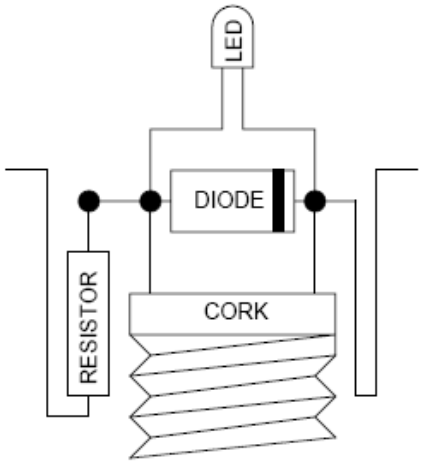
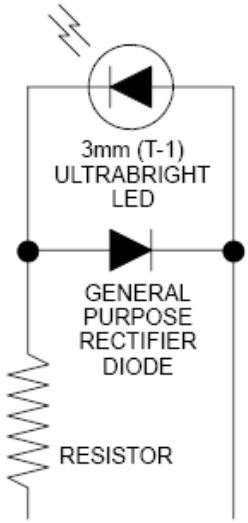
LED HEADLIGHT RETROFIT
for
American Flyer Steamer (314AW shown)

The objective of this modification is to replace the incandescent 18VAC headlight bulb with an ultrabright LED in such a way that the process is completely reversible, i.e., no permanent modification to the engine. Also, unlike some LED bulb replacements, this arrangement allows directing the LED's maximum output through the headlight opening. This document depicts one alternative which is known to work. There are, no doubt, countless others. Although this particular modification was on a 314AW engine, it should work on any steamer with a similar boiler front/headlight socket arrangement.



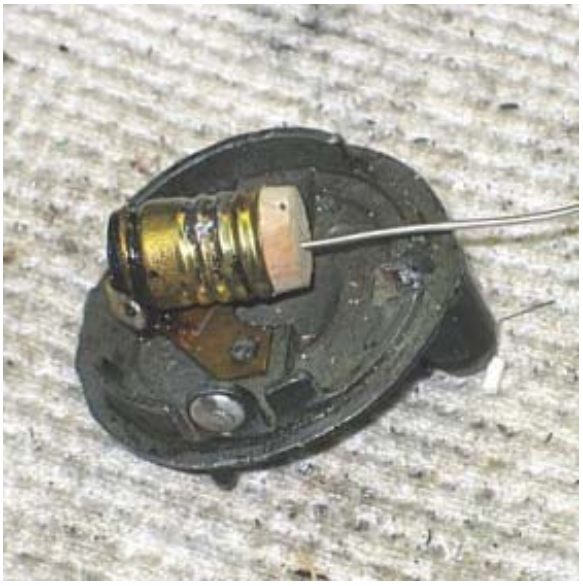
DIAGRAM



SCHEMATIC

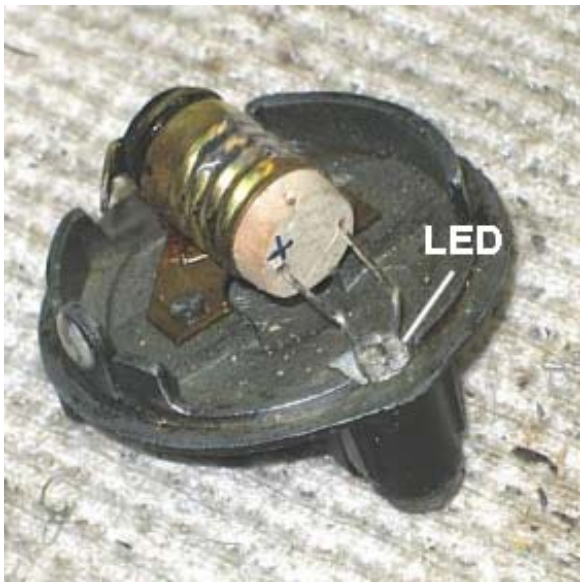
The figures to the left provide a simplified diagram of the component layout, and an electrical schematic. What follows is a pictorial presentation on assembling the components. A limited discussion of electrical considerations is at the end of this document.

