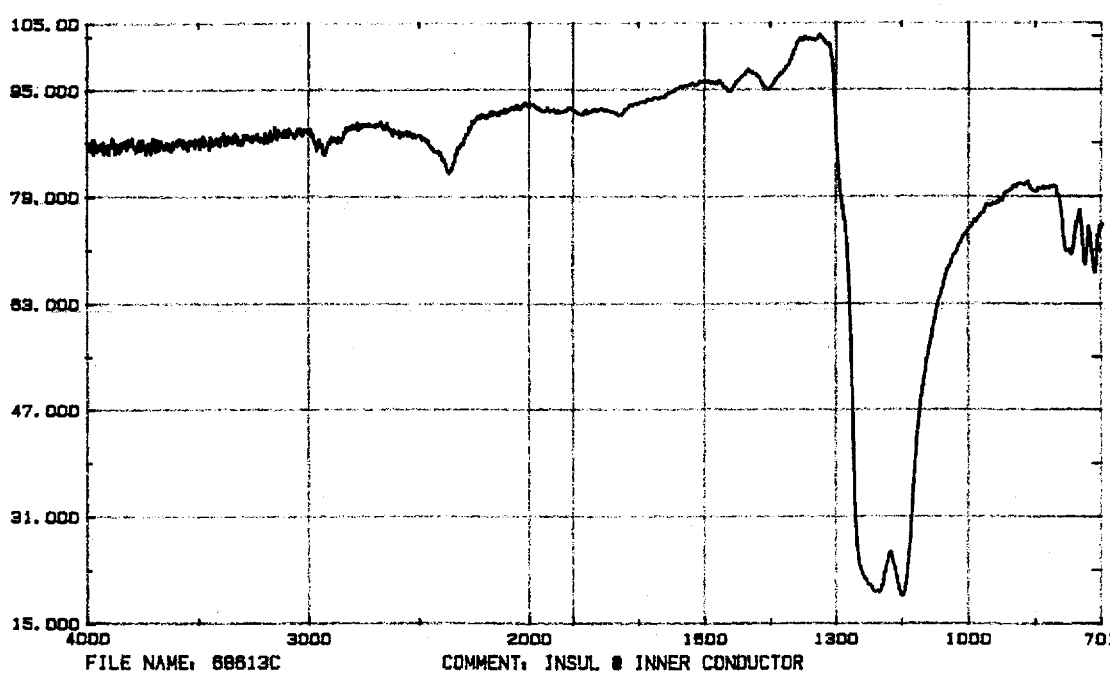
In addition to the mechanical damage seen in the PTFE wire insulation, residues with high concentrations of copper, silver, and sulfur were found on insulation adjacent to exposed conductors (Figures 36, 40, and 41). Apparently, sulfur in the fuel can combine with wire plating and base metals to form these films. According to engineering handbook data, these compounds are not soluble in water. It has been demonstrated that, when these films are continuous, they are semiconductive and support low level current flow. During the study of N17105 material, these deposits were seen on insulation immediately adjacent to breaks in wire insulation or at exposed wire ends at the terminal block (Figures 36, and 38 through 43). There is an apparent time dependency in forming such films.

# APPENDIX B

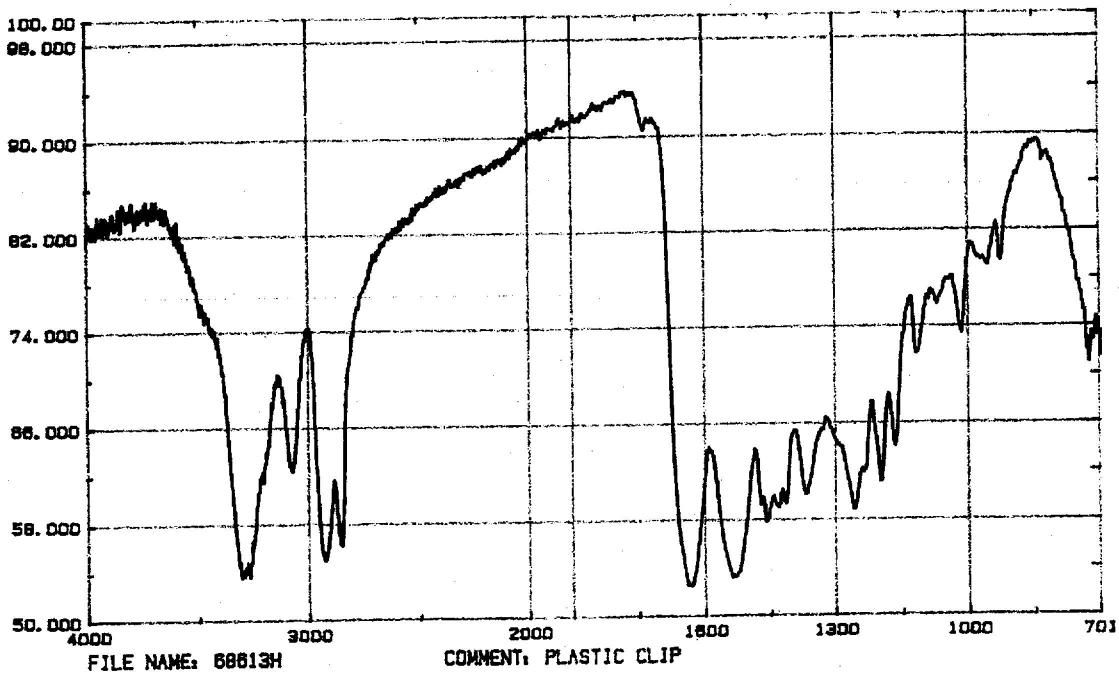
## Report P68613 FTIR Spectra




**Spectrum 1. FTIR spectrum of insulation layer on the outside of the outer conductor in a coaxial wire. The spectrum matches reference spectra for polytetrafluoroethylene (PTFE) material.**

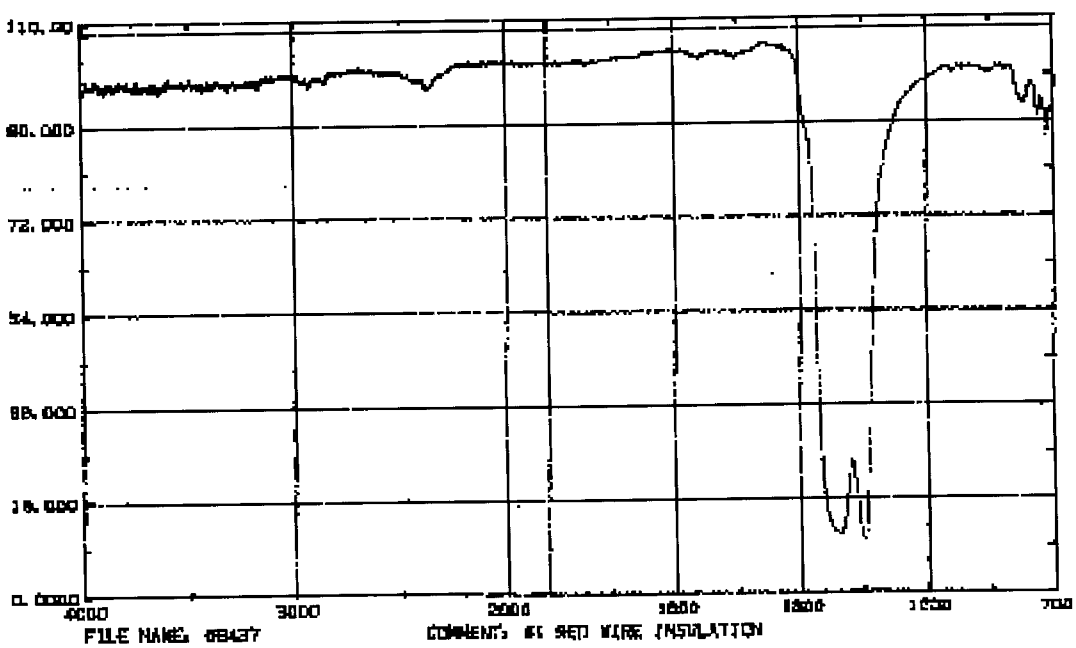



**Spectrum 2. FTIR spectrum of insulation layer surrounding the inner conductor of the coaxial wire. The spectrum matches reference spectra for polytetrafluoroethylene (PTFE) material.**



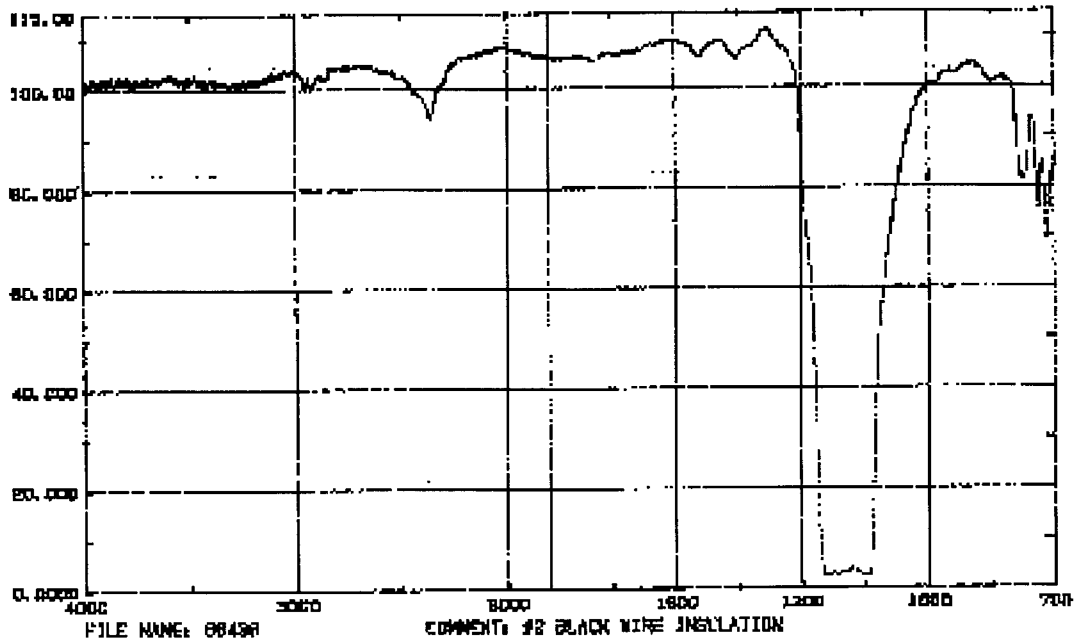

**Spectrum 3.** **FTIR spectum of the plastic tie down. The spectrum matches reference spectra for polyamide materials.**

