Sam's F-Lamp FAQ

Fluorescent Lamps, Ballasts, and Fixtures

Principles of Operation, Circuits, Troubleshooting, Repair
Version 2.11

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Preface

Author and Copyright

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Acknowledgements

Thanks to Don Klipstein (don@misty.com) for his comments and additions to this document. His Web site (http://www.misty.com/~don/) is a valuable resource for information relating to lighting technology in general and also includes additional articles dealing with fluorescent and other discharge lamps.

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Introduction

Fluorescent Lamp Basics

The fluorescent lamp was the first major advance to be a commercial success in small scale lighting since the tungsten incandescent bulb. Its greatly increased efficiency resulted in cool (temperature wise) brightly lit workplaces (offices and factories) as well as home kitchens and baths. The development of the mercury vapor high intensity discharge (HID) lamp actually predates the fluorescent (the latter being introduced commercially in 1938, four years after the HID). However, HID type lamps have only relatively recently become popular in small sizes for task lighting in the home and office; yard and security area lighting; and light source applications in overhead, computer, and video projectors.

Fluorescent lamps are a type of gas discharge tube similar to neon signs and mercury or sodium vapor street or yard lights. A pair of electrodes, one at each end - are sealed along with a drop of mercury and some inert gases (usually argon) at very low pressure inside a glass tube. The inside of the tube is coated with a phosphor which produces visible light when excited with ultra-violet (UV) radiation. The electrodes are in the form of filaments which for preheat and rapid or warm start fixtures are heated during the starting process to decrease the voltage requirements and remain hot during normal operation as a result of the gas discharge (bombardment by positive ions).

When the lamp is off, the mercury/gas mixture is non-conductive. When power is first applied, a high voltage (several hundred volts) is needed to initiate the discharge. However, once this takes place, a much lower voltage - usually under 100 V for tubes under 30 watts, 100 to 175 volts for 30 watts or more - is needed to maintain it.

The electric current passing through the low pressure gases emits quite a bit of UV (but not much visible light). The gas discharge's radiation is almost entirely mercury radiation, although the gas mixture is mostly inert gas and generally around something like 1 percent mercury vapor. The internal phosphor coating very efficiently converts most of the UV to visible light. The mix of the phosphor(s) is used to tailor the light spectrum to the intended application. Thus, there are cool white, warm white, colored, and black light fluorescent (long wave UV) lamps. There are also lamps intended for medical or industrial uses with a special envelope such as quartz that passes short wave UV radiation. Some have an uncoated envelope, and emit short-wave UV mercury radiation. Others have phosphors that convert shortwave UV to medium wave UV.

(Caution: Some specialty UV lamps emit shortwave or medium wave UV which is harmful and should not be used without appropriate protection or in an enclosure which prevents the escape of harmful UV radiation.)

Fluorescent lamps are about 2 to 4 times as efficient as incandescent lamps at producing light at the wavelengths that are useful to humans. Thus, they run cooler for the same effective light output. The bulbs themselves also last a lot longer - 10,000 to 20,000 hours versus 750 to 1,000 hours for a typical incandescent. However, for certain types of ballasts, this is only achieved if the fluorescent lamp is left on for long periods of time without frequent on-off cycles.

Over the years, fluorescent lamps in approximately the shape of incandescent lamps with built-in ballasts have been evolving. These "compact fluorescent lamps" or CFLs have all of the advantages of ordinary fluorescent lamps but fit into most table lamps and incandescent fixtures. Phosphors have been improved to the point where the color is very similar to that of incandescent lamps. While the initial cost is high ($5 to $20), this is easily recovered several times over in the energy savings over the long life of the lamp due to the much higher efficiency (typically 4X) since most of the lifecycle cost of an incandescent is in the electricity used (typically $10 for power versus $0.50 for the lamp) and not the lamp itself.

Fluorescent Lamp Labeling

The actual fluorescent tubes are identified by several letters and numbers and will look something like 'F40CW-T12' or 'FC12-T10'.

So, the typical labeling is of the form FSWWCCC-TDD (variations on this format are possible):

- F - Fluorescent lamp. G means Germicidal shortwave UV lamp.
- S - Style - no letter indicates normal straight tube; C for Circline.
- WW - Nominal power in Watts. 4, 5, 8, 12, 15, 20, 30, 40, etc.
- CCC - Color. W=White, CW=Cool white, WW=Warm white, BL/BLB=Black light, etc.
- T - Tubular bulb.
- DD - Diameter of tube in of eighths of an inch. T8 is 1", T12 is 1.5", etc.

For the most common T12 (1.5 inch) tube, the wattage (except for newer energy saving types) is usually 5/6 of the length in inches. Thus, an F40-T12 tube is 48 inches long.

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Safely Working with Fluorescent Lamps and Fixtures

There aren't many dangers associated with typical fluorescent lamps and fixtures:

- Electric shock. There is usually little need to probe a live fixture. Most problems can be identified by inspection or with an ohmmeter or continuity tester when unplugged.