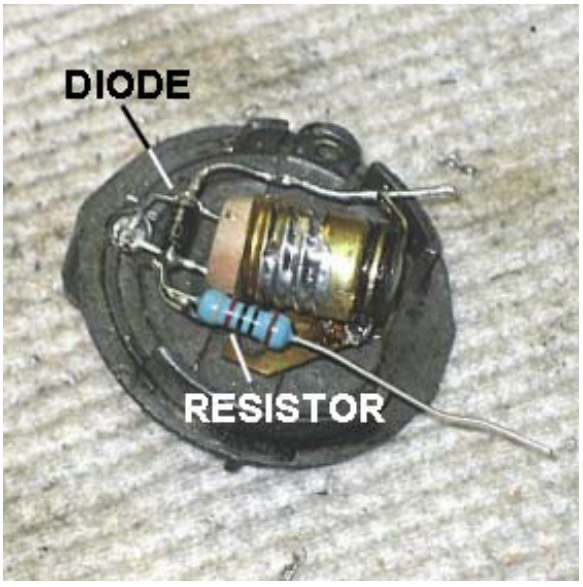
1. Remove the boiler front from the engine; then remove the bulb and the attached wiring. Now fashion a piece of cork that fits tightly into the bulb socket. Start with a small cork and file it down with a fine metal file. Be sure to leave a bit of cork protruding to facilitate removal should modification reversal ever be required.



2. Using a small diameter probe (20 gauge copper wire with insulation stripped shown here), poke two holes in the cork near the outer edges, on a diameter parallel to the boiler front. The holes need to be far enough apart for the rectifier to fit between them. Be careful that the holes do not allow contact with the socket sides as these holes will be the mounting holes for the LED leads.

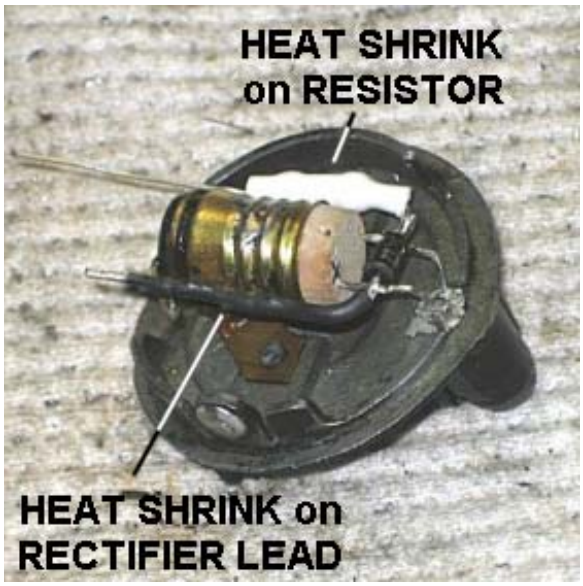
3. Clip the LED leads short enough so that when the LED is inserted into the holes and bent into position in the headlight opening they do not touch the bottom of the socket. Note the positive (longer) LED lead has been marked on the cork. Lead length may be adjusted by inserting the LED before the leads are bent, noting how much the leads need to be shortened, removing the LED, and then clipping the leads. An iterative approach (a little at a time) will insure the leads are not cut too short. Once a proper length is achieved, bend the LED into the headlight opening. Use a fine needle nose pliers to grip both leads firmly at the same time and pull the leads away from the headlight opening while bending the LED into the opening. If possible, before proceeding, use an ohmmeter to verify that the LED leads are not contacting any metal part of the boiler front or socket.