**Report P68434 FTIR Spectra**

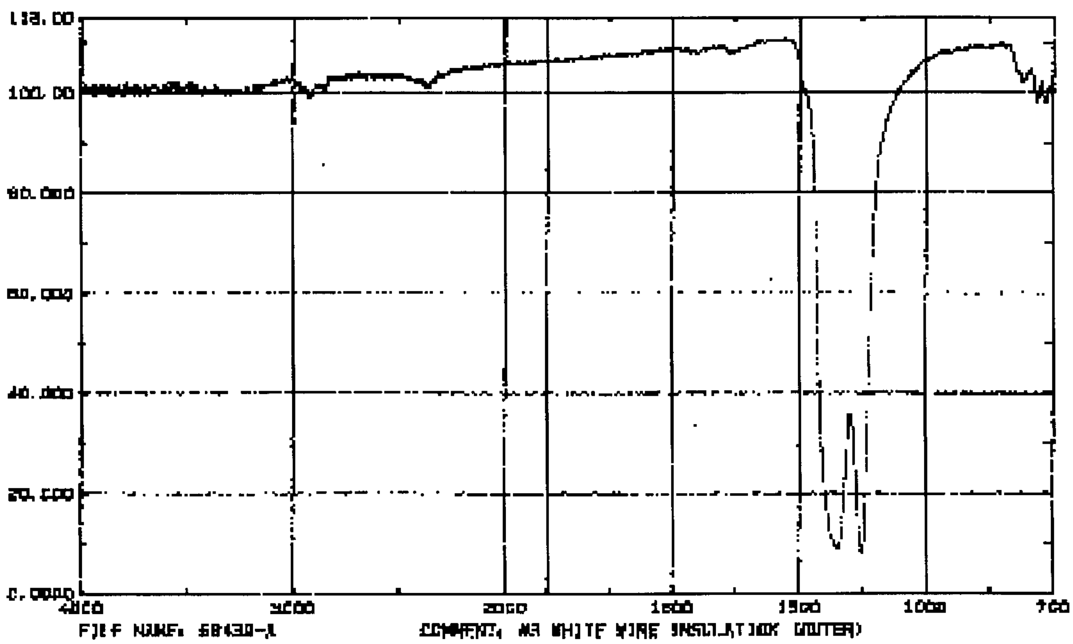



**Spectrum 1.** **FTIR spectrum for the red-colored insulation material. The spectrum matches reference spectra for polytetrafluoroethylene (PTFE) material.**

000233

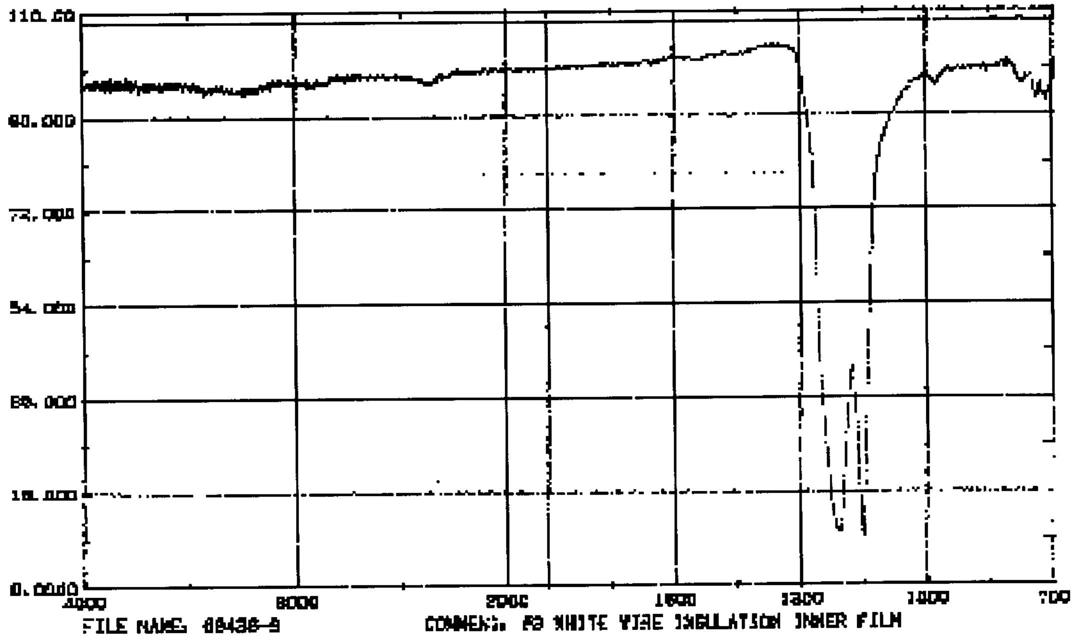



**Spectrum 2. FTIR spectrum for the black-colored insulation material. The spectrum matches reference spectra for polytetrafluoroethylene (PTFE) material.**

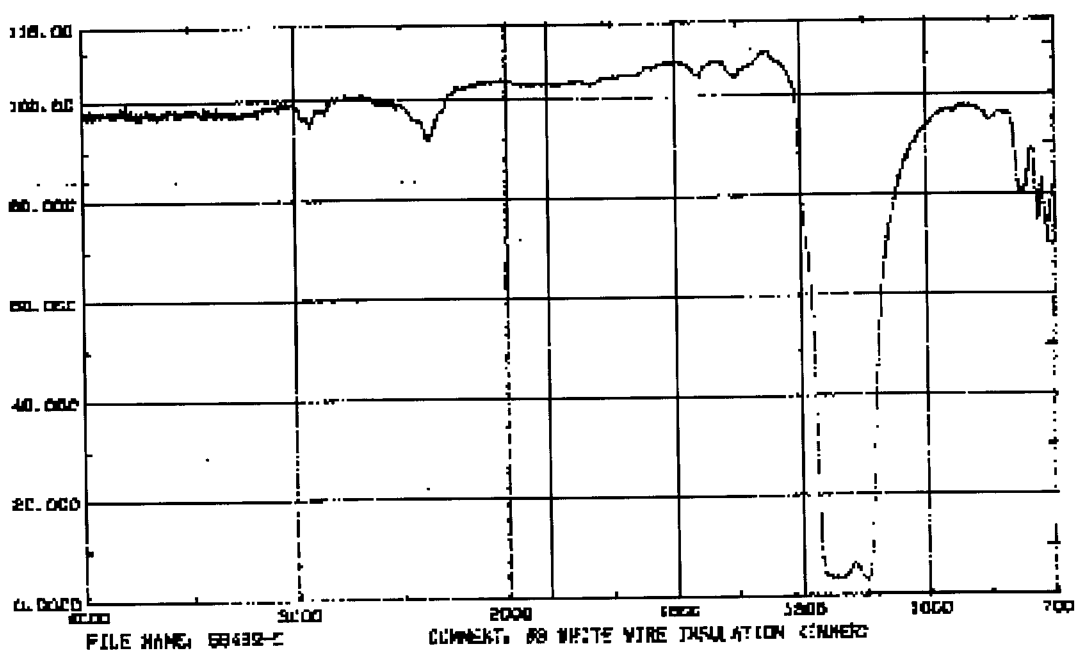



**Spectrum 3. FTIR spectrum for the outer film of the white-colored insulation material. The spectrum matches reference spectra for polytetrafluoroethylene (PTFE) material.**

000234



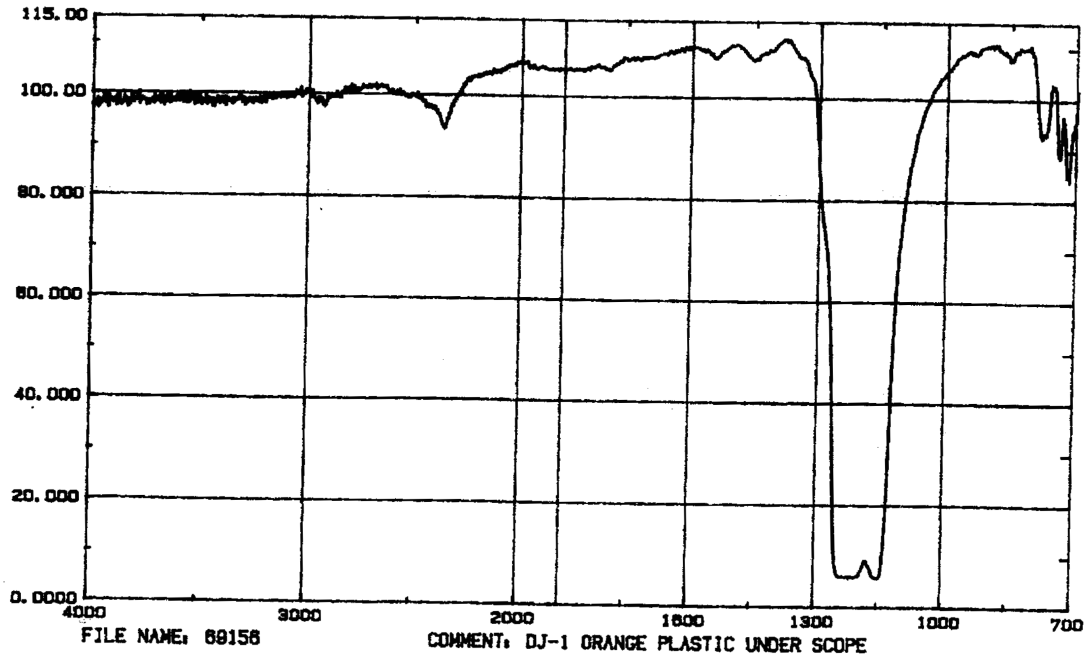

**Spectrum 4. FTIR spectrum for the inner film of the white-colored insulation material. The spectrum matches reference spectra for polytetrafluoroethylene (PTFE) material.**




**Spectrum 5. FTIR spectrum for another inner film of the white-colored insulation material. The spectrum matches reference spectra for polytetrafluoroethylene (PTFE) material.**

