Cab Lighting Fixtures Using Light Emitting Diodes (LEDs)

Part 2
(Small Scale Live Steam Engine Lighting Fixture Layout and Fabrication)

By

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The first part of this two part article covered the technical aspects and usage of both 3mm and 5mm white LEDs. It also included a two LED lighting diagram with a circuit description. The second part of this article contains the layout and fabrication of cab lighting fixtures using LEDs. A simple lighting fixture can be constructed by following the sequential steps provided which has corresponding sketches and photos to help make it easy. Although only one style of lighting fixture is constructed (**Figure 1,** fixture 2), several variations are possible using similar building techniques and materials described in the article and offers a basis to start from which can be customized as desired.

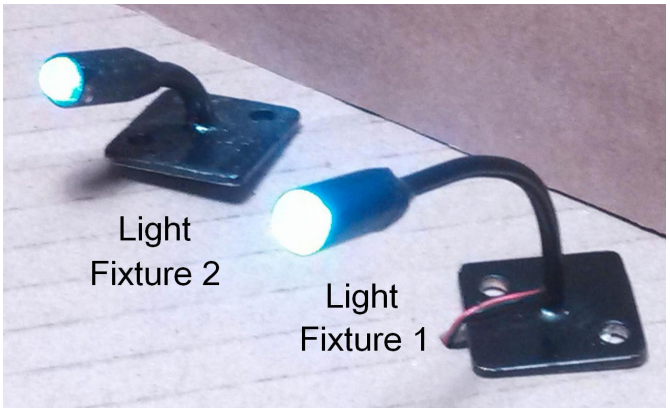

Figure 1

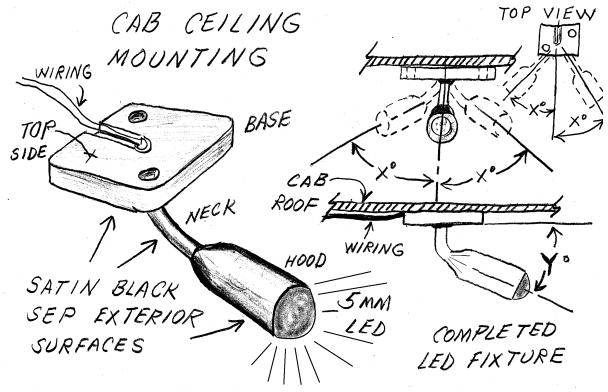

Figure 2

Concept and Layout

It would be presumptuous to expect that one fixture style would satisfy all cab lighting needs, so this article offers a place to begin and create other fixture styles which is only limited by one's imagination. A brief list of general items shown below should help start the process and although it is not a complete list, it should help stimulate some ideas towards a personal layout and/or fixture design.

- Sketch out placement, number of fixtures and wire routing in the cab to see whether or not they will be suitable for installation and produce any unwanted reflective light in the engineer's vision.
  NOTE: *Some potential overlooked problems can include interference with hand access to controls, light fixture placement that help at night but partially blocks the view during daylight, the fastening of fixture being impractical due to heat, location or type of material being mounted on, the type of power source, location (s) prone to accidental damage, type of wiring method and location used from tender to engine, and probably many others.*
- Select an adequate source of power, an electrical protection device and an ON/OFF switch (Bright/dim switch optional) which all should be installed in a convenient place. It is likely that a constant loss battery system will be used to power the light fixtures and be located in a dedicated section of the tender unless the engine is equipped with a steam driven dynamo. Equipping a tender with a charging jack will eliminate the ongoing removal and re-installation of the battery. Depending on the number of LED light fixtures, the use of disposable flashlight batteries may offer a less expensive alternative but the batteries should be housed in a proper battery holder for reliable usage and easy replacement. Although disposable **D** cell batteries provide economical operating power for a cab lighting system for a couple of LEDs, frequent operations at night may eventually justify the cost in the long run for a rechargeable battery and charger.
- Power wiring from the tender battery to the cab lights should have adequate current handling capacity, be routed in such a manner to prevent damage, have adequate flexibility and not interfere with other lines or train equipment.

Before Starting Prior to undertaking this project, it should be noted at this point that this construction process is suggested for those who have a minimum skill level of novice and above average skill level in model building and/or metal working. If the participant is a first time enthusiast, it may be beneficial for him/her to first seek advice and/or help from a qualified individual with experience in these related crafts.

Lighting Plan

In this project a 5 mm LED light fixture will be constructed to illuminate a steam pressure gauge. Looking at the conceptualization sketch in **Figure 3**, the cab roof is shown as a heavy broken outline and is transparent so that the 2 fixture placements can be seen as installed. The light fixtures are labeled as **1** and **2** which are located towards the rear of the cab ceiling and aimed at a downward angle to minimize any reflective light which is pointed out in **Figure 6**. The installed fixtures should not interfere with hands reaching into the cab to operate controls and not be located in such a manner to suffer incidental damage from normal interior cab operations. Referring to **Figures 2, 3** and 4, the **X** and **Y** angles provide the inward offset and downward tilt respectively of the fixture's light output. The sides of the fixture base are mostly parallel with side edges of the cab roof. The amount of **X** angle is the inward swing needed to completely illuminate the width of the water glass for fixture **1**. The **Y** angle is the amount of azimuth or downward tilt from the fixture base surface (cab ceiling) needed to illuminate the entire height of the water glass. The same angle criteria would also apply to fixture **2**. Additionally in **Figure 3** there is an arrow labeled FW (Fixture Wiring) which points to the wiring that connects both fixtures **1** and **2** with the tender power source. On the upper front area of the cab interior the fixture wiring straddles the top back head of the boiler between points **A** and **B.** This section of wiring should be sheathed in a high temperature protective sleeving such as Teflon if the wiring is going to be have virtual contact with the boiler surface. Miniature cable clamps or some other type of fastening method must be used to secure the wiring in place to prevent it from damage or becoming a snagging problem.