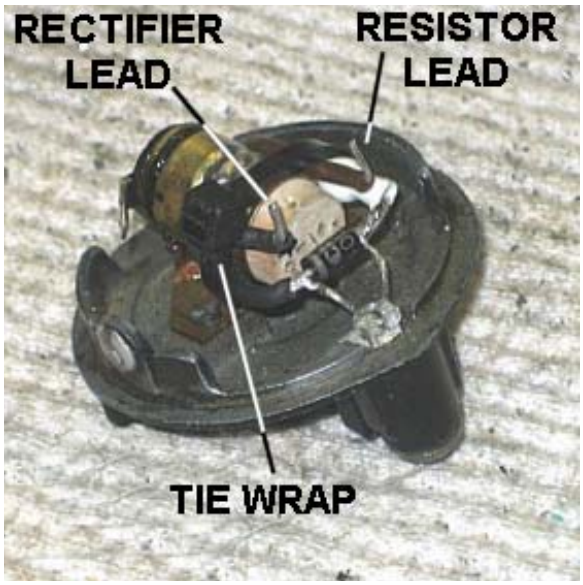
4. Solder a rectifier (1N4001 shown) across the LED leads. The “arrow point” of the rectifier (the lined end) should be connected to the positive LED lead. After soldering, clip the left rectifier lead as shown and solder the resistor (1 K ohm, ½ watt shown) to the clipped lead. Bend the other rectifier lead down along the side of the socket parallel to the resistor.

5. Insulate the bare rectifier lead and resistor with heat shrink tubing (resistor insulation is optional). Then insulate the remainder of the resistor lead (not shown here). In lieu of heat shrink tubing, insulation stripped off of scrap wire may be slipped over the bare leads to insulate them.



6. Bend the insulated rectifier and resistor leads back up toward the top of the boiler front (essentially bending them back on themselves), and secure them in position with a small tie wrap around the socket. As the leads are insulated and the socket will not be energized, a wire tie could also be used to hold these components together. This rigidity is required to insure that the electrical connection points cannot move around within the boiler.

7. With the leads secured to the socket, bend them 90 degrees away from the boiler front. These will be the attachment (solder) points for the leads coming from the smoke box.



8. Although the “fit” of this assembly checks out OK, a little electrical insurance will be obtained by coating the LED leads with a dab of “liquid tape” as shown. Although white is shown here (it was handy), black is also available. Black may be preferable … if it is also used to also coat the back of the LED, it will help prevent any light leaks around the edge of the boiler front if it does not seal tightly against the boiler shell.

9. View inside boiler after installation of boiler front showing clearance inside boiler.

10. The finished product. If the LED light is too white / blue for your liking, try placing a circle of transparent yellow film between the LED and the headlight lens. The plastic tabs from old notebook dividers are a potential source of such material. Note that although there are circuits which will hold the LED illumination constant regardless of applied voltage (e.g., while varying engine speed), this circuit works just like the incandescent bulb, illumination intensity varies with speed (though less noticeably so than with the incandescent bulb).

Components

The LED used is an ultrabright white, 3mm diameter, T-1 LED from LedTech, part number UT03W3-41-URC2, available from All Electronics (www.allelectronics.com) as their item number LED-83 ($1.20 as of this writing). The pertinent specs are a reverse voltage of 5 volts, a forward current of 20 milliamps, and a forward voltage drop of 3.6 volts (4.0 max).

The rectifier diode required is a general purpose rectifier with a peak inverse voltage rating of at least 35 volts and a current capacity of at least 100 milliamps. These requirements were picked because they are standard sizes and adequate for this application. The diode used here is a 1N4001 (1 amp, 50 PIV). It's common and was available.

The required resistor must be of sufficient size to limit the current through the LED to 20 milliamps or less. The resistor used here is 1000 ohms, ½ watt.