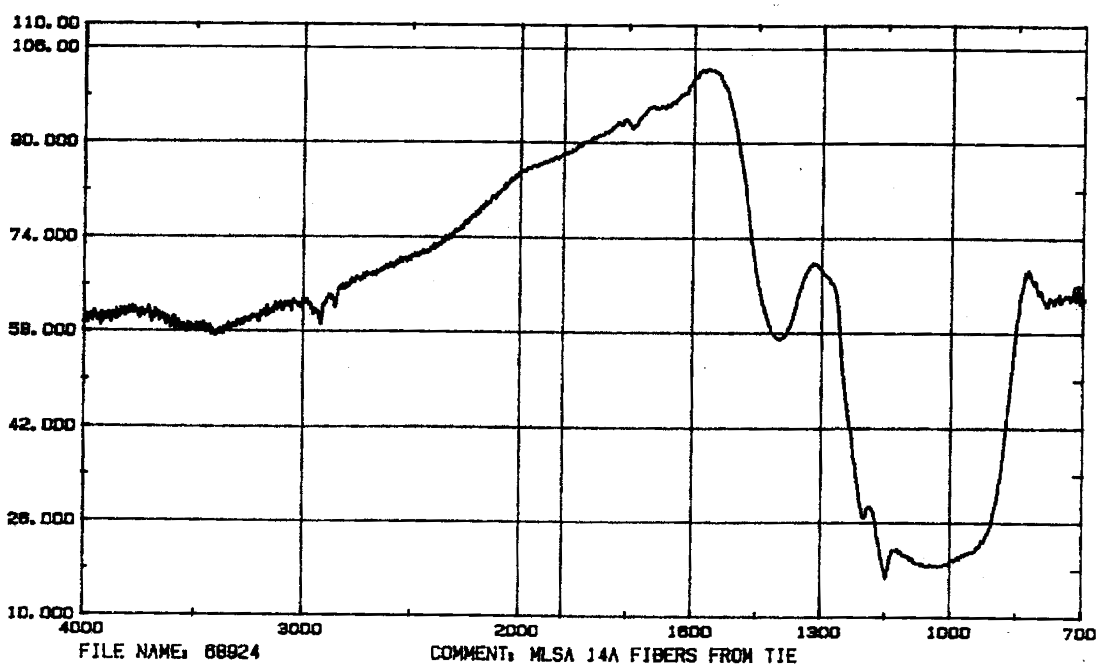
000235

**Report P69156 FTIR Spectrum**

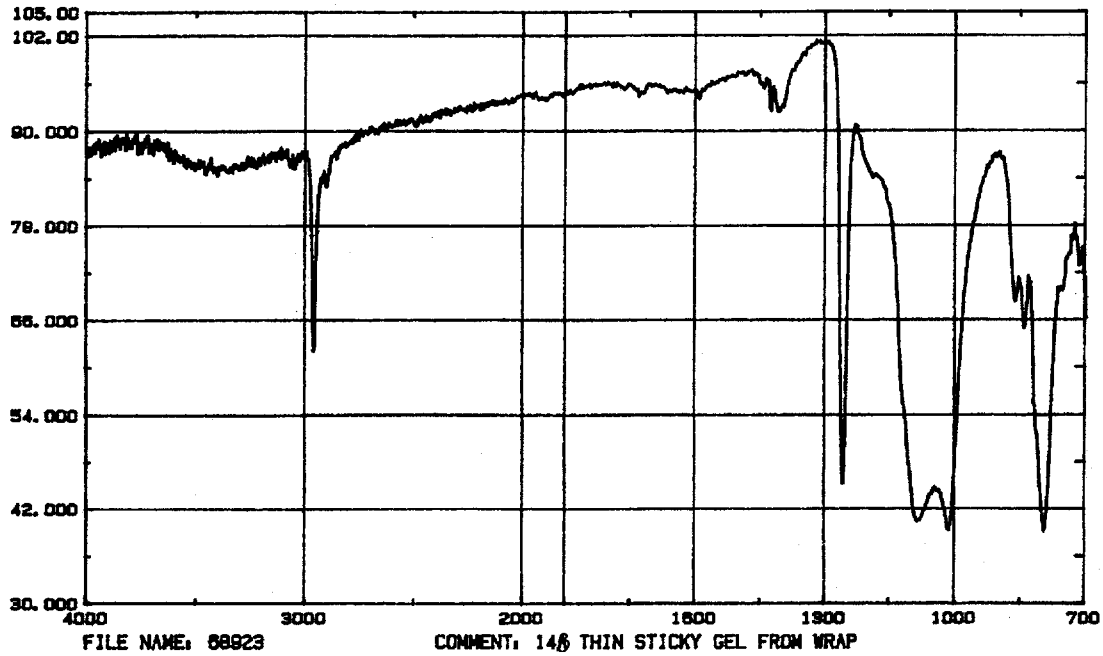



**Spectrum 1. FTIR spectrum for orange-colored spacer used between the inner and outer electrode. The spectrum matches reference spectra for polytetrafluoroethylene (PTFE, Teflon).**

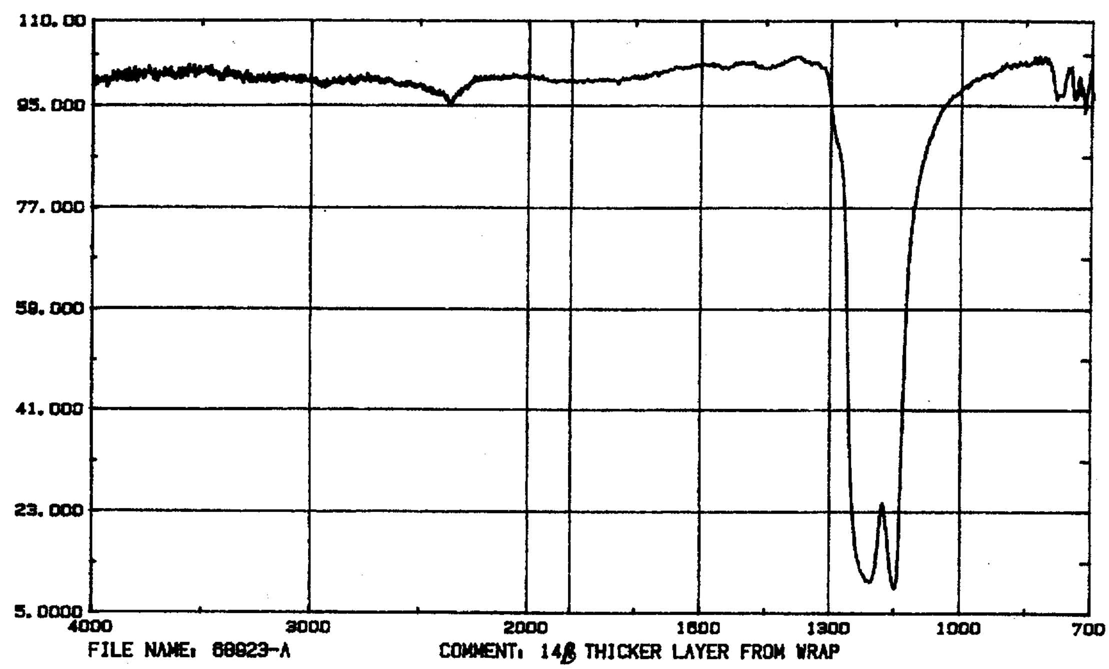
**Report P68923 FTIR Spectra**




**Spectrum 1. FTIR spectrum of the fibers removed from the tie. The spectrum matches reference spectra for silica glass materials.**



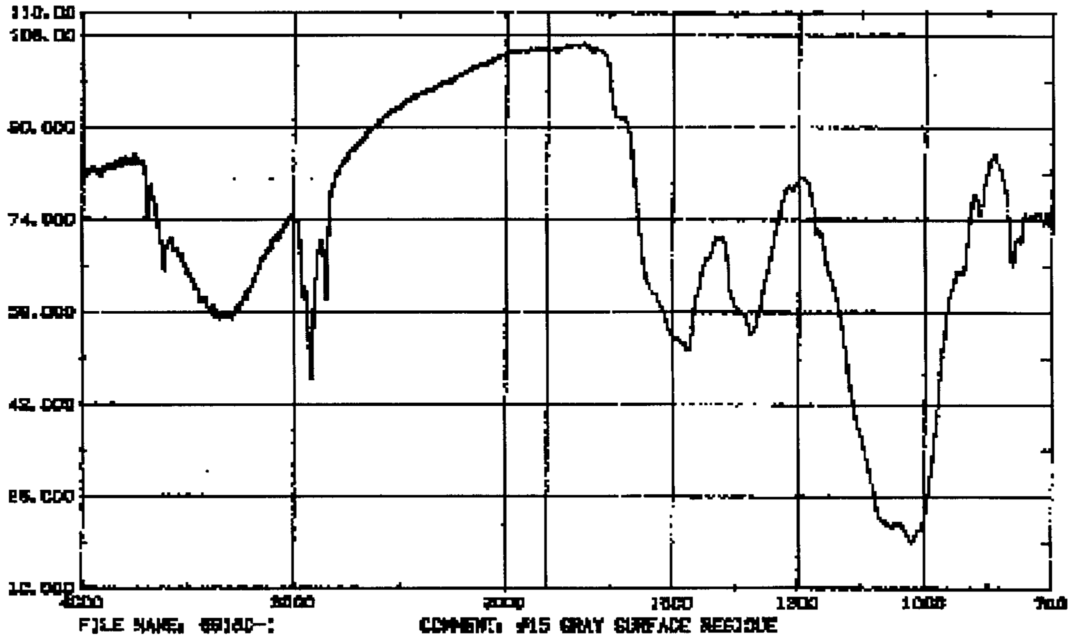

Spectrum 2. FTIR spectrum for the adhesive material on the gray-colored wrapping tape. The spectrum matches reference spectra for methyl silicone materials.



