

Finally, Helen seems to have relaxed. She's got her music on, her eyes are closed, and her breathing has slowed. Even the divots she dug in your arm during takeoff are returning to their normal color. She'll be at it again for landing, of course, and you're idly wondering how much a pair of falcon-handling gloves cost when the man next to you wrinkles his nose up, narrows his eyes and mouth and looks over at you to ask: "Do you smell smoke?" Then the lights go off.

Commercial airliners carry miles of labyrinthine wires hidden throughout the pressurized and depressurized areas of the aircraft, some far more accessible than others. The amperage load many of these wires carry is energetic enough to melt anything less than high-grade insulation. Given the drastic repercussions of an in flight electrical fire, aircraft manufacturers specify high-quality sheathing, made of heat-resistant, durable materials such as polytetrafluoroethylene (PTFE). However, the production of PTFE is not a simple process, and manufacturers must be certain they are using the appropriate instruments to guarantee quality control.



Miles of wiring power the avionics of this Sukhoi Superjet 100. Image Credit: Flickr User [Dmitry Terekhov](#) CC BY 2.0

Inherent Difficulties in the Synthesis of Polytetrafluoroethylene

PTFE is in many ways¹ a perfect material for this application, due to its flame resistance and low smoke generation, excellent dielectric constants, low dissipation factors, high-frequency stabilities. Its continuous service temperature range of $-260\text{ }^{\circ}\text{C}$ to $260\text{ }^{\circ}\text{C}$ (melts at $327\text{ }^{\circ}\text{C}$), resistance to all common chemicals and solvents, and moisture and volume resistance help it stand up to the rigors of high altitude flight.

However, manufacturers are well aware of the expense and difficulty² of creating this material. PTFE is synthesized in two stages: the initial three-stage chemical reactions used to create

tetrafluoroethylene, then the polymerization of the base TFE. These reactions necessitate the use of extremely hazardous materials including strong acids and the temperatures required range from below zero to 700°C. Specially designed safeguards must be employed to contain what can be a violently exothermic polymerization process. Mistakes can be destructive and dangerous and given the complexities inherent in the lengthy formulation process, highly expensive. To produce insulation, PTFE is coated over wiring before the sintering process. Each batch rejected due to failure in the quality control stage will significantly impact an operation's profitability. When used for aerospace electrical insulation, a further complication is introduced to the process: color.

Historically, PTFE was colored by cadmium pigments, which are highly toxic. With the worldwide adoption of RoHS, manufacturers are looking for replacements to the heavy metals containing inorganic pigments. Pigments are mixed with powdered PTFE in a dry blending process. Care must be taken to use as little pigment as possible to prevent arcing. Uniform dispersion is important to prevent edge lifting, folding, tape breaking, or electrical breakdown. Color quality control is essential to PTFE manufacturers, as color-coding is used to indicate the voltage or purpose of avionics wiring, and miscolored wires can be rejected by their clients. Matching these colors using heavy metals free pigments is difficult.

In keeping with the rigor of the rest of the PTFE synthesis, the accurate prediction of final color from a predetermined formula is frustratingly difficult. This is due to the whiteness of PTFE powder, and the material's 98% crystallinity. Not only does the color change when the dry powder blend is extruded into the tape, the crystallinity breaks down during sinterization as well, changing the background color and affecting the final result.



The high amperages required in avionics wiring can melt the low-grade insulation. Image Credit: Flickr User [Sam DeLong](#) CC BY 2.0

Spectrophotometric Color Quality Solutions for PTFE

The use of spectrophotometers, such as [HunterLab's UltraScan PRO](#), can help aerospace insulation manufacturers reduce uncertainty in their quality control process in two ways. First, samples of finished products can be scanned to determine whether they fall within the acceptable color range of the client. A color measurement instrument can eliminate the guesswork that comes with human color matching, measuring the full visual spectrum of the sample. The UltraScan Pro, with $d/8^\circ$ optics operating in spectral inclusion mode, allows users to determine the total color of the PTFE insulation, leading to an objective assessment on the part of both client and manufacturer of the color quality of the insulation. Standardized illumination settings prevent disagreements arising between colors viewed in different lighting environments. This usage ensures that all parties are measuring on the same, certifiable scale, removing the potential for mistaken rejections.

Second, the thorough integration of the spectrophotometer into the production process can build data sets to help manufacturers predict color based on their results. By knowing the exact L*a*b* coordinates of the final PTFE, and at each preceding stage in which color changes, manufacturers can understand how a given set of variables produce a given color. While a large number of batches must be processed to generate a data set upon which predictions can be based, each data point is an accurate measure of color. As more and more data is compiled, manufacturers will be able to further understand the coloration process, achieving a greater and greater degree of predictability.

The complex, expensive, and dangerous nature of PTFE avionics insulation demands precision at each step of production. By incorporating spectrophotometric assessments in the formulation process, manufacturers can reduce color uncertainty, cut down batch failures, and improve their bottom lines. For more information on how spectrophotometers can improve your operation, [contact the experts](#) at HunterLab today.

1. "Development of RoHS Compliance Colored PTFE Tape for Aerospace Electric Wire Insulation," http://technetics.com/bin/RoHS_PTFE_Tape.pdf
2. "Production Process of PTFE Polymer," <http://www.standard-ptfe.com/production-process-of-ptfe.php>