Electrical Considerations

Light emitting and rectifier diodes tend to be thought of in DC terms, however in this case they are being used in an AC powered circuit. The rectifier diode is required in the circuit "opposing" the light emitting diode to prevent the LED from being subjected to a reverse voltage beyond its capability. In the schematic at the top of this document, when the imposed AC voltage causes current to flow from right to left, the rectifier blocks flow in its circuit branch while the LED allows current flow and illuminates. The voltage drop across both diodes at this point is typically less than 4 volts, the LED's maximum forward voltage drop. When the AC voltage "reverses" and prompts current flow from left to right, the LED blocks current flow in its branch while the rectifier allows current flow. The voltage drop across both diodes at this point is typically less than 1.1 volts, the rectifier's maximum forward voltage drop. If the rectifier were not present, the full AC voltage would be impressed upon the LED in the reverse direction … and that would be what? The common values used to describe AC voltage levels are actually RMS (root mean square) values. RMS values are on the order of only 70% of the actual peak voltage levels (when the AC voltage sine wave peaks). So a train transformer with a measured AC voltage (most voltmeters measure RMS) of 16 volts actually has a peak voltage around 23 volts. The poor little LED with a reverse voltage rating of 5 volts isn't going to stand a reverse voltage of 23 volts for too long. It might last for a while since the peak is intermittent and the voltage is varying (allowing some recovery), but this stressing can cause fundamental changes of the junction materials in the LED which will eventually lead to its failure.

It almost got lost in the forest of the above paragraph but what happened to the rest of that voltage? If there are 23 peak volts being applied to the circuit and the drop across the diodes only varies from 1.1 (rectifier) to 4 volts (LED) maximum, where's the other 19 to 21.9 volts? Across the resistor! Assuming a worst case peak of 23 volts (at very low current the rectifier forward drop will be less than its 1.1 volt max) and a maximum current of 20 mA, Ohm's law yields a resistor of 1150 ohms (resistance = voltage/current). Interestingly enough, when this particular circuit (1000 ohm resistor) was tested, it drew 17.5 mA (RMS meter) while operating at 16.34 volts (RMS meter) … which suggests that peak current is hitting 25mA … but that current is only flowing ½ cycle through the LED (and ½ cycle through the rectifier) so the "average" impact on the LED is significantly less. Since the LED is rated for 20 mA on a continuous basis, it's likely capable of this very intermittent "overload". In fact, there are any number of circuits published for such application which use a significantly smaller current limiting resistor, apparently without issue. The power dissipated in the circuit is calculated at 0.286 watts (measured voltage * measured current) and it is almost all dissipated in the resistor, so a ½ watt resistor is fine. A ¼ watt resistor would be a little dicey.

An aside, measurements of the original 18VAC incandescent bulb showed it to be drawing 3.6 watts. This circuit draws less than 0.3 watts. That's a power reduction of 92% !

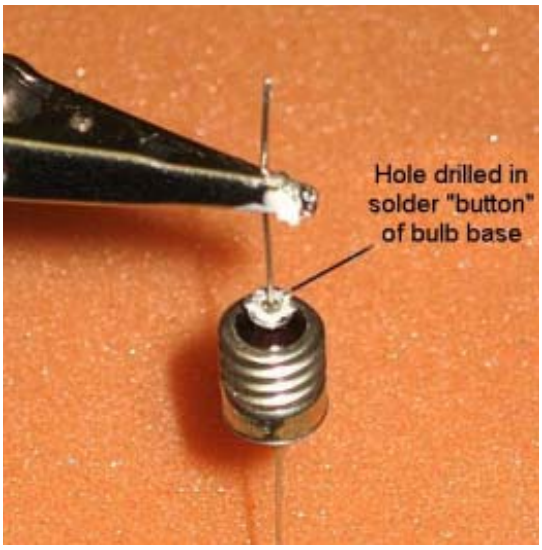
TWO LED HEADLIGHT RETROFIT
for
American Flyer Steamer (302 shown)

