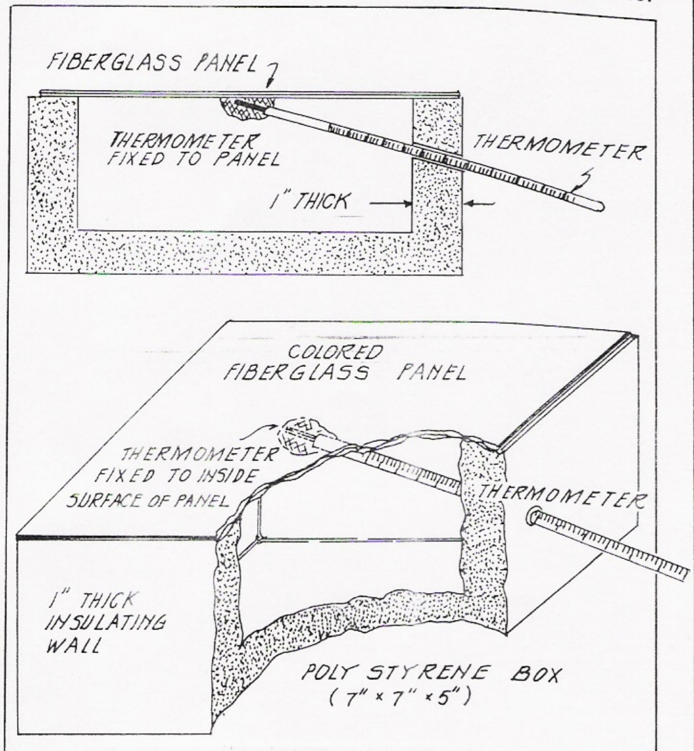
Why is White so Sacred?

Energy absorption & color in fiberglass

by JOHN P. GREENE

Traditionally, glass sailplanes have been produced with a white finish only, and even the limited use of colored trim has been a rare factory option. There are some apparently valid reasons for staying with white and these will be briefly discussed. However, the main thrust in this report will investigate the temperature rise at the skin surface of a colored sailplane resulting from direct exposure to sunlight. Additionally, means will be provided for predicting approximate peak temperatures which might be experienced with different colors and shades, but first, let's list the major objections to a colored finish. They are:

1. To detect where damage actually occurred in a professionally repaired ship is practically impossible. This condition will prevail so long as the finish is white. However, invisible repairs to a colored structure are something else again. Acceptable color matching could turn into a genuine nightmare.
2. The soaring fraternity has long accepted a beautiful white glass sailplane. Primary concern involves things like performance, cost, and availability—not color. So why chance something so new and unproven?
3. With only a limited market, how could a manufacturer hope to sensibly select colors and shades? To produce a colored sailplane is not a simple task. Ideally, color should be an integral part of the structure. Once again, why change something that works?
4. We know that a colored surface gets considerably hotter than a white surface when exposed to direct sunlight. Considering the risks of distortion, softening, and differential expansion, there is ample reason for genuine concern. The following quote is taken directly from the brochure of a contemporary high-performance glass ship. "The only available finish is white in order to minimize surface heating."