  - Fluorescent lamps and fixtures using iron ballasts are basically pretty inert when unplugged. Even if there are small capacitors inside the ballast(s) or for RFI prevention, these are not likely to bite. However, you do have to remember to unplug the fixture before touching anything!

  - However, those using electronic ballasts can have some nasty charged capacitors so avoid going inside the ballast module and it won't hurt to check between its outputs with a voltmeter before touching anything. Troubleshooting the electronic ballast module is similar to that of a switchmode power supply. See the document: Notes on the Troubleshooting and Repair of Small Switchmode Power Supplies

- Nasty chemicals: While the phosphors on the inside of fluorescent tubes are not particularly poisonous, there is a small amount of metallic mercury and contact with this substance should be avoided. If a tube breaks, clean up the mess and dispose of it properly and promptly. Of course, don't go out of your way to get cut on the broken glass!

And take care around sharp sheet metal!

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Fluorescent Fixtures and Ballasts

Fluorescent Fixtures

The typical fixture consists of:

- Lamp holder - the most common is designed for the straight bipin base bulb. The 12, 15, 24, and 48 inch straight fixtures are common in household and office use. The 4 foot (48") type is probably the most widely used size. U shaped, circular (Circline(tm).) and other specialty tubes are also available.

- Ballast(s) - these are available for either 1 or 2 lamps. Fixtures with 4 lamps usually have two ballasts. See the sections below on ballasts. The ballast performs two functions: current limiting and providing the starting kick to ionize the gas in the fluorescent tube(s).

- Switch - on/off control unless connected directly to building wiring in which case there will be a switch or relay elsewhere. The power switch may have a momentary 'start' position if there is no starter and the ballast does not provide this function.

- Starter (preheat fixtures only) - device to initiate the electrode preheating and high voltage "kick" needed for starting. In other fixture types, the ballast handles this function.

Fluorescent Lamp Ballasts

For a detailed explanation, check your library. Here is a brief summary.

1. Provide the starting kick.

2. Limit the current to the proper value for the tube you are using.

In the old days fluorescent fixtures had a starter or a power switch with a 'start' position which is in essence a manual starter. Some cheap ones still do use this technology.

The starter is a time delay switch which when first powered, allows the filaments at each end of the tube to warm up and then interrupts this part of the circuit. The inductive kick as a result of interrupting the current through the inductive ballast provides enough voltage to ionize the gas mixture in the tube and then the current through the tube keeps the filaments hot - usually. You will notice that a few iterations are sometimes needed to get the tube to light. The starter may keep cycling indefinitely if either it or one of the tubes is faulty. While the lamp is on, a preheat ballast is just an inductor which at 60 Hz (or 50 Hz) has the appropriate impedance to limit the current to the tube(s) to the proper value.

Ballasts must generally be fairly closely matched to the lamp in terms tube wattage, length, and diameter.

There are two general types of ballast: Iron ballasts consist of a core, windings, and maybe a few other passive components like capacitors. Electronic ballasts are basically switching power supplies.

Types of Iron Ballasts

Preheat ballasts require starters or manual starting switches. Instant start, trigger start, rapid start, etc. ballasts include loosely coupled high voltage windings and other stuff which does away with the starter:

1. The ballast for a preheat fixture (combined with a starter or power switch with a 'start' position) is basically a series inductor. Interrupting current through the inductor provides the starting voltage.

2. The ballast for a rapid start fixture has in addition small windings for heating the filaments reducing the required starting voltage to 250 to 400 V. There are probably the most common types in use today. Trigger start fixtures are similar to rapid start fixtures.

3. The ballast for an instant start fixture has a loosely coupled high voltage transformer winding providing about 500 to 600 V for starting in addition to the series inductor. The electrodes of "instant start" bulbs are designed for starting without preheating. In fact, they are shorted out internally and are thus incompatible with preheat and rapid start ballasts (and they have only a single pin at each end!). The electrodes still emit electrons due to thermal emission but since they are shorted out cannot be pre-heated. That is why they require a higher starting voltage from the ballast. They they light instantly, but this slightly reduces lamp life.

Starting voltage is either provided by the inductive kick upon interruption of the current bypassed through the starter for (1) or a high voltage winding in (2) and (3).

In all cases, the current limiting is provided primarily by the impedance of the series inductance at 60 Hz (or 50 Hz depending on where you live).

(From: Vic Roberts (Vic@RobertsResearchInc.com).)

The most basic ballast is nothing more than a current limiting device, such as an inductor, resistor or capacitor. For 50 and 60 Hz applications, the most common current limiting device is an inductor.

A simple current limiter works best when the line voltage is at least 2 times the lamp voltage. So, a simple inductor can be used in Europe, where the line voltage is 220 to 240 VAC, to operate a 4 foot lamp, which operates at 85 to 100 volts, depending upon design.

In the US and other places that use 120 VAC lines the ballast is a combination autotransformer (to raise the voltage) and inductor (the current limiter).

In addition, a Rapid Start ballast has additional windings to supply about 3.6 VAC to heat the filaments.

(From: Asimov (Asimov@juxta.mn.pubnix.ten).)