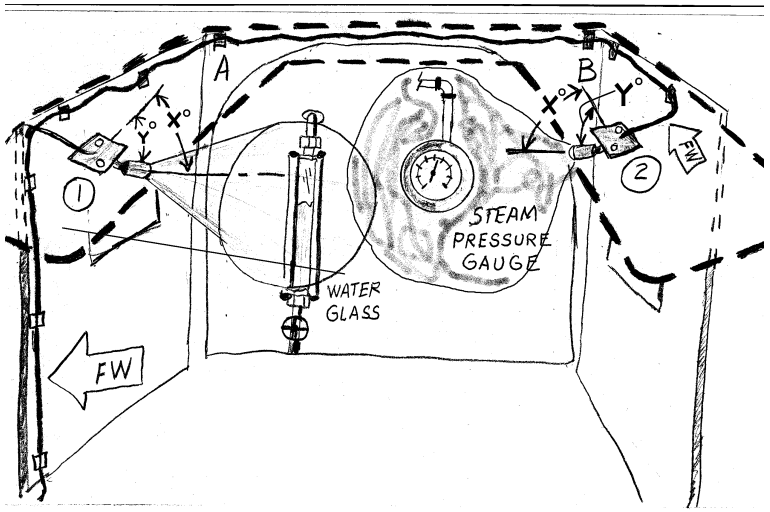

Figure 3

Deciding a Style

At this point a light fixture style should be determined. Style variables include but not limited to long or short necks, straight or curved, a big or small base, hood sizes and so forth. Light output from the LED can be clear or diffused. The LED also can be recessed in the hood or exposed depending on lighting requirements. Whatever choice is made, it will determine the construction process from this point forward. For this article a basic style is shown in **Figure 1,** fixture 2 and to the right in **Figure 4.** It will be constructed with the following features:

- All materials are brass
- Small base with mounting holes
- Grooved channel in the base for LED leads
- Short curved neck, smaller diameter
- Short hood for exposed LED
- Black satin paint finish
- 5mm diffused LED
- 24" LED leads [1-Black, 1-Red]

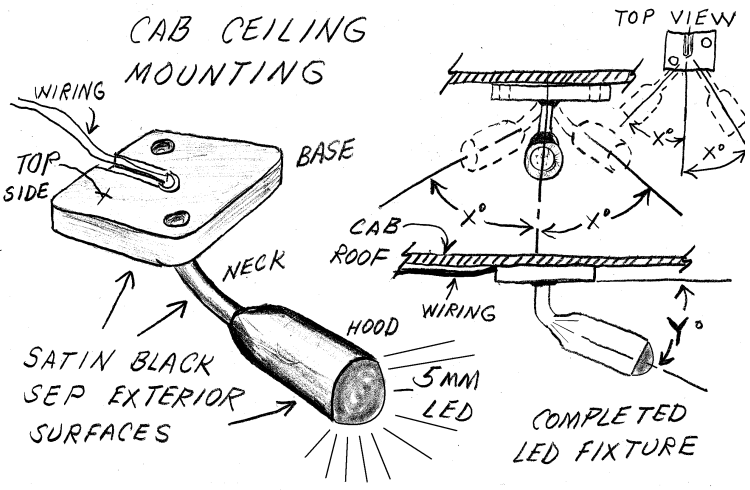

Figure 4

In **Figure 4** some of the features of the proposed fixture are shown. The **X, Y** angles have been determined and the fixture has an exposed diffused LED which produces a lower intensity light output but will illuminate a larger area than fixture 1 in **Figures 1** and **3.**

Preview In Faux Cab of Working Fixtures

In sort of a “sneak peek” look, **Figures 5 and 5A** show an engineer’s view running at night using a mock up cab and a couple of lighting fixtures from **Figure 1**. They are installed as drawn in the conceptual sketch from **Figure 3**. Light fixtures **1** and **2** are suspended in place to simulate a cab ceiling mounting with the use of 1/8” aluminum rods. Fixture **1** has a recessed LED with a clear end producing a brighter but smaller beam of light. Fixture **2** uses an exposed LED with a diffused end to cover a wider area with less intensity. Although the water level is barely distinguishable in the light coming from fixture 1 in the photo of figure **5**, it is easily seen in actual operation which is a better option than in **Figure 5A** with only fixture **2** lit. If a throttle handle and Johnson bar stand were included in **Figures 5** and **5A** they would be visible. **Figures 5** and **5A** clearly show the differences between a single fixture versus two fixtures and the light comparison of clear and diffused LEDs. Even with a single light fixture ideally placed using a clear or diffused LED, there would be insufficient light to see both the water level and steam pressure gauge for the open cab roof style shown in **Figure 3**.