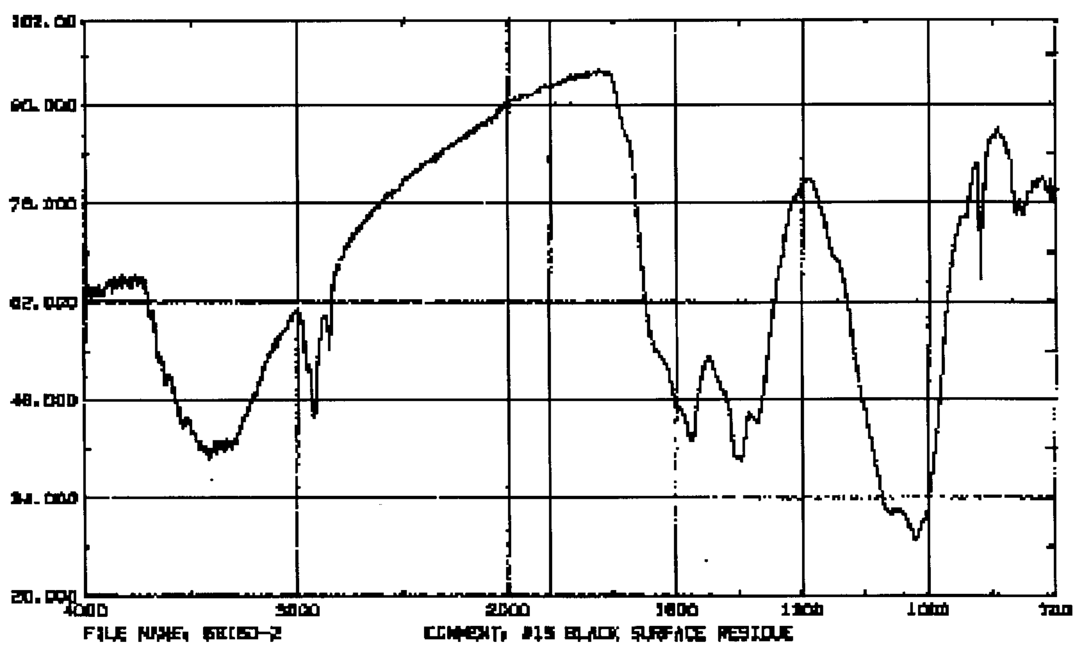

Spectrum 3. FTIR spectrum for the gray-colored wrapping tape. The spectrum matches reference spectra for polytetrafluoroethylene (PTFE, Teflon®) materials.

000237

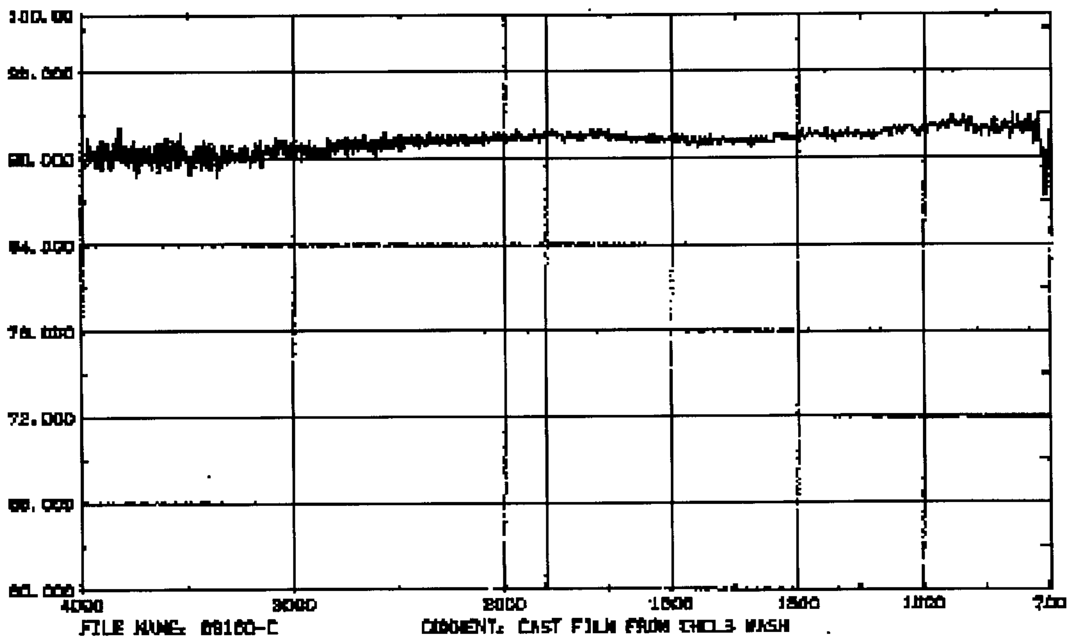
## Report P68160 FTIR Spectra



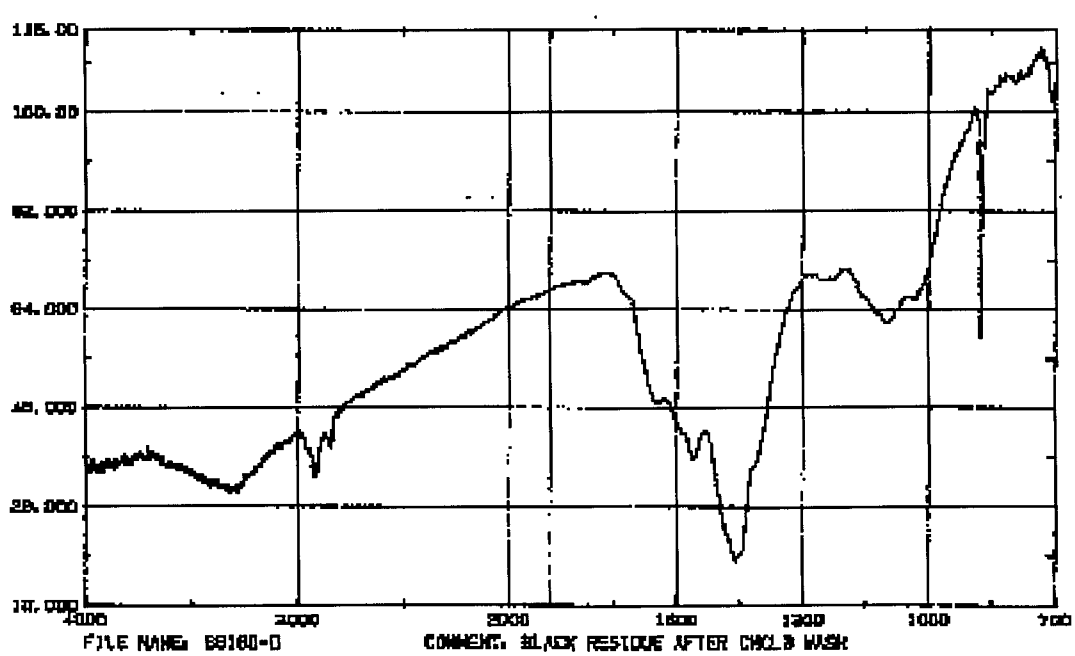

**Spectrum 1. FTIR spectrum for part of the black-colored residue. The spectrum was typical of a mixture of organic and inorganic components which includes carbonates, silicates, and aliphatic hydrocarbons, cellulose materials and carboxylic acid salts.**




**Spectrum 2. FTIR spectrum for another portion of the black-colored residue. The spectrum was typical of a mixture of organic and inorganic components which includes carbonates, silicates, and aliphatic hydrocarbons, cellulose materials and carboxylic acid salts.**