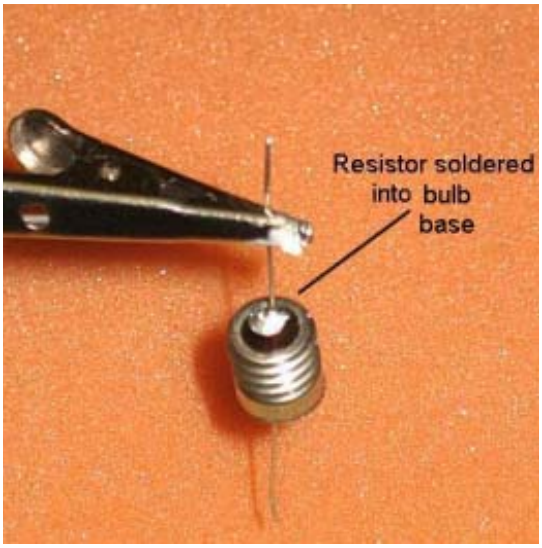
Subsequent to posting the previous retrofit detail on the Yahoo S Gauge Users Group, a response from Tim Benner asked if it would be possible to use two “opposing” LEDs in lieu of a diode opposing the headlight LED. Specifically, the question was could a red LED be used as the second LED so as to provide colored illumination from inside the boiler smokestack thus simulating a fiery glow from within. This type of simulation was a standard feature on some of the later engines, achieving the effect by using a red colored plastic smoke tube and painting the interior of the boiler smokestack white. Tim also mentioned he had made an LED replacement by assembling the components in the base of a burned out bulb. Merging these questions and comments with the above approach yielded the following alternative – a dual LED replacement constructed in a bulb base. Though it still requires some bending of the headlight LED leads, this assembly can actually be removed/replaced from the boiler front socket more readily than the previous approach.

1. Obtain a burned out or otherwise expendable lamp, and carefully remove the glass, cement, and wiring therein. One way to accomplish this is to crush the glass with a pliers while holding the bulb down in a trash receptacle. The point is to contain all the bits of breaking glass. Be sure to wear eye and hand protection. The glass and cement which remains in the bulb base can slowly be ground out by hand using various size drill bits, small dental style picks, and a fine needle nose pliers. Use proper protection and take care to contain all the bits. Use of power tools here is not recommended both because of the risk of flying pieces and the likelihood of deforming the bulb base in properly securing it. It would be extremely dangerous to be holding something as small as a bulb base while drilling or grinding in it with a power tool.

2. Obtain a small cork and cut / file it down so that it will fit inside of the bulb base. Test fit the cork by screwing it down into the base. The cork will conform to the threads in the base and can be screwed in and out. The best result will likely be obtained by a few iterations of trimming, fitting, trimming, etc. The cork need not go all the way down in the base, but it needs to be enough to result in a firm, tight fit. The top of the cork will be cut down to size in a later step. Remove the cork prior to the next step.

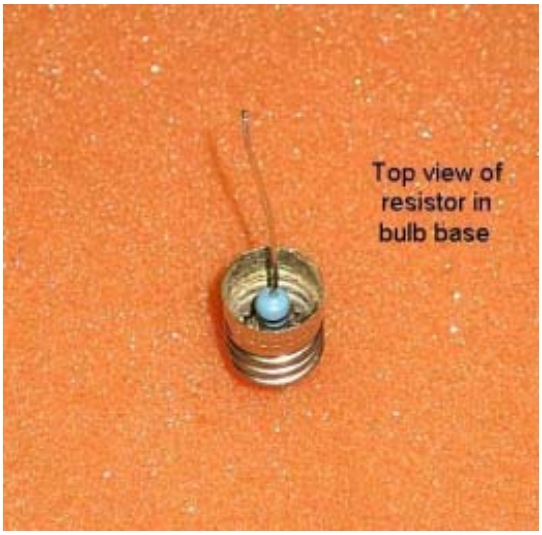
3. Drill a hole in the bottom center of the base. Drilling from the inside will make this task easier. Unlike the grinding required in step 1, it is possible to clamp the bulb base securely enough for this simple drilling operation without distorting it. Insert the resistor from the inside and hold this “assembly” upside down as shown in preparation for soldering.