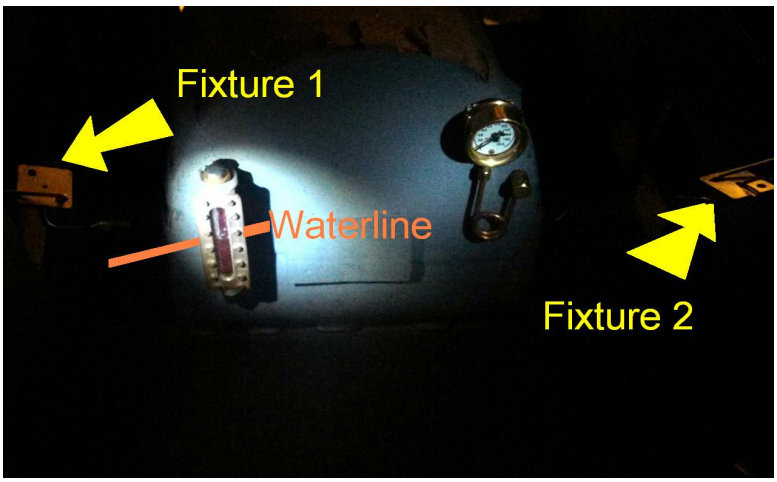

Figure 5

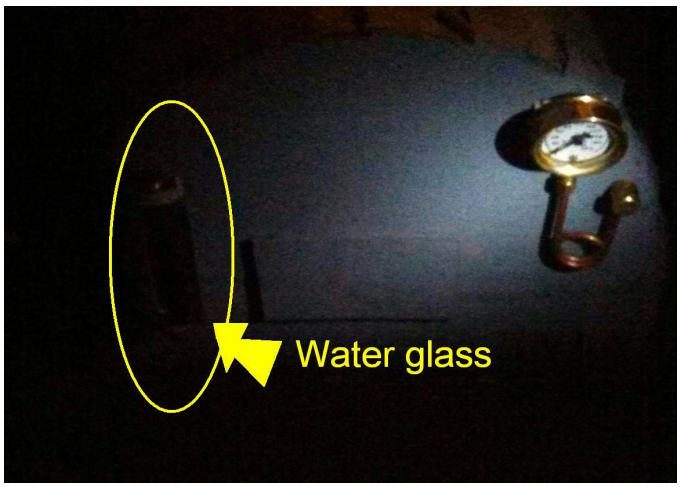

Figure 5A

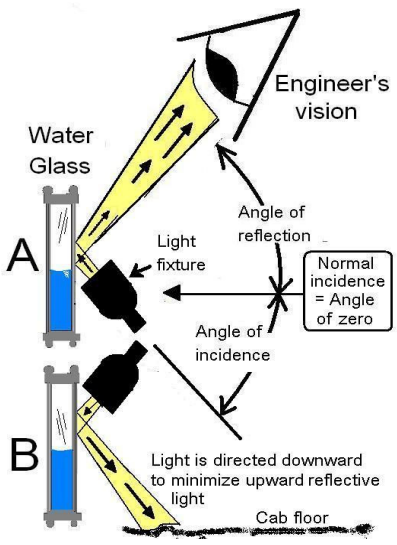

Figure 6

In **Figure 6,** light from the fixture is shown reflecting off water glass examples **A** and **B**. Upward projected light from the light fixture produces unwanted glare towards the engineer’s vision from water glass **A**, whereas the downward projected light on water glass **B** is minimal as it mostly disperses across the cab floor. Unexpected and unwanted reflective light from shiny surfaces are sometimes discovered only after the fixtures have been installed. In some cases it may be difficult to change a fixture’s location or modify it in order to eliminate the glare. For these situations it is possible to apply a flat type of paint to the offending area or in extreme cases “slightly” reforming (carefully bending) the light fixture’s neck to redirect the light only as needed. However this tactic should be considered as a last resort effort.

S A F E T Y F I R S T

*** * * IMPORTANT * * ***

The construction of any items as described in this article requires the use of hand and power tools, a soldering iron/gun and exposure to a corrosive liquid. ***Participants utilizing this article do so at their own risk****. It is strongly recommended participants have a working knowledge and have sufficient skill on the use of equipment and handling of materials needed in this process while observing related safety practices at all times and wearing proper safety equipment.*

Fixture Material Selection

There are different materials available which can be used to build a light fixture (*aluminum, brass, stainless steel)*. An example of a completed fixture in shown **Figure 1**, light fixture 2 and **Figure 29** at the end of this article. It is constructed out of brass which is a good material because it is economical, readily available, comes in a variety of shapes and thicknesses and will not rust. It is also has sufficient strength for this application and has an affinity for low temperature alloy soldering. silver soldering or brazing processes.

Suggested Tools and Material

TOOLS: Needle nose pliers, small diagonal pliers, hack saw (32T blade), tin snips, Dremel tool w/asst bits, ruler, small tube bender, drill press (preferable), drill bits, wire strippers, fine flat and round files or set of jewelers' files, 40W or 60W soldering iron with chisel and small pencil tips (both types preferred) or soldering gun (not recommended for soldering LED leads) for soldering fixture pieces, modeler's vise or builders clips and cotton swabs, (optional - pin vise and flush cutter pliers)

MATERIALS: Assorted brass stock as shown in **Figure 7**, low temperature alloy solder (high strength), liquid solder flux, small diameter rosin solder (60/40 preferable), 5mm LED white-ultra water clear, 24" 26 gauge stranded wire 1Black & 1Red w/.040" max O.D. insulation, 3/32 diameter X 3/16" L heat shrink piece, cotton swabs, sheet of #220 grit abrasive paper, small section of #1000 grit abrasive paper, denatured alcohol, black satin finish SEP primer spray paint, black satin spray paint finish coat, small Teflon sleeving or equivalent material (E.M. = solder will not melt or adhere to it), Nitrile rubber disposable examination gloves.

