LIGHT BOX CONSTRUCTION

Introduction

Starting with the 2001 championships, the Australian-International Model Solar Car Challenge regulations, will use a handicapping method based on the actual power produced by the cells that make up the solar panel. Obviously, a reliable low cost system of measuring the power produced by the solar panels fitted to the model solar racing cars must be provided.

The attached drawings and specifications are a guide for constructing a one sun equivalent light box, suitable for testing the solar panels on model solar cars. All the dimensions and material specifications are the same as the prototype light box used at the 2000 championships in Sydney.

This light box has been designed to produce the same response from a solar panel that would occur when the same panel is exposed to full sunlight. No attempt has been made to color correct the incandescent light produced by the light box to form spectrally equivalent sun light. While this could be done by using appropriate 'blue' filters placed over the acrylic cover, it was not considered necessary.

The measurement of the power from the solar panel is carried out by a separate 'power monitor' which must first be connected to the solar panel under test. A separate paper will describe the construction of the 'power monitor'.

Description of the Light Box

The light source for the light box consists of 18, 50 watt 12 volt halogen lamps connected in series across the mains. In order to reduce the voltage down to the required 216 volts, a multi-tapped 100 VA transformer is used to reduce (buck) the 240 volt supply to the lamps. Where the mains supply is consistently above or below 240 volts, other taps on the transformer can be used to compensate. However, for the sake of cost, the voltage supply to the lamps is not regulated.

The lamps are held in place by small ceramic bases bolted to the aluminium base of the light box. On the other side of the aluminium base, the lamps are wired together using hard (high temperature) plastic or ceramic termination blocks. For protection, a double pole switch is used together with a fuse and the exposed metal parts are connected to mains earth.

The reflective surface on the sides of the box consists of recycled aluminium sheets from used lithographic printing plates stapled to the inside surface. This appears to be effective enough for the purpose. However, household type aluminium wrapping foil could be used instead.

Medium density fibre board was used to construct the box with the edges nailed and glued together. The bottom cover consists of a piece of thin plywood while the top uses a clear acrylic cover screwed to the top of the box. The acrylic cover may be removed to gain access to the lamps.

Construction

Only the inside dimensions of the box are listed in the drawing. This is because the overall dimensions will depend on the thickness of the material being used.

Since the edges of the box are not subject to any appreciable loads, the bonding method can simply be gluing and nailing. Similarly, the bottom cover of the box is more or less there to keep fingers away from the mains voltage and can be any available sheet of material on hand. Three millimeter plywood to ten millimeter hard board could be used. The only stress that will be applied to this cover sheet will come from the four rubber feet attached near each of the corners.

The top of the box must be covered with a 3 mm (or more) thick clear acrylic sheet screwed to the top edge. The actual thickness is not critical since the light attenuation through clear acrylic is very low. Tinted or colored sheets are not suitable - only clear should be used.

The ceramic lamp bases are mounted on a 1.5 mm thick sheet of aluminium formed to fit inside the light box. Persons familiar with metal working should have little trouble with this operation. However, the availability of a metal bender is required to accurately form the edges. Ideally, the metal base should be a push fit inside the box where self tapping screws positioned on the outside of the box, can fix it into position.

The use of steel sheeting instead of aluminium, is not recommended because:-

1. the long term reflectivity of aluminium is better; and

2. the heat transfer property of aluminium is better.

However, the thickness of the aluminium sheet could be reduced to 1.2 mm without causing any problems.

As shown in figure 2, the lamp bases are mounted on the aluminium sheet with centres 100 mm apart. However, the ceramic lamp mounting bases are attached to the sheet by two 3 mm bolts positioned symmetrically on both sides of the lamp centres. Two other holes for the heat resistant connecting wires must also be drilled. In other words, four holes are required for each of the 18 lamps.

Much of the heat from the lamps is absorbed by the aluminium sheet, which can become quite hot. Therefore simply soldering the leads of the lamps together is not recommended. (The solder may melt.) Instead, heat resistant hard plastic or ceramic screw terminal blocks should be used. These are attached to the aluminium sheet at convenient places using 3 mm bolts. The 'voltage bucking' transformer, also needs to be attached at some convenient place on the aluminium sheet. However if a transformer other then the type specified is going to be used, make sure that it will fit first.

All 18 lamps must be wired in series using the screw terminal blocks. The 'voltage bucking' secondary of the transformer must also be in series. Refer to the Testing section to determine how the primary of the transformer should be wired. Note that if

the transformer primary is reversed, the voltage across the 18 lamps will rise to about 264 volts, not 216 volts as it should be!