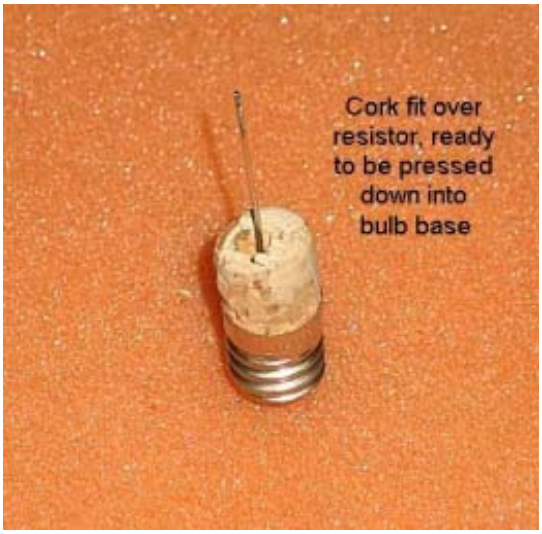




4. Solder the resistor lead to the center contact of the bulb base as shown.

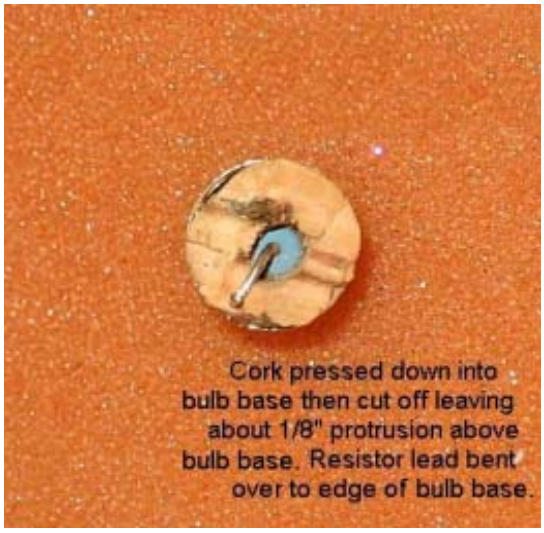
5. If required, bend the resistor inside the bulb base so that it is parallel to the sides of the base.

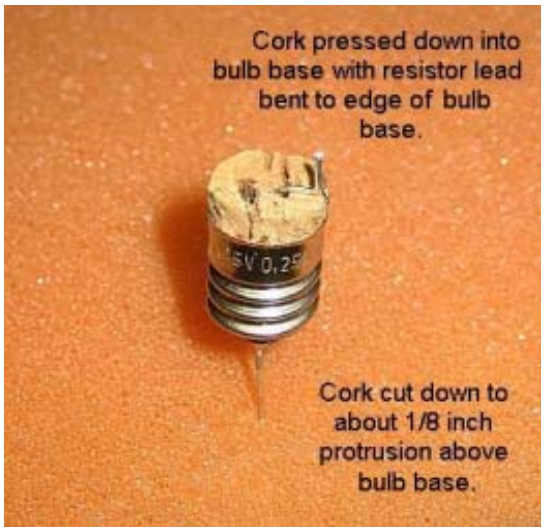




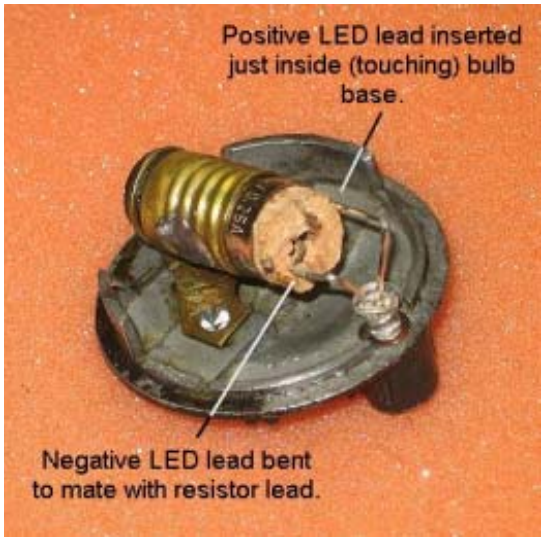
6. Select a drill bit slightly larger than the diameter of the resistor and carefully hand drill a hole all the way through the center of the cork. Patience is a requirement of this step as imperfections in the cork may cause it to want to split apart. However, if you keep it tightly bound and go slow it should not be all that difficult. Fit the cork over the resistor and screw it down into the bulb base.