Fabrication Begins *It is recommended that **ALL** steps be read and understood before attempting to build the fixture.*

The following steps are in sequential order of construction. Most steps have corresponding drawings and photos for each specific stage. It may be beneficial to use a small vise or some builders clips to secure pieces that become HOT during assembly and when applying soldering flux. Since the fixture is being mounted on the cab ceiling, the normal **TOP** and **BOTTOM** surfaces of the base have been **" reversed "** to save confusion as installed. **NOTE:** Ensure no portion of the hood or neck alignment interferes with the mounting hole openings in the base before soldering.

1. ***Component Preparation*** Refer to **Figure 7, 8.** Obtain the materials shown in the illustration. Prepare the raw pieces shown for later assembly. Deburr all ends and edges of the pieces, slightly chamfer fixture base holes.

2. ***Hood Preparation*** Refer to **Figure 9** and **10** As shown make a series of 8 equally spaced cuts on one end of the fixture hood. Using needle nose pliers carefully twist each cut section and collapse it on each adjoining section to form an open tapered (cone) shape end. Ensure there is sufficient opening at the twisted sections to allow the neck tubing to be inserted.

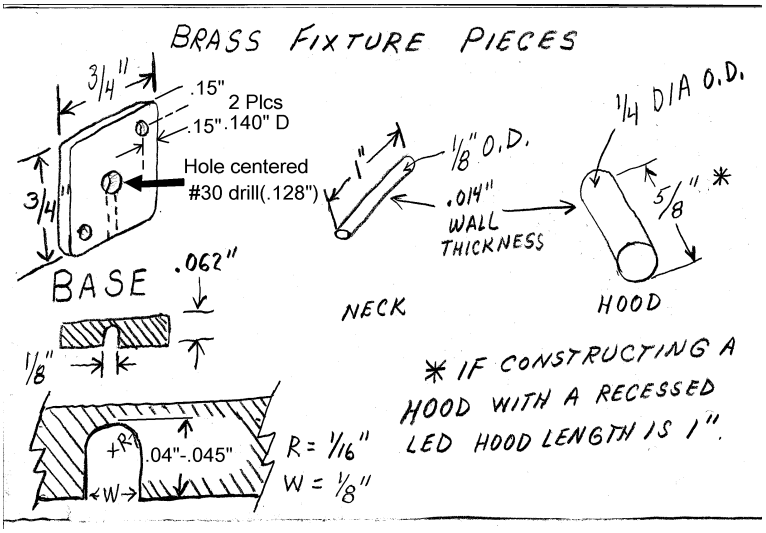

Figure 7

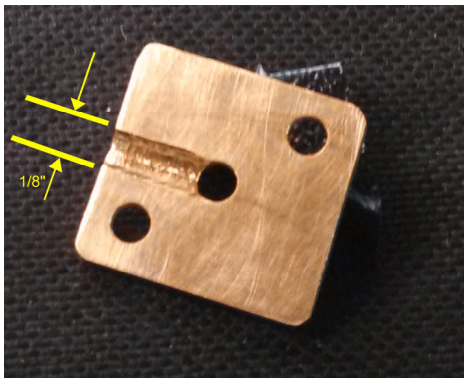

Figure 8

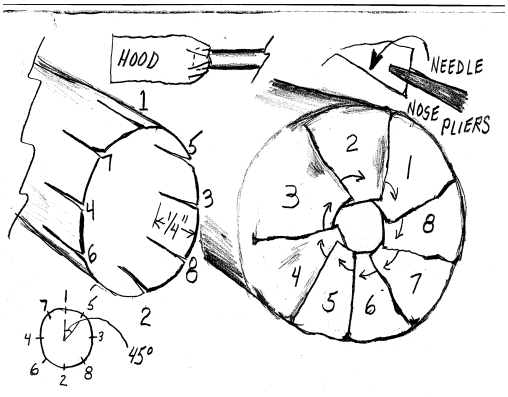

Figure 9

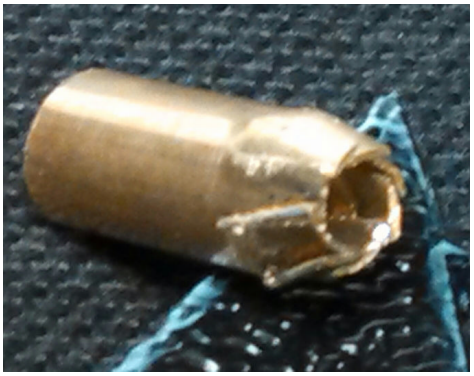

Figure 10

3. ***Neck, Hood and Base Fitment*** Refer to **Figures 11, 12, 13** At this point if the fixture calls for a curved neck it must be formed before being soldered in the hood piece. Once the neck has been formed insert it as shown in the hood to the correct depth. Check for fitment. (Note: *It may be necessary to repeat adjustment of the neck diameter opening to ensure correct fitment. Proper fitment allows the neck to slide freely when it is moved in or out of the opening but not be excessively loose or sloppy*). At this time insert the other end of the neck into the fixture base neck hole for fitment. If tight, increase the opening of the hole to provide more clearance but not excessively loose. Some clearance of a few thousandths of inch is needed for proper flow of solder to fill the gap between the neck and the hole in the base.