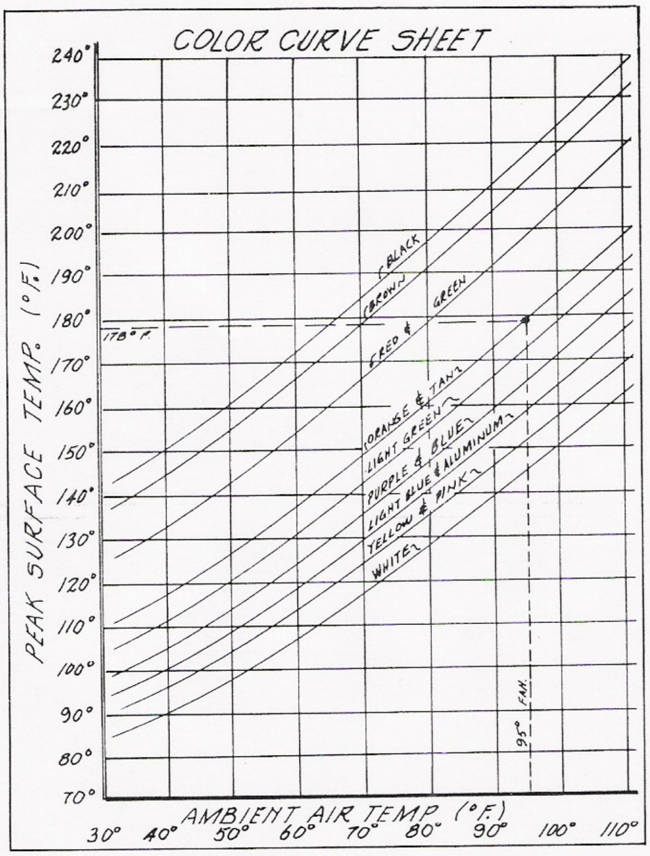
BOX SAMPLE (FIG. 1)

But if we choose to ignore this last serious factor, the other objections would hardly be insurmountable. If, in fact, surface heating was not a problem, I believe we would be looking at colored glass today. So now we might ask: "Why the big fuss over color?" The answer is simple. MAKE THAT SAILPLANE EASY TO SEE! Put yourself in the following picture: A hazy sky with a milky white background, a poorly defined horizon, the sun in a late afternoon position to further reduce visibility. Introduce a couple of narrow-profiled sailplanes approaching from different directions and throw in some power traffic or a towplane for added distraction. Quite clearly, a hazardous situation could be developing. In parts of Europe, this danger has been recognized and specific areas of the sailplane are now brightly colored for better visibility. However, effectiveness is limited and something additional might be required—like complete coloring of the total sailplane.

Fundamentals Review

The balance of this article investigates the relationship between color and surface heating resulting from direct, continuous exposure to sunlight. So we might well start with a very brief review of basic fundamentals and a promise to keep the technical aspects of such a discussion to the barest minimum.

Sunlight, a form of energy, cannot be detected until it strikes an object and is converted into useful light or heat. Light-colored and shiny surfaces generally tend to reflect radiant thermal energy (sunlight). Dark surfaces absorb this energy. If a surface did, in fact, absorb most of the sunlight falling on it, the energy gained would manifest itself in the form of heat—the surface would quickly get hot. Now what happens when a pigment is added to color the surface? Loosely defined, a pigment is a substance which absorbs some colors and predominantly reflects others. Sunlight contains all the colors of the spectrum—the total visible band from red to violet including orange, yellow, green, and blue. Each of these colors has its own wave length; different pigments have the unique capability of sorting out these wave lengths—absorbing some while reflecting others. The human eye receives these reflections as sensible color. Very pure white will reflect about 90% of the total light shining on it and there is little storage of heat. The purest black will absorb about 95% of the total light shining on it and the substantial temperature rise which results is hardly surprising. But what about the six colors noted above and all the shades that fall between? What effect will these have on surface heating?



Test Apparatus and Program

To answer these questions, an experimental program was conducted involving thousands of temperature readings with dozens of colored samples. Testing was conducted in New Jersey during the years from 1972 to 1974. To closely simulate conditions that might exist on the skin surface of a real sailplane, samples were prepared from polystyrene boxes measuring 7″ x 7″ x 5″ on the outside dimensions with 1-inch thick sides. One face of each box was removed and replaced with a colored fiberglass panel. A number of these test samples were prepared using different colors and shades in addition to black and white. To complete the construction, a mercury thermometer was inserted through the side of each box with the sensing bulb in contact with the colored panel and secured in place with epoxy resin. (See Fig.1) We now have a tight enclosure with five well-insulated walls and the remaining sixth side as a colored fiberglass panel. Similarity to an actual wing or fuselage structure is quite apparent. Actual testing was conducted as follows.