**Spectrum 3. FTIR spectrum of the cast film of the chloroform washing of the black-colored residue.**

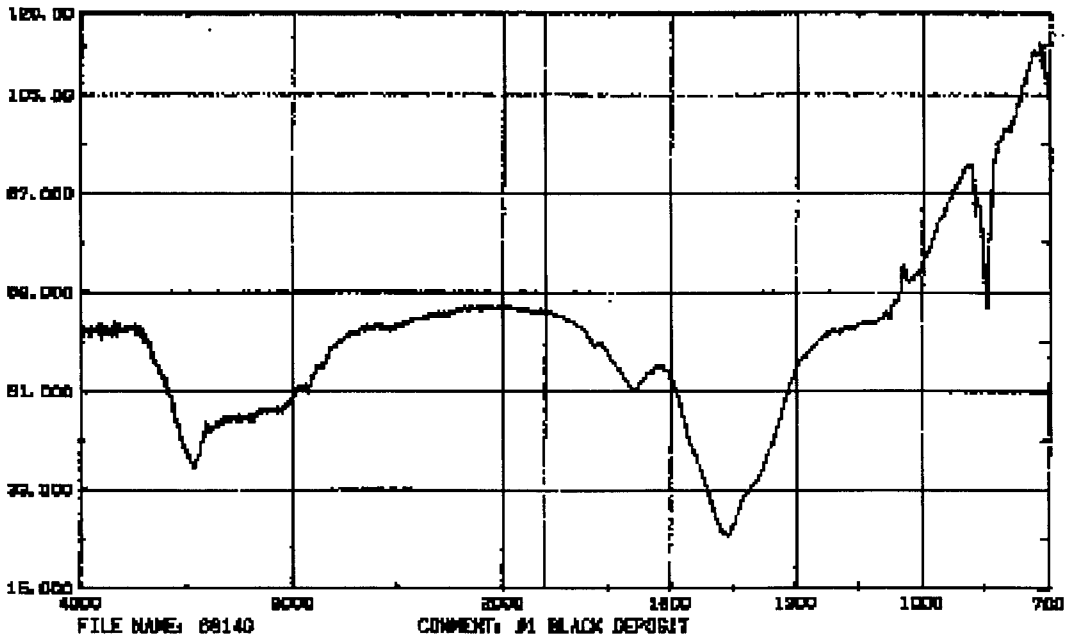



**Spectrum 4. FTIR spectrum of the black-colored residue after chloroform washing.**

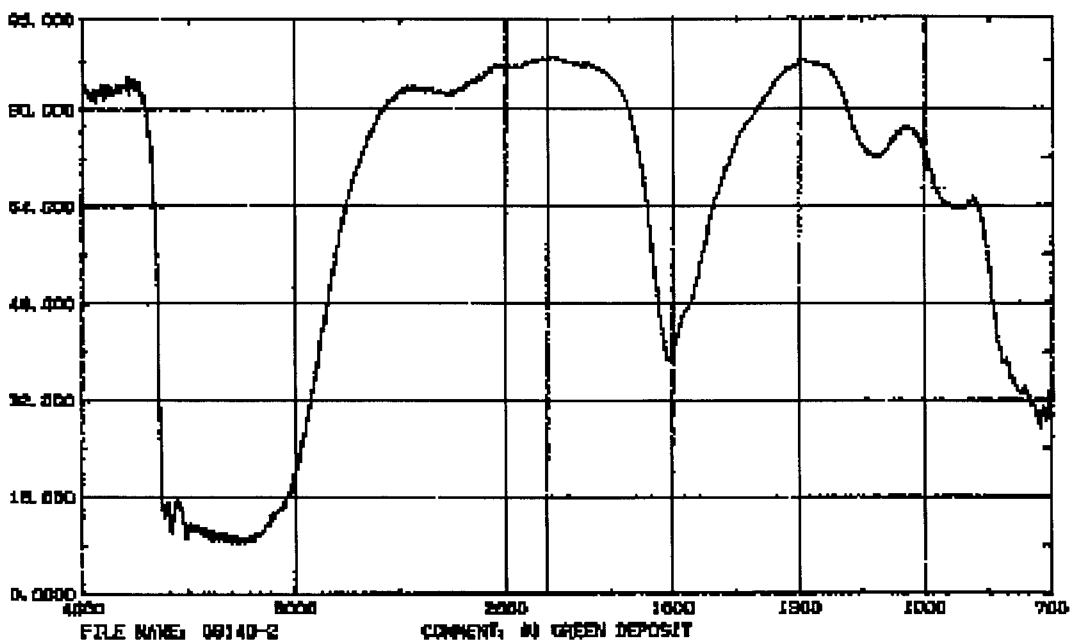


000239

**Report P68140 FTIR Spectra**

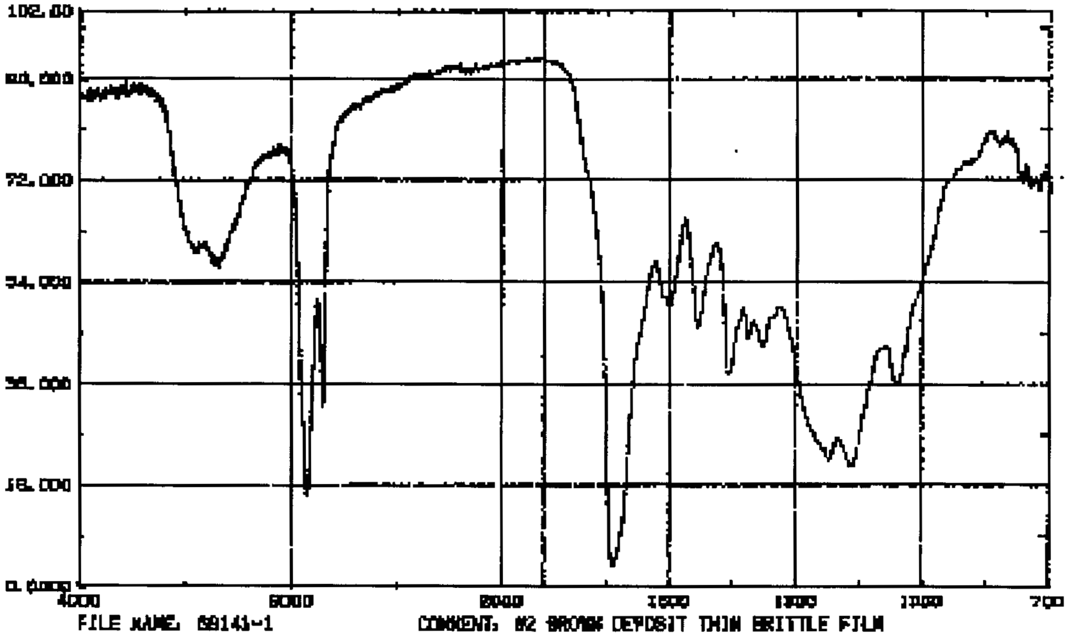



**Spectrum 1. Micro FTIR spectrum obtained for scrapings from the black discoloration area. The spectrum most closely matched references for inorganic carbonate compounds with possible presence of some inorganic silicate materials. There was no evidence of any organic materials observed.**

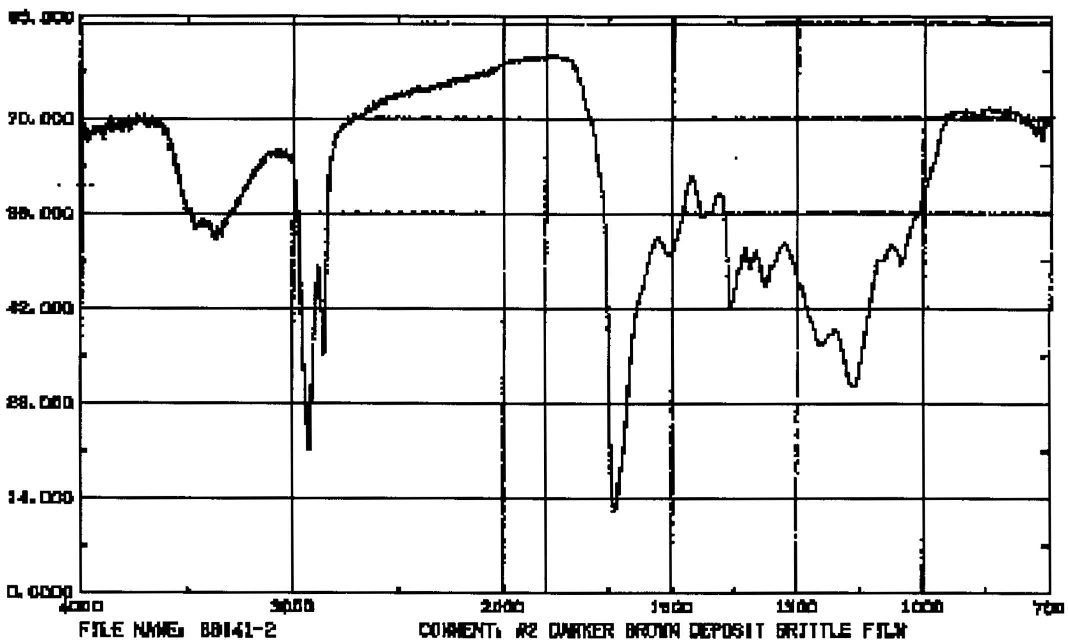



**Spectrum 2. Micro FTIR spectrum obtained for the green material found in the area of black discoloration. The spectrum suggests the presence of hydrated inorganic oxides or hydroxides. There was no evidence of any organic materials observed.**

000240



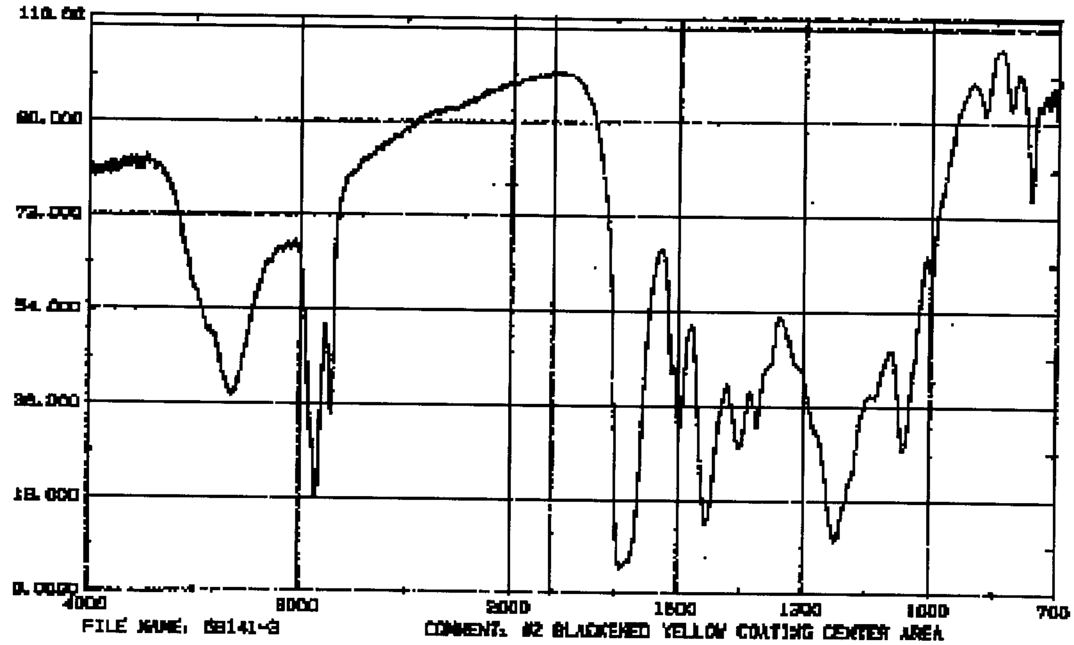

**Spectrum 3. Micro FTIR spectrum obtained for the brown deposit (thin brittle film) near the bare end of the tube. The spectrum obtained was similar to some reference spectra for polyurethane materials.**



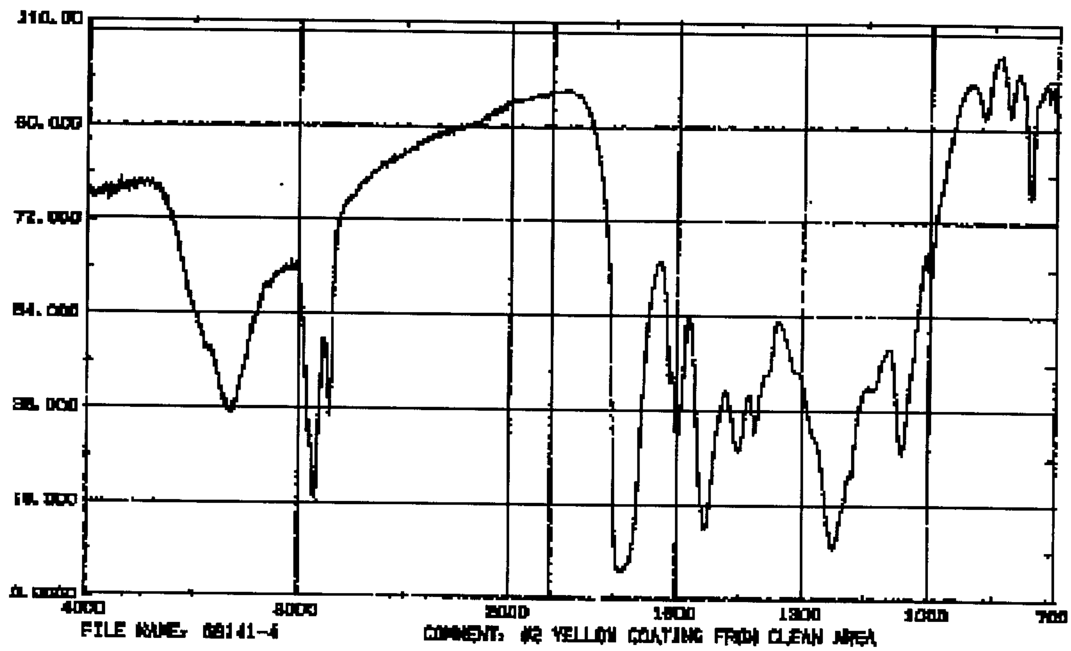

**Spectrum 4. Micro FTIR spectrum obtained for the brown deposit (thin brittle film) near the bare end of the tube. The spectrum obtained was similar to some reference spectra for polyurethane materials.**