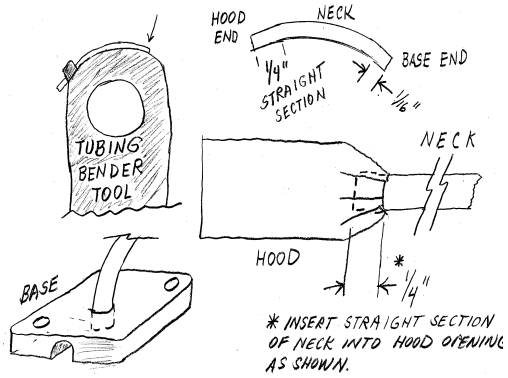

Figure 11

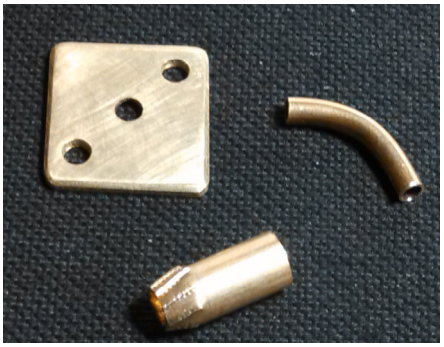

Figure 12

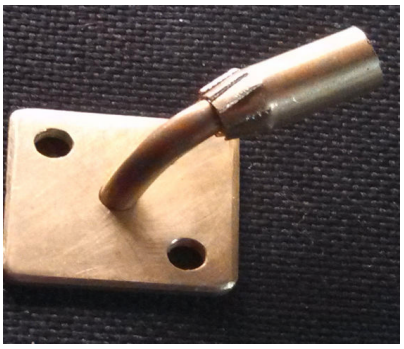

Figure 13

4. ***Solder Preparation*** Refer to **Figure 14** Remove the neck from the opening. Place the hood in a holding device so that it can be positioned as an aid when soldering the neck in place. Tightly insert one end of some Teflon sleeving or E.M. into the open end of the neck used for hood fitment. Ensure that sleeving is secure in place to prevent solder from flowing into the **neck** during soldering. Cut the other end of the sleeving leaving it long enough to extend beyond the open end of the hood for removal after soldering is completed. Using a cotton swab soaked in liquid flux, apply it liberally to the end of the **neck** to be soldered and the indicated surfaces of the cut sections of the hood. Feed the free end of the sleeving into hood opening with the cut sections being careful not to loosen the other end of the sleeving in the neck to a depth as shown in **Figures 11** and **14.**

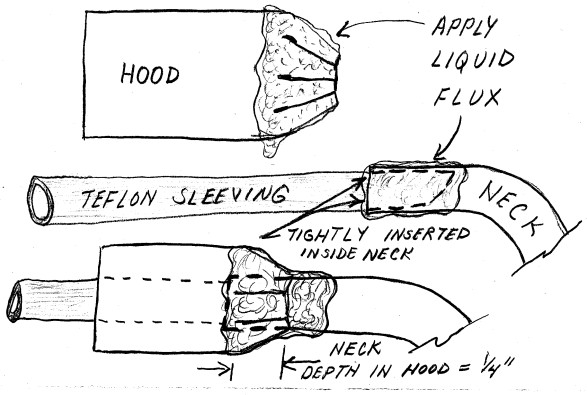

Figure 14

5. ***Soldering the Hood and Neck*** Refer to **Figures 15, 16, 17, 18.** Solder the area a using low temperature high strength alloy solder as shown while ensuring correct alignment of the neck and hood pieces. Allow pieces to sufficiently cool. Re-check alignment and make any adjustments if needed. Remove Teflon sleeving and rinse soldered areas with clean water and dry. Verify inside the hood, the **neck opening** is completely clear of solder, if not use various sizes of drill bits installed in a pin vise to remove excessive solder, ***AVOID USING POWER DRILLS*** as their torque will twist and deform the hood and/or neck if the drill bit snags inside the hood. Depending on the amount of solder that has built up during soldering of the hood/neck joint, some removal of the excess solder and /or exposed edges of the twisted hood sections may need filing down and smoothed as shown in **Figure 21**. Verify solder has flowed inside the very back area of the hood and has completely encircled the neck tubing **but not entered the neck opening.**