Test samples were mounted in a simple frame with the colored surfaces aimed squarely at the sun. This frame was continuously tilted and turned to follow the sun across the sky, thus maintaining squareness with the source of energy. Ambient air temperature and surface temperature of all samples were continuously recorded until a peak was reached for existing conditions. This procedure was repeated as often as possible to assure a statistically valid set of recorded values. The term, "ambient air," always refers to dry-bulb temperature measured in the shade and stated in degrees fahrenheit. Test requirements called for a very clear sky without the slightest cloud formation or haze. The minutest development of high haze, hardly discernible to the eye, would immediately cause sample temperatures to drop and bring testing to a conclusion. Also, the slightest breeze introduced an appreciable cooling factor and tests were conducted only in very calm air. The ultimate goal was to determine the highest skin surface temperature a colored sailplane might experience when parked under a blazing sun with no cloud cover, no shade, not the slightest breeze, and a very high ambient.

After two years of testing, significant data was sorted out and plotted on the curve sheet to develop temperature rise curves for each color and for black and white. Referring to these curves, note that the baseline represents ambient air and the vertical scale represents maximum sample temperature. As might be expected, the curves are bounded on the top by black and on the bottom by white. These finished curves are simply a graphical presentation of the highest temperatures recorded for each color based on a broad ambient temperature range from 30 degrees to 110 degrees.

Interpreting the Findings

Now what does all this mean? How can this data be put to practical use? The curves clearly indicate a black sailplane could achieve a surface temperature of 115 to 120 degrees above ambient air. For example, on a day with a temperature of 90 to 95 degrees in the shade, it is conceivable the skin surface of a black sailplane could reach the temperature of boiling water. Now there is no intention to suggest black as a finish for a sailplane. However, black will absorb more solar energy than any color (black in itself is not a color) and therefore, will indicate the most severe heating condition which could be experienced. However, for high altitude wave work under extremely cold conditions, it would be practical to paint the entire cockpit area and even some of the canopy with a coat of washable black. This would effect some increase in cockpit temperature.

The curve sheet also indicates an all-white sailplane could attain a peak temperature of 45 to 50 degrees above ambient —about 70 degrees lower than the corresponding figure for black. Looking at the color curves, we see that brown shows a decided tendency to absorb heat—not too different from black. Colors like red and green should be avoided if moderately high surface temperatures are objectionable. Orange and tan fall near the middle of the range and orange has the unique property of being very visible. The coolest colors are pink, yellow, and light blue, along with all pastel shades. Note the position of the aluminum sample.

To get an approximation of peak temperature which might be expected for a specific color on a glass sailplane, use the following procedure: Select the color and determine the maximum ambient which might be expected for that particular area. On the curve sheet base line, find the ambient temperature and move vertically to the appropriate color line. From this color line, move horizontally to read peak temperature on the vertical scale. For example, with a maximum ambient of 95 degrees, we might expect an orange sailplane to reach a peak temperature of 175 to 180 degrees under the most severe conditions. This simple problem has been worked out (in broken-dash lines) on the curve sheet. It might be interesting to note that during the testing phase of this study, an eclipse occurred which resulted in a 25-degree drop in black sample temperatures and only negligible drop in ambient air temperature.

Conclusion

The reader should treat the values given in this report as an approximation—an indication—of what might be expected. It is more important that the magnitude of the problem be appreciated. For every color, there are countless shades and hues, all with different capacities to absorb or reflect solar energy and it is entirely possible the position of two adjacent colors on the curve sheet could be interchanged simply by deepening one while adding white to lighten the other. Nor is it within the scope of this study to draw any firm conclusions, pro or con, with regard to the use of color as a finish for fiberglass sailplanes. This would require an exhaustive physical testing program to develop reliable data. However, the numbers which appear on the curve sheet clearly suggest that in some parts of the country, with certain colors, overheating from solar radiation (sunlight) could present a serious problem. On the other hand, we might also suspect that any of the pastel shades such as light yellow, pink, or powder blue, could be safely used as a finish for a glass sailplane. But where do you draw the line?

COLOR CURVE SHEET