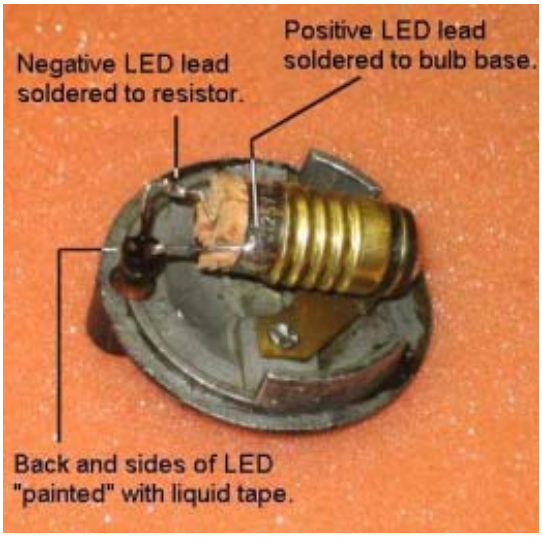
7. Once the cork is down around the resistor as far as it will go, cut the cork parallel to the top of the bulb base, leaving a protrusion of about 1/8". An Exacto knife or straight edge razor should work acceptably. With the excess cork removed, bend the resistor lead over to the edge of the base, and then up parallel to the base sidewall, then clip the resistor lead to a height of about 1/8".





8. Clip the resistor lead protruding from the bottom of the bulb base flush with the solder button through which it passes. Screw the assembly into the socket on the boiler front and note where the resistor lead is relative to the boiler front. Re-bend the resistor or, if required, remove the assembly from the boiler front and file the solder button so that when screwed into the socket, the resistor lead lies on the diameter of the socket that is parallel to the boiler front. Insert the positive lead of the white LED just inside and touching the bulb base on the side opposite the resistor lead (the negative lead may need to be temporarily bent out of the way). Bend both LED leads so that the LED points out the headlight opening. Now clip and bend the negative LED lead so that it is parallel to and touching the resistor lead.





9. Solder the positive LED lead to the bulb base and the negative LED lead to the resistor lead. Optional – coat the sides and back of the LED with black “Liquid Tape” (or black paint). This will help prevent any white light leaks around the boiler front if it does not seal tightly against the boiler shell.

10. Bend the leads of the red LED back toward its top. Take care to insure that the width of the bent LED leads matches the width of the white LED leads.

11. Solder the positive lead of the red LED to the resistor lead & negative white LED lead. Solder the negative lead of the red LED to the positive lead of the white LED.

12. Bend the red LED back so that it will point into the smokestack opening in the boiler.

13. Test power the finished assembly – both LEDs should be illuminated.

14. Insert boiler front with LED assembly into the boiler to check clearances. To insure the "red glow" effect of the smokestack as produced by AF engines with a red plastic smoke tube, the interior of the boiler smokestack should be painted white. Though not shown here, "painting" the bottom terminal of the lamp socket with liquid tape (after soldering on the wire from the smoke box) will insure there's no electrical contact with the boiler. This wasn't an issue in this installation, but it bears close scrutiny.

15. Reassemble the engine, and you're ready to roll.

Electrical considerations for this alternative are essentially the same as for the single LED version. The difference is in substituting a second LED for the rectifier. If you're not after the red glow effect, you could also use two white LEDs aimed at the headlight opening.

In this instance I obtained the high output red LED from BestHongKong.com (their item BURLC224W20BA07). I was a bit leery about ordering directly, but there wasn't really much at risk. At a quantity of 10, this LED costs $.49 each. Air mail shipping was $3.13. My order arrived 14 days after I placed it.