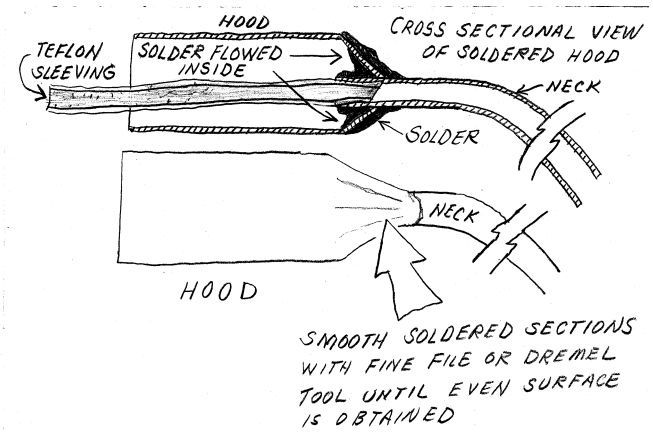

Figure 15

Figure 16

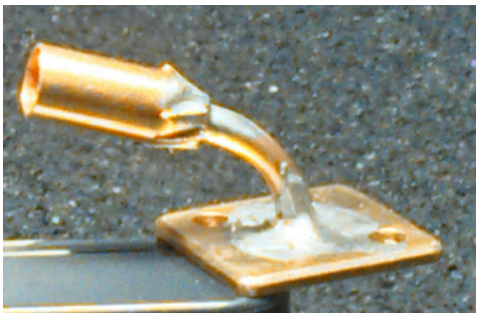

Figure 17

Figure 18

6. ***Soldering the Neck and Base*** Refer to **Figures 17, 18, 19, 20, 21, 22** Position the fixture base so it can be soldered as shown, as before tightly insert the Teflon sleeving or E.M. into the unsoldered end of the neck and feed it through the neck hole of the base until the end of the neck **slightly** protrudes on the mounting side. Once dry fitment is acceptable remove the neck from the base just enough to liberally apply flux as shown to the neck and base hole area. Insert the neck as before and ensure neck alignment will be correct for soldering. Likely the neck will have to be held in place with aid of a device or another person while soldering. **Verify base holes are NOT blocked by the hood or neck**. Solder the neck at the base as shown while ensuring correct alignment is maintained. Allow the pieces to cool sufficiently. Check neck /hood alignment and adjust if needed. Remove sleeving and rinse the soldered areas with clean water and dry.

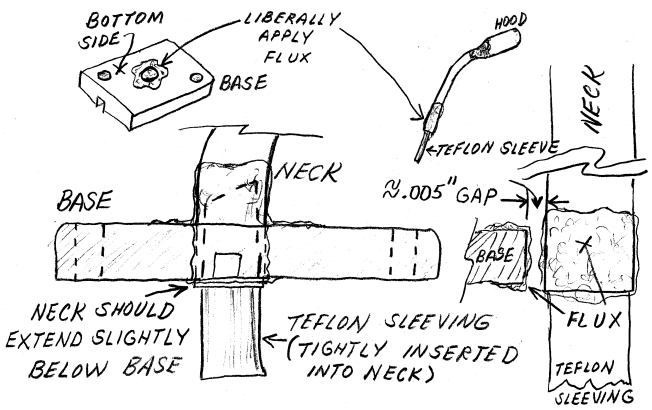

Figure 19

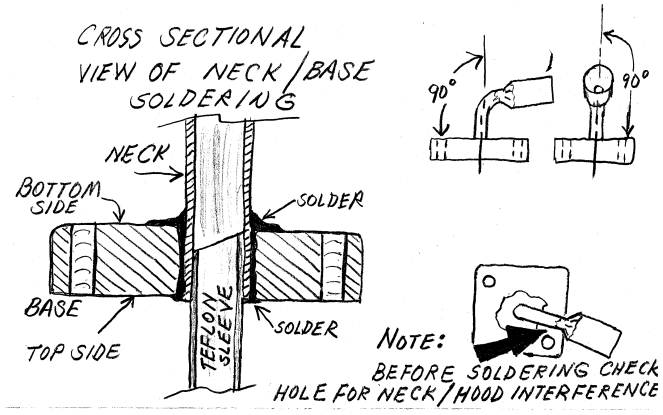

Figure 20

Figure 21

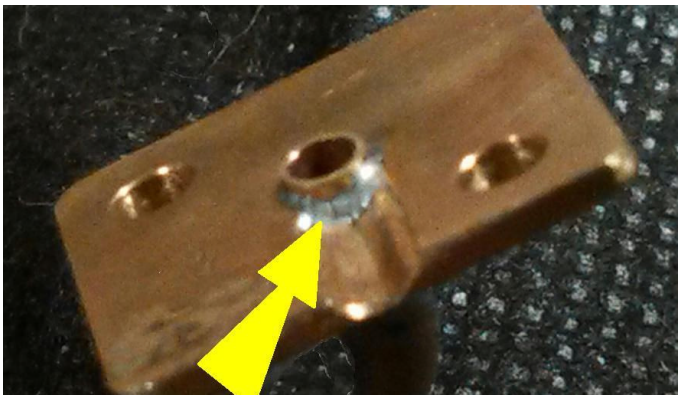

Figure 22

7. ***Base Touchup*** Refer to **Figures 22, 23** Create an even surface for the mounting side of the base by pressing it downward onto a sheet of #220 grit abrasive paper resting on a hard flat surface. Move the base it in a circular motion until the small protruding neck material is flush with the base. Verify that the neck opening in the base is free of solder, and if not it must be cleared at this time.

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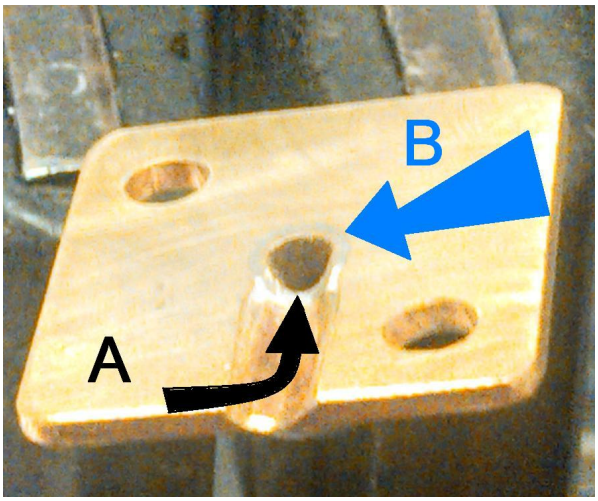