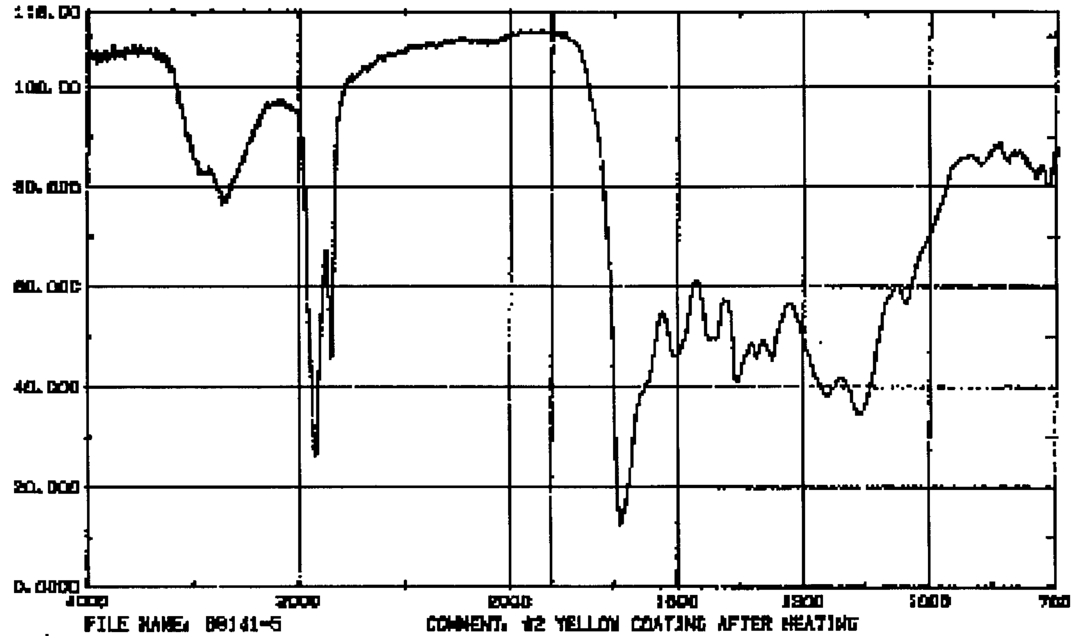
000241




**Spectrum 5. FTIR spectrum for a blackened yellow coating on the center area of the tube. The spectrum most closely matched references for polyurethane materials.**

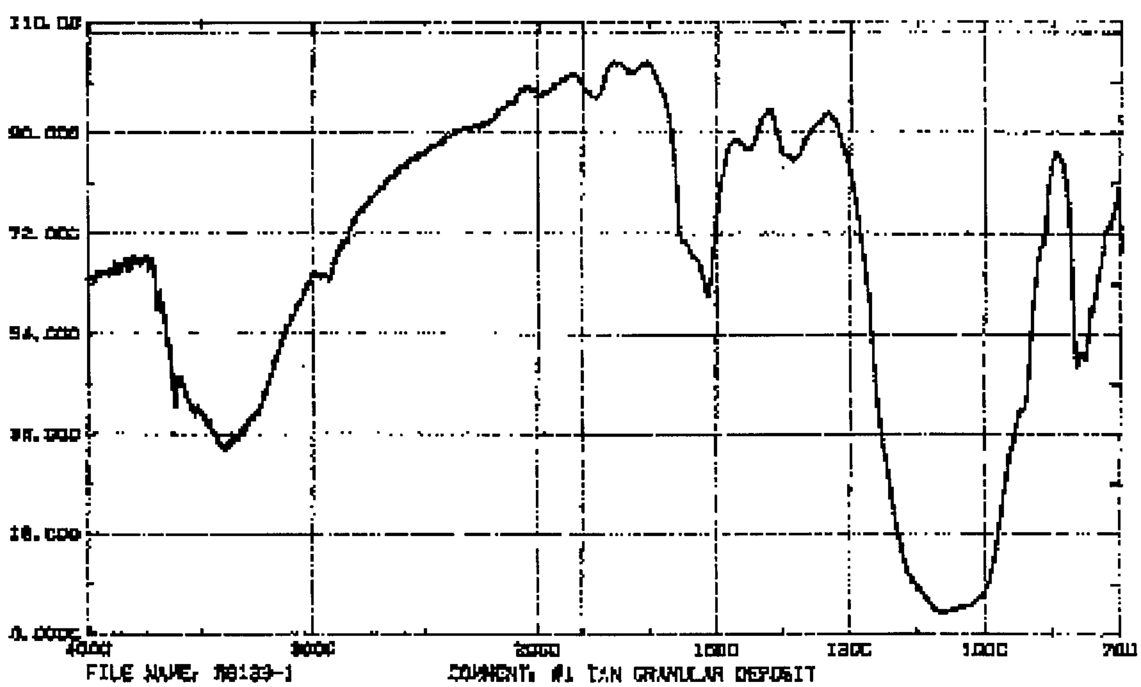



**Spectrum 6. FTIR spectrum for a clean undamaged portion of the yellow coating on the tube. The spectrum most closely matched references for polyurethane materials.**




Spectrum 7. FTIR spectrum of a portion of the clean yellow coating following heating. The spectrum obtained matched very closely with those obtained for the brown deposit. Data suggest the brown deposit was composed of thermally degraded urethane coating.

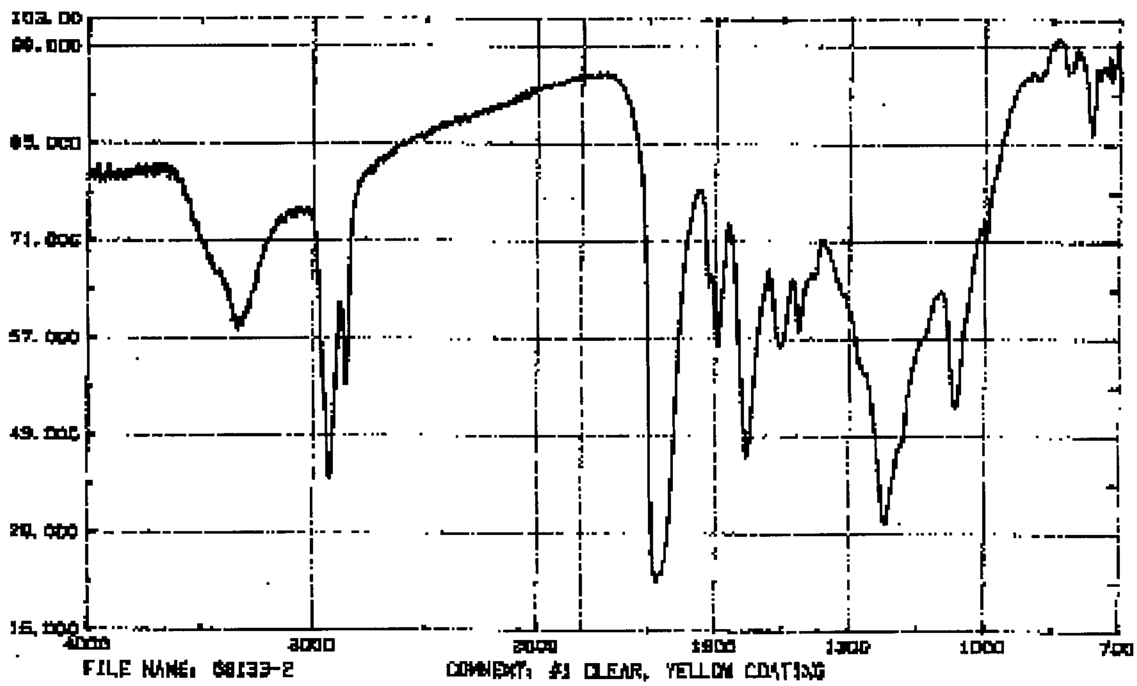
**Report P68127 FTIR Spectra**



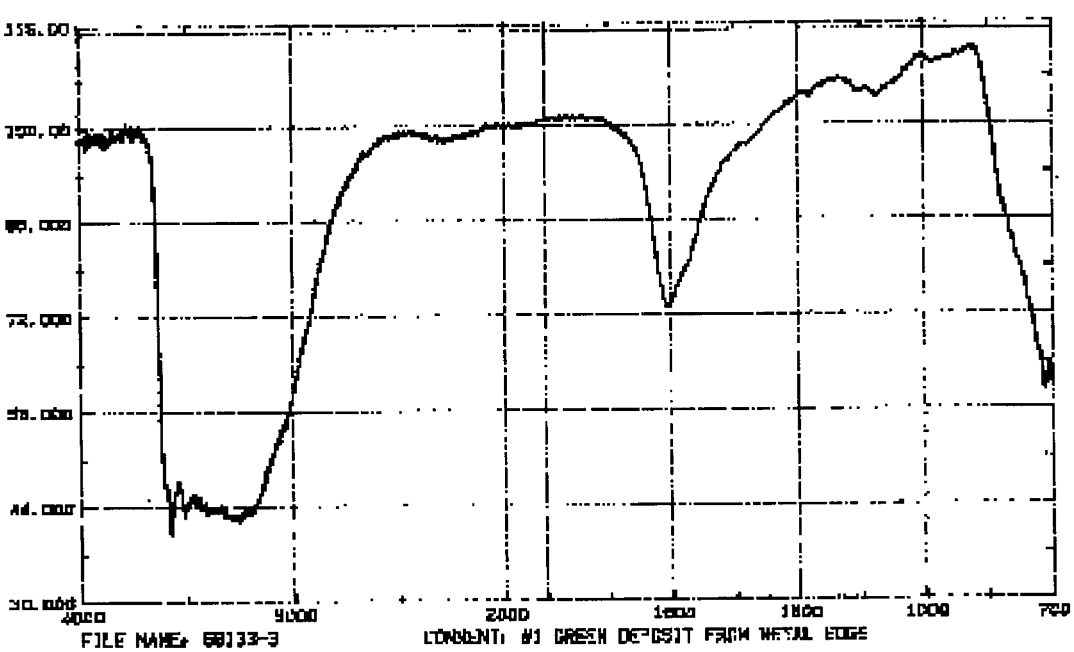

Spectrum 1. FTIR spectrum obtained for the gray-tan colored granular deposit on the metal plate. The spectrum was most similar to references for silicate type minerals.