Mount the power switch and fuse holder on a small 50mm by 50mm (approximately) piece of aluminium or steel plate and attach it to one of the short sides after cutting a suitable hole in the box. The mains cord must be anchored securely to the side of the box using appropriate clamps. A small 'U' shaped groove can be filed on the bottom edge of the box near the switch and fuse plate, to allow the power cord to come out of the box. In this way, the cord will be held in place when the bottom cover is screwed in place.

Selecting and Handling of Lamps

There are a variety of 50 watt 12 volt quartz halogen lamps available from a number of different suppliers. Not all of them are suitable for use in the light box. The cheaper types tend to have wider manufacturing tolerances in both their current rating and accuracy of focus. Therefore their use is not recommended.

At the other end of the scale, the more expensive types do tend to have more even light spread and require less adjustment to obtain an acceptable light intensity over the full area of the light box.

Other lamps of medium quality are also available and are recommended for use in the light box. Some fiddling of lamp positions may be necessary in order to obtain an even light, but not as much as would be required for the cheaper types. The type listed in the specifications is readily available from the supplier, along with the ceramic bases.

The lamps specified have a protective cover over the bulb. This means that problems associated with touching the bulb with fingers, do not exist. However, any finger marks on the protective cover should be removed before applying power to the lamp. This can be done by using a paper tissue and methylated spirits.

Testing

Before turning on the lamps, check that the voltage between (A) and (B) (refer to figure 1) is about 216 volts. CAUTION. These voltages can be lethal. Only competent persons should carry out these tests using appropriate test equipment.

If the voltage reading is close to 264 volts, then the primary winding of the transformer should be reversed. This must be done with the mains plug removed from the power outlet. When the reading is close to 216 volts, the mains plug should again be removed before connecting the series string of 18 lamps into place.

When all is ready, the light box can be turned on. Since all the lamps are in series, one faulty lamp will stop the rest from working. Faulty lamps can be found by placing an ohm meter across appropriate terminals on the terminal blocks (once the power is turned off!).

As mentioned in the previous section, some fiddling of the lamp positions may be necessary in order to obtain an even light over the active surface, when using the recommended 'medium quality' lamps. This can be done by placing sheets of copying paper over the acrylic cover. The positions of the extra bright (or dull) lamps will show themselves and can be repositioned. Sometimes it may be necessary to reject a lamp completely, but this should be rare.

Once the light intensity variation over the total area of the acrylic sheet is acceptable, the light box can be tested for sunlight equivalence. Ideally a silicon solar panel with an area less then the acrylic top of the light box should be used. Silicon cell based light meters without color correcting filters can also be used.

Place the solar panel at right angles to the sun at midday sun time on a clear day and record the short circuit current (Isc) from the panel. Note that the midday sun time intensity variation between the beginning of October and the end of March for Sydney, Melbourne, Adelaide and Perth, is about 5%. (For Brisbane it may be slightly less and Hobart slightly more.) White woolly clouds within 10 degrees of the sun can increase the solar panel current by over 10%, while high wispy clouds and air pollution can cut the current by over 30%. Therefore, it is important to carry out this test on a clear day. However, the ambient air temperature at the time of the test is not important.

Next, the test panel can be placed on the light box and the Isc measured. If the Isc reading from the light box is not within 5% of the reading obtained from the sun, the lightbox output can be adjusted by changing the taps on the transformer secondary winding. Note that a 5 volt change in voltage will change the Isc reading by about 5%.

That's about it. The light box should now be ready to test model solar racing car panels.

Things to Consider

Cost limitations meant that the mains voltage across the lamps is unregulated. A decrease in the mains voltage from 240 down to 230 volts will cause a decrease in the short circuit current from the solar panels of about 10%. Fortunately however, mains voltage variations of this magnitude in most places around Australia are rare and usually of short duration. Never the less, it is recommended that a separate AC voltmeter be used to monitor the mains voltage and this be recorded at the same time as the solar panel responses from the light box.