Figure 24

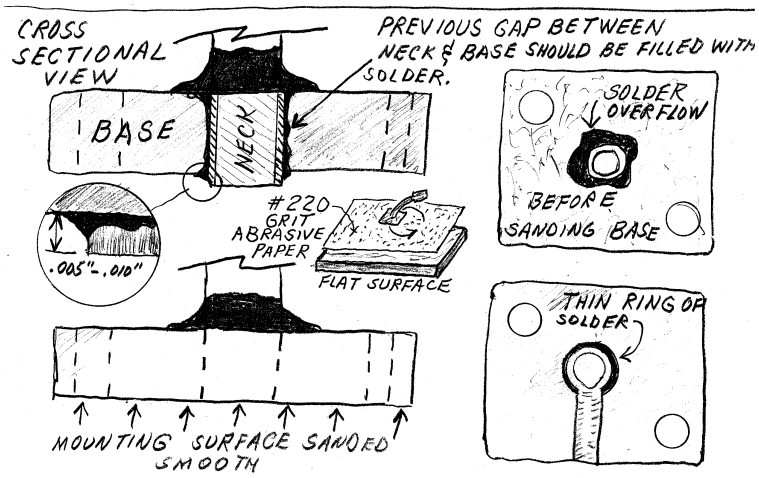
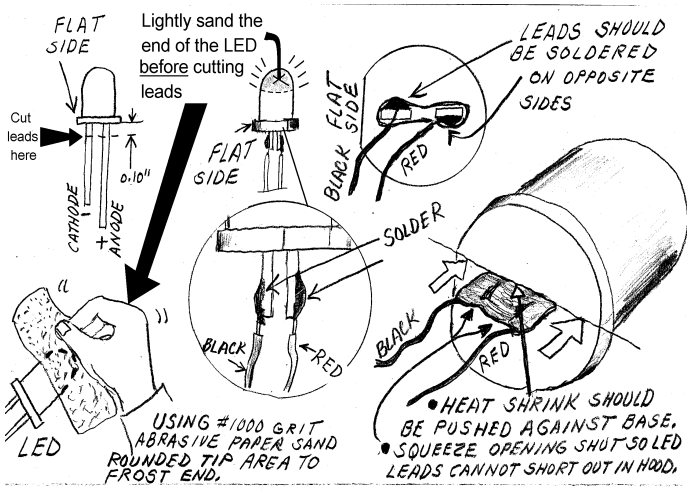


Figure 23

8. **Final Base Work** Refer to **Figure 24** A thin ring of solder between the neck and the base should be visible after sanding as shown at arrow **B.** There is extra neck material blocking the LED wiring groove shown by the arrow in **Figure 22.** It **must** be removed, deburred and smoothed sufficiently as shown at arrow **A** to prevent piercing the LED wiring insulation when it lies in the groove once the fixture is installed.

Figure 25

9. ***Soldering LED Leads*** Refer to **Figures 25, 26, 27** Before cutting the LED leads use a small piece of #1000 grit abrasive paper to lightly sand the rounded end area of the LED. Trim the LED leads as shown to 0.1" length, using small diagonal or flush cutter pliers. Secure the LED body in place for soldering leads onto the LED terminals. Using 60/40 rosin core solder, solder a stranded black #26 gauge wire lead to the negative terminal (Cathode) of the LED, then solder a stranded red #26 gauge wire lead to the positive lead (Anode) on the opposite side of the lead as shown in **Figure 25. CAUTION**: ***minimize heating of LED leads by limiting soldering time to 3 seconds or less at 750 degrees F*** Slip the piece of heat shrink onto the leads pushing it up against the base of the LED (**Figure 27**, arrow **A)** and shrink it in place as shown using the tip of a soldering iron or heat gun again keeping heat applied only long enough to sufficiently form the heat shrink in place while squeezing it completely closed with needle nose pliers as shown in **Figure 27-** arrow **B**, **NOTE:** *This will reduce the chances of the LED connections contacting the interior back surface of the hood and shorting out*. **Before** proceeding to the next step, it is recommended to test the LED for illumination with clip leads (test jumpers) or tack solder LED wire leads onto a current limiting resistor to a 12 volt power source as shown in the diagram of part 1 of the article. **NOTE:** when the inside diameter of the hood is smaller than diameter of the LED's flange (Figure **26**) it can be reduced by sanding or filing or a Dremel tool using the appropriate bit, *Removing the flange with diagonal pliers or flush cutters is NOT recommended as the epoxy body of the LED could fracture risking the possibly of permanently damaging its internal connections*.