000243

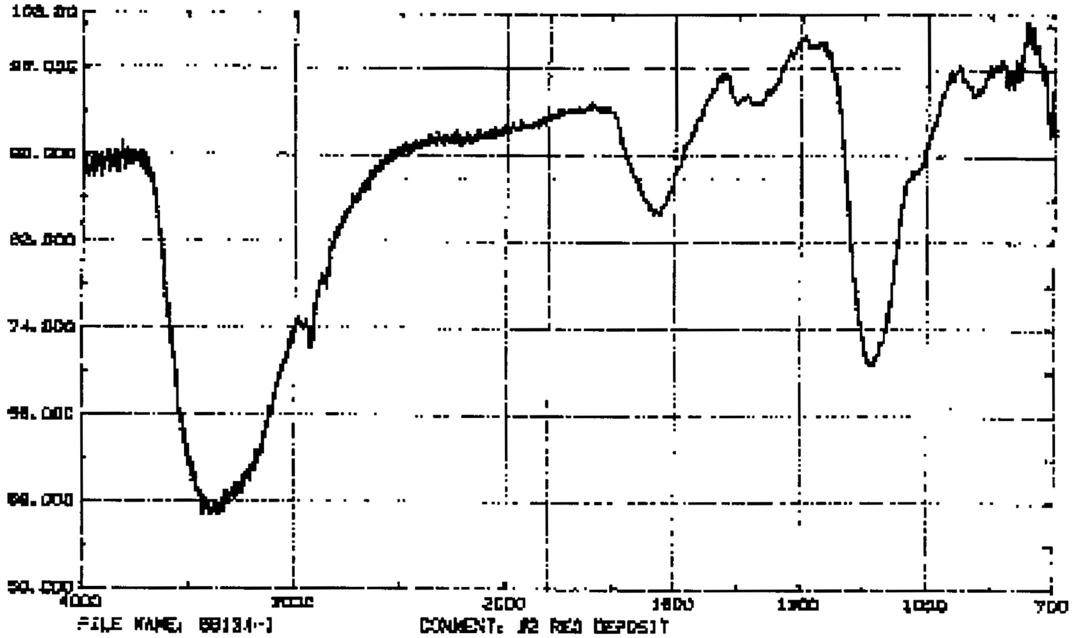



Spectrum 2. Micro FTIR spectrum obtained for the yellow coating material on the metal plate. The spectrum obtained most closely matched references for poylurethane materials.

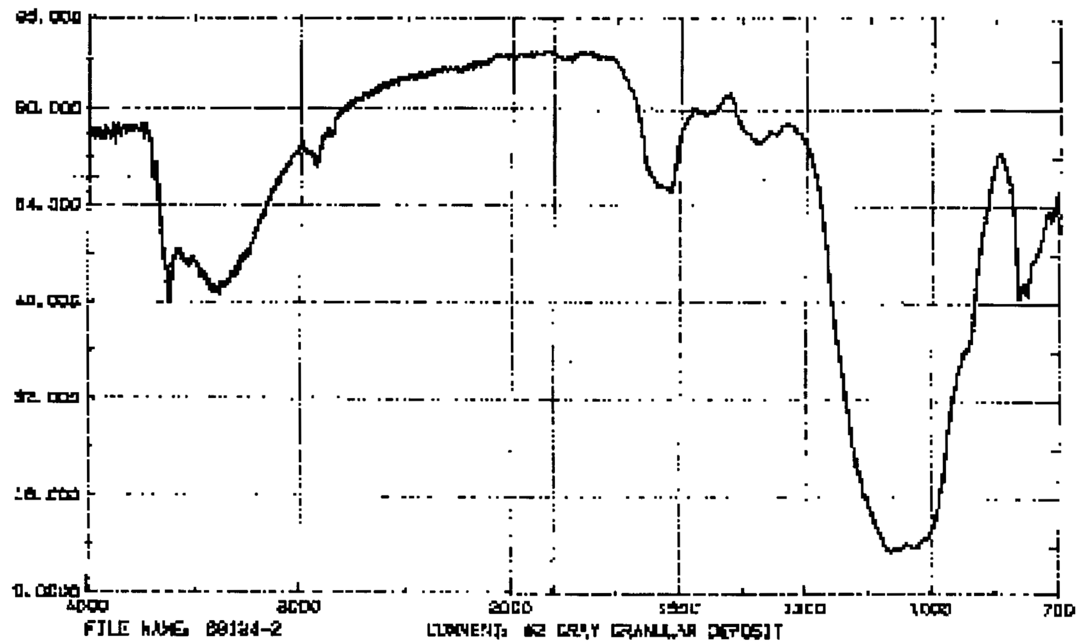



Spectrum 3. FTIR spectrum for the green crystalline solid observed near one edge of the metal plate. The spectrum obtained suggested it was composed of a hydrated inorganic oxide or hydroxide.

000244

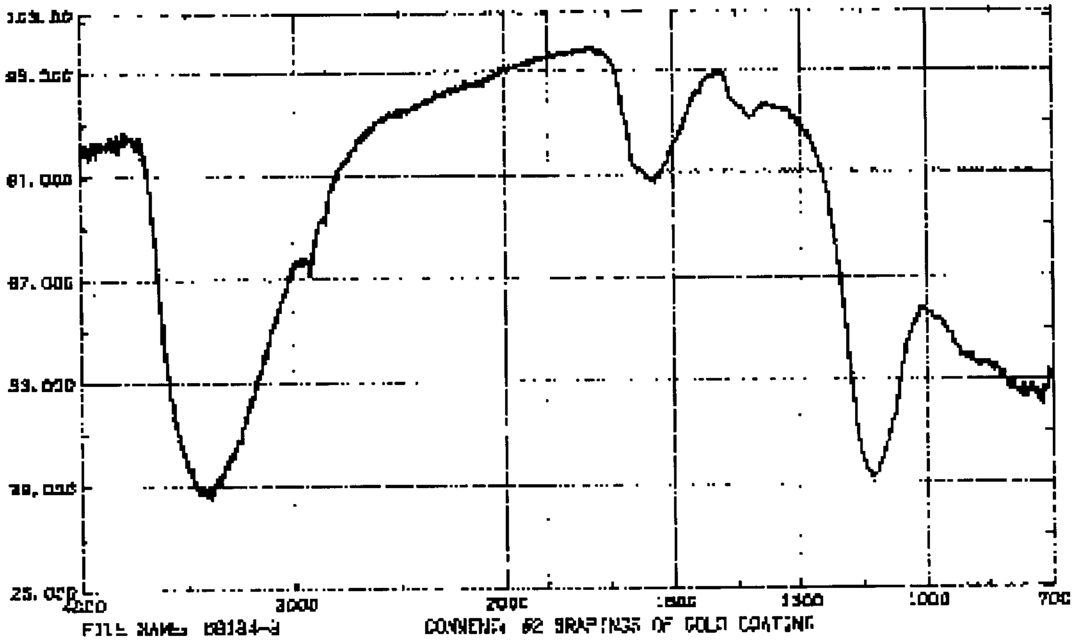



**Spectrum 4. FTIR spectrum for the red deposit found on one area of the metallic plate. The spectrum obtained suggested the presence of hydrated inorganic oxide or hydroxide compounds. The absorption observed at 1137 $cm^{-1}$ could be due to the presence of either inorganic silicate or sulfate compounds. Weak absorptions in the 2940 $cm^{-1}$ region suggested the presence of small amounts of organic material.**

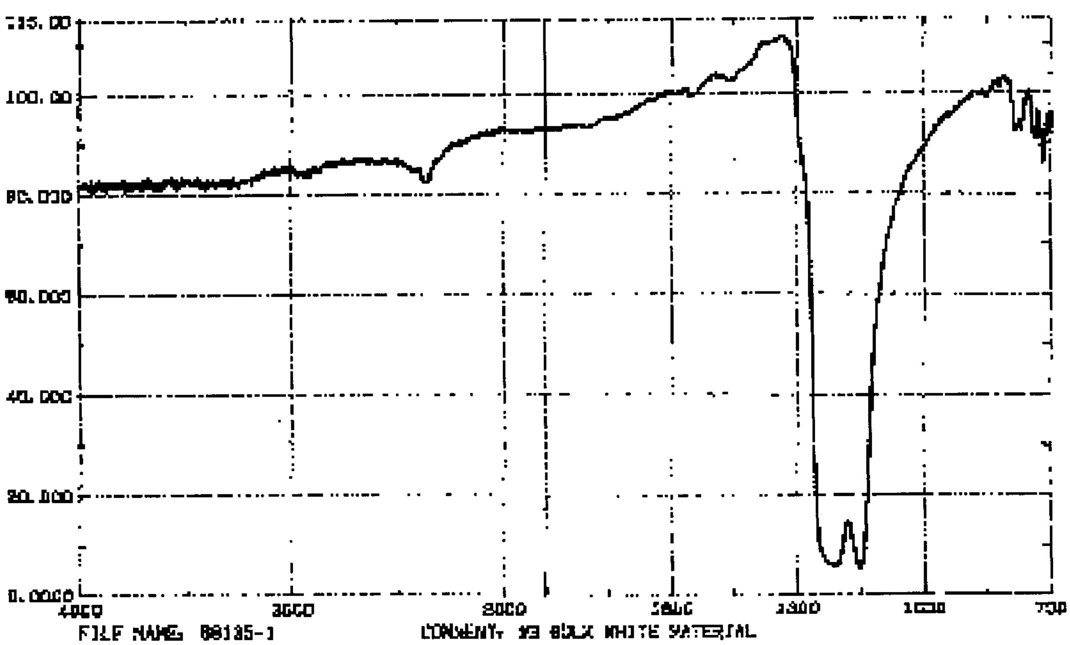



**Spectrum 5. FTIR spectrum obtained for the gray granular deposits. The spectrum suggested the presence of silicate type minerals.**