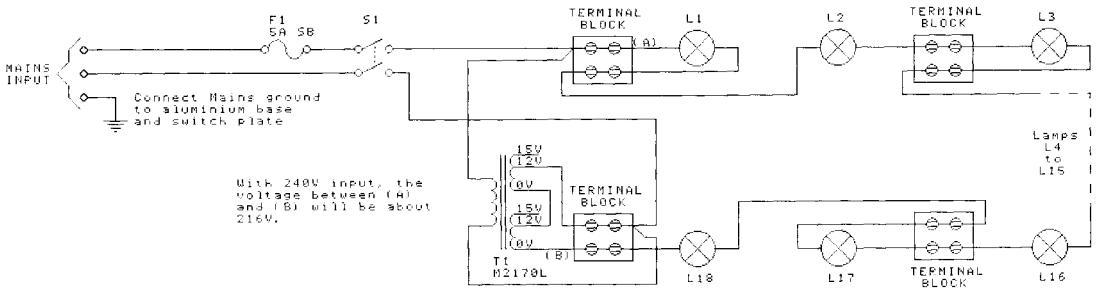

FIGURE 1
LIGHT BOX CIRCUIT

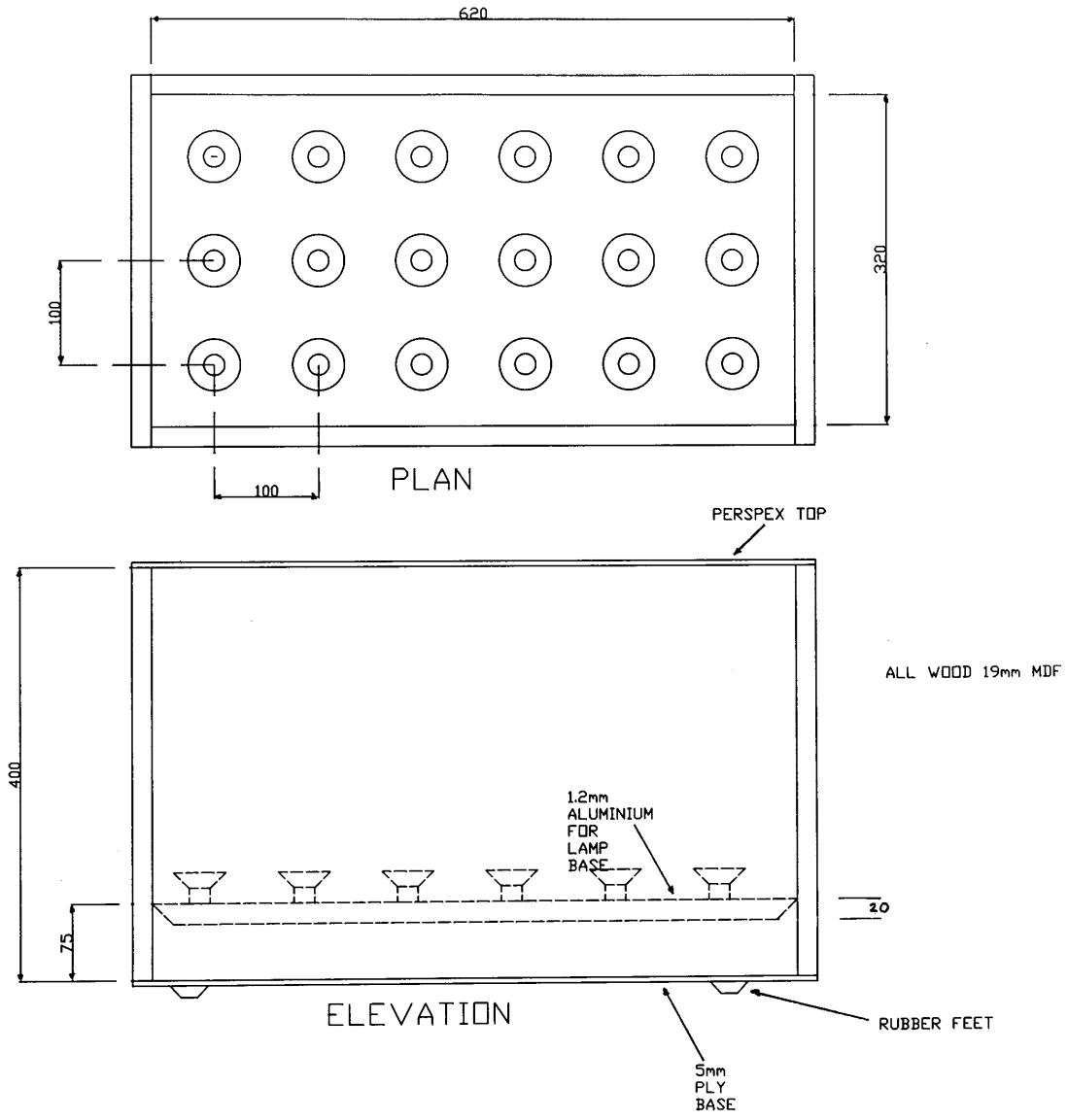

FIGURE 2: SOLAR ARRAY TESTING LIGHTBOX