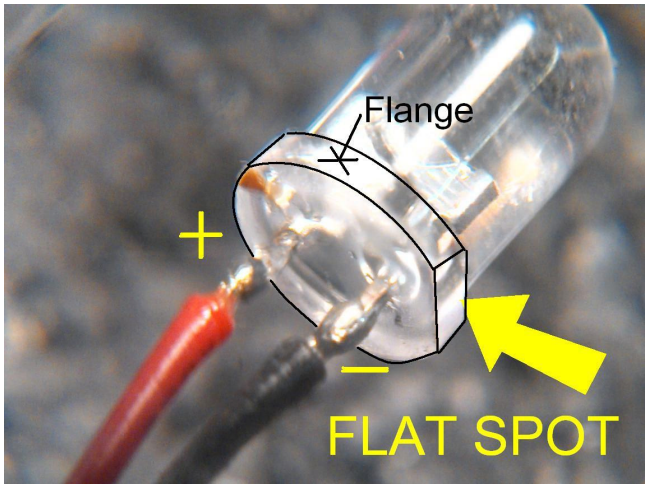


Figure 26

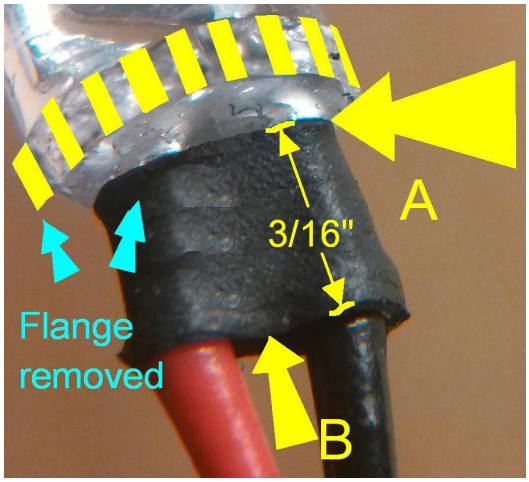


Figure 27

10. ***Fixture Painting*** Refer to **Figure 28** Close off the hood opening by inserting it with some paper tissue or equivalent material. **NOTE:** *Smooth or shiny brass surfaces may require roughing up using #220 grit abrasive paper for better paint adhesion*. It is suggested to test paint on a separate piece of brass before painting the fixture. Wipe all fixture surfaces with a clean dry rag dampened in denatured alcohol. **NOTE:** *Avoid petroleum solvents as they can leave a residue*. Once the alcohol has entirely evaporated apply a spray coat of satin black SEP (self etching primer) or a builder's preferred paint in a well ventilated area. Once the paint has dried thoroughly, spray a finish coat using black satin paint. When the finish coat has dried completely, remove the tissue and proceed with the LED installation.

11. ***LED Installation*** Refer to **Figure 28** Use the following technique if the soldered LED wires are not rigid enough to push all the way through the neck of the fixture:

Attach the free ends of the LED leads to a loop on the end of a "fish" line made from a solid stiff wire such as a metal guitar string or a small safety wire by forming a tiny loop or use another technique that will allow the leads to be pulled through the assembled fixture pieces. Insert the free end of the fishing wire into the hood opening and continue pushing the wire into the neck opening until the wire emerges from the opening in the base. Grasp and carefully pull on the fishing wire until the LED leads can be used for pulling.

At this point when either the LED leads or the fishing wire becomes available, continue pulling the LED towards the hood watching the LED as it reaches the hood opening. If the wire binds at any point, withdraw it, fix the source of the bind, clear it and try feeding the wire again. Once the LED reaches the lip of the hood opening make sure it will enter without snagging. When it is about halfway into the hood slowly push it in as far as it will go while keeping a slight tension on the leads to prevent them from bunching up inside the hood. **DO NOT** jam or force the LED into the hood.

12. ***Construction Ends*** Prior to installing the fixture it is suggested to apply power to ensure the connections or the wiring has not been damaged during the insertion of the LED into the hood. **Congratulations!** The fabrication of the cab light fixture is now complete and ready to be installed. The fixture leads should have sufficient length for most interiors to reach either a scaled electrical junction enclosure or other connection point inside the cab. The leads should run through a protective sleeving especially if they are going to be exposed to high temperatures or have chaffing problems. If fastener hardware is going to secure the fixture, ensure that LED leads are within the base groove and are not pinched once the fixture is installed.

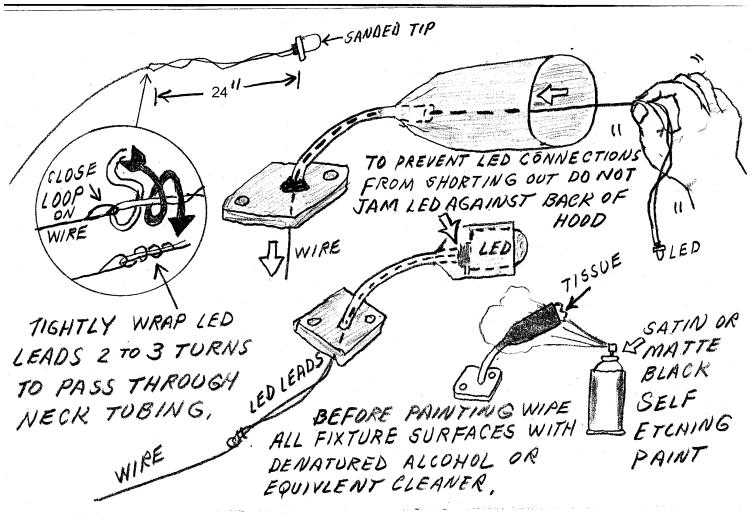


Figure 28

13. ***A Last Reminder*** Going back to Part 1 for a moment, there was some discussion about the necessity of limiting current for LEDs. As the author of this article I can personally attest to the fact when you connect a LED to a power source **without** the benefit of a current limiting resistor...you are quickly rewarded for your mental lapse by helplessly watching the device promptly destroy itself as it bids you a permanent "good bye!". ***Always try to keep in mind where there is a LED, it should have a resistor as well.*** There are some *exceptions* however to the resistor requirement. Whenever a LED is connected to a power source that has been specifically designed to supply safe operating voltages and currents, then the requirement no longer applies. In other cases there are LEDs that have been specifically manufactured with internal current limiting circuitry.

If the builder has constructed a light fixture by following the steps from this article and wishes to do so, they can checkout their effort against the fixture in **Figure 29** at the right. (Due to the type of light present when this photo was taken, the black painted fixture appears to have a bluish tint).

Figure 29 – 5mm diffused, exposed LED light fixture.

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