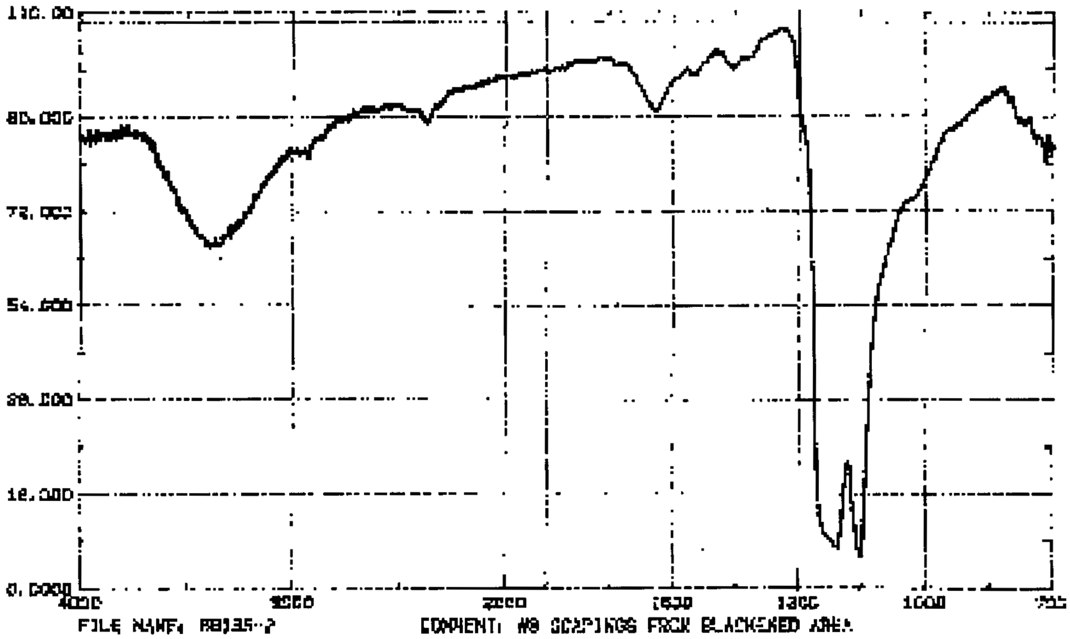
000245



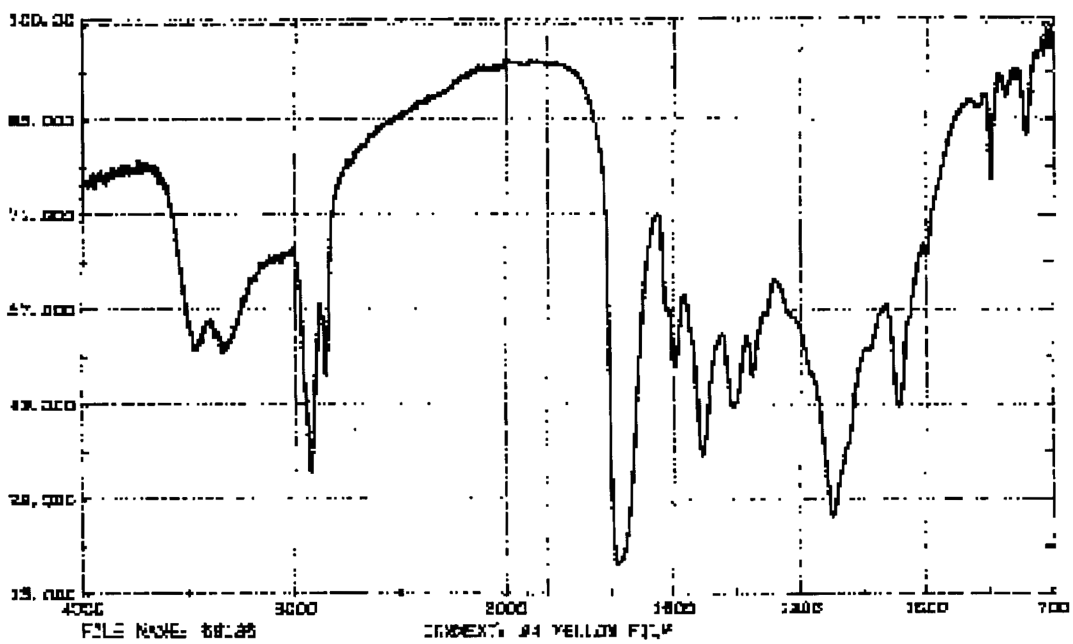

**Spectrum 6. FTIR spectrum for the scrapings from the gold-colored area of the sample surface. The spectrum suggested the presence of inorganic oxides and possibly silicate materials. The general appearance of the gold-colored surface, as well as the spectral data, were consistent with those characteristics for anodized aluminum alloys.**




**Spectrum 7. FTIR spectrum for the bulk white plastic material. The spectrum most closely matched references for poyltetrafluoroethylene (PTFE) materials.**

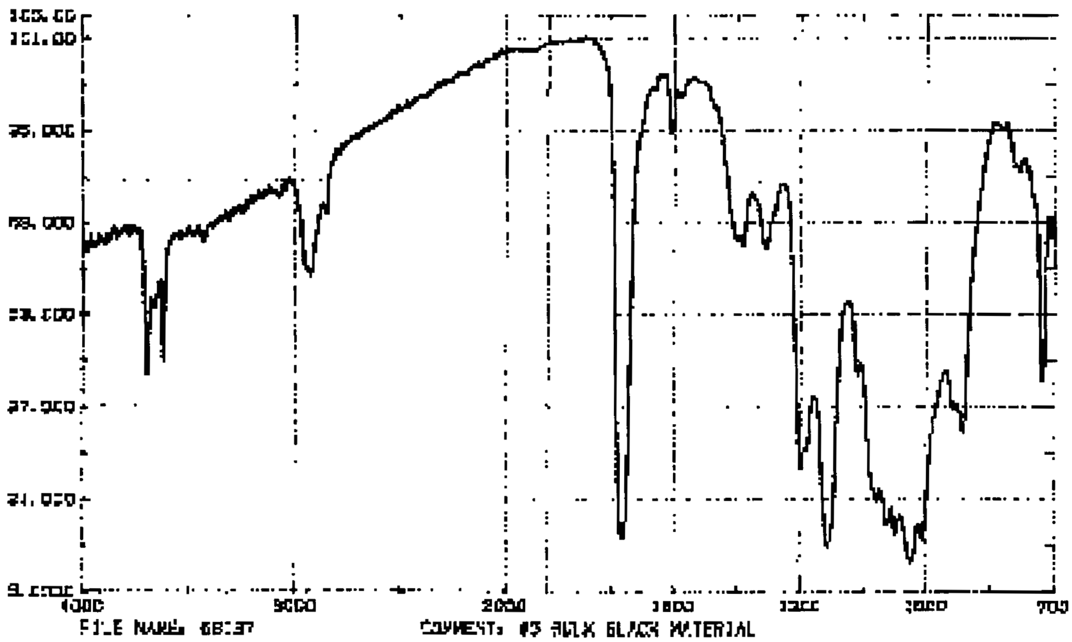


**Spectrum 8. FTIR spectrum for the black deposit found on the white colored plastic material. The spectrum exhibited weak absorptions which suggested the possible presence of a hydrated inorganic compound.**



**Spectrum 9. FTIR spectrum for the clear yellow film. The spectrum obtained most closely matched references for some polyurethane materials.**

000247




**Spectrum 10. FTIR spectrum for the black plastic material. The spectrum most closely matched references which indicated the sample was composed of an isophthalic acid based polyester with a kaolinite type silicate filler.**

The residue on the terminal block near the Hi-Z terminal and under the steel clamp was probed electrically (Figure 52). Needle point probes, a fixed 1/8 inch apart, were used to evaluate the residue. A HP4329A high resistance meter was used to measure the insulation resistance at 10 volts dc. The areas probed are shown in Figure 52. Readings were unstable and could vary by an order of magnitude with slight movement. Outside the residue or stain insulation resistance was in the $10^{14}$ ohm range. In the residue area, readings varied in the low $10^{8}$ ohm range. The resistance was too high to be measured with a HP 2378A multimeter (full scale ($30X10^{12}$ at 1.3 Volts). While probing the residue area on the top surface seen in Figure 52, an even darker residue was noted on the side of the terminal block (white arrow, Figure 52). Resistance values were in the megohm range using the HP 2378A multimeter and the 1/8 inch fixed distance probes. The readings were again unstable (Figures 54) and varied by at least an order of magnitude. The resistance values were too low to be measured with the high resistance meter (minimum scale $10^{6}$ ohms at 10 volts). A 10 volt dc potential was applied across the fixed probes and the resulting current was measured (Figure 55). The readings were again unstable and the calculated resistance was as low as 100 kilohms. Once an area was probed, the resistance would increase by one or two orders of magnitude. The films were apparently being mechanically damaged by probing, or electrically damaged by current flow during measurements.

EDS of the residues identified high concentrations of copper, silver, and sulfur (Figure 53).

SUMMARY OF FINDINGS - N17105 PROBE AND COMPENSATOR WIRING STUDY

No functional electrical anomalies were found.

Breaks in the PTFE insulation were found on Hi-Z, Lo-Z, and Hi-Z shield pigtail lead wires on, or close to, the terminal block. Both mechanical and cold flow damage were observed in the PTFE insulation.

Sites with both types of damage were found to have residues with high concentrations of silver, copper, and sulfur on the adjacent insulation. These residues appeared similar to silver sulfide and copper sulfide films seen in previous Air Force fuel probes studies. Since the formation of these films requires the immersion of the conductor in fuel, and their formation is time dependent, it can be presumed their presence predated removal from the aircraft.

000230