A ballast is a simple transformer with a very high impedance secondary winding which makes its current self-limiting. It also has windings for each lamp filaments. At startup the filaments get most of the power and heat up to facilitate ionization.

Meanwhile the secondary builds up a very high EMF which finally fully ionizes the plasma between both filaments. At this point the effective resistance of the conducting plasma is quite low and the current flow is limited by the secondary's impedance. This also partially saturates the core and as consequence reduces power to the filaments.

The usual failure in ballasts is that the secondary's insulation deteriorates and it starts leaking to ground. Often because the proper wiring polarity was not observed. The secondary can thus no longer generate the high EMF required to start the plasma conducting.

The KISS test method is to use a known good lamp. If it lights, the ballast is good too. The ballast can also be tested with the power off by checking for continuity in the filament windings and a very high resistance to ground for each filament. Don't try this with power on!

(From: Craig J. Larson (larson@freenet.msp.mn.us).)

Call Magnetek, a ballast manufacturer on 1-800-BALLAST. Ask for a copy of their Troubleshooting & Maintenance Guide for Linear Fluorescent Lighting Systems. Its a nice little guide book for teaching you the basics.

Electronic Ballasts

These devices are basically switching power supplies that eliminate the large, heavy, 'iron' ballast and replace it with an integrated high frequency inverter/switcher. Current limiting is then done by a very small inductor, which has sufficient impedance at the high frequency. Properly designed electronic ballasts should be very reliable. Whether they actual are reliable in practice depends on their location with respect to the heat produced by the lamps as well as many other factors. Since these ballasts include rectification, filtering, and operate the tubes at a high frequency, they also usually eliminate or greatly reduce the 100/120 Hz flicker associated with iron ballasted systems. However, this is not always the case and depending on design (mainly how much filtering there is on the rectified line voltage), varying amounts of 100/120 can still be present.

I have heard, however, of problems with these relating to radio frequency interference from the ballasts and tubes. Other complaints have resulted due to erratic behavior of electronic equipment using infra red remote controls.

There is a small amount of IR emission from the fluorescent tubes themselves and this ends up being pulsed at the inverter frequencies which are sometimes similar to those used by IR hand held remote controls.

Some electronic ballasts draw odd current waveforms with high peak currents. This is due to the fact that these ballasts (low-power-factor type) have a full-wave-bridge rectifier and a filter capacitor. Current can only be drawn during the brief times that the instantaneous line voltage exceeds the filter capacitor voltage.

Because of the high peak currents drawn by some electronic ballasts, it is often important to size wiring properly for these high peak currents. For wiring heating and fuse/circuit considerations, one should allow for a current of 4 to 6 times the ratio of lamp watts to line volts. For wiring voltage drop considerations (drop in voltage the ballast's filter capacitor gets charged to), the effective current is even higher, sometimes as high as 15 to 20 times the ratio of the lamp watts to RMS line volts.

For less than 50 watts, the current drawn by low-power-factor electronic ballasts is usually not a problem. For multiple ballasts or total wattages over 50 watts, it may be important to consider the effective current drawn by low-power-factor electronic ballasts.

If you want to get an idea of some typical modern electronic ballast designs, see the International Rectifier web site. Search for 'electronic ballasts' or download the following reference design notes:

- Linear Ballast
- Compact Ballast

Two typical commercial electronic ballasts compact fluorescent lamps are shown in:

- CFL Electronic Ballast 1 (Techna-Bright EDXR-38-16).
- CFL Electronic Ballast 2 (General Electric FLE26HT3/2/SW).

For additional info on these as well as a variety of simple inverters to operate fluorescent lamps on low voltage DC, see the collection in the document: Various Schematics and Diagrams.

Comments on CFL Ballasts

(From: Tony (tonyreo@ameritech.net).)

I work in a R&D lab for a VERY large corporation. We design CFLs (Compact Fluorescent Lamps).

Today, 90 percent of CFLs are electronic ballasted lamps and they come in two basic varieties: (1) High power factors (somewhere between .9 and very close to 1) and (2) Low power factor (usually less than .6).

The high power factor lamps require more components (or from the corporations point of view, cost) so there are more low power factor lamps on the market than high power factor. From what I understand using either will not make a difference in what your electric meter reads and bills you for.

Our typical electronic ballast has two FETs that switch at anywhere from 75 kHz to 105 kHz. And actually we have one product that runs at 2.5 MHz. In the power input section we use a full wave bridge followed by a electrolytic capacitor with a value of anywhere from 10 uF to 47 uF depending on the design of the lamp. There are also a few other components here that reduce EMI (Electro Magnetic Interference) that could be conducted back into the AC line. All of the input components, collectively, will have a part in the input characteristics of the lamp.

One more note that you may find interesting relates to the starting time of CFLs. The CFLs that do not start instantly (pre-heat types) will have a longer life than the "instant start" type. The pre-heat systems heat the cathodes for 150 milliseconds to 1 second (or more) before the lamp is allowed to light. This increases the cathode life which is one of the main factors in lamp life.

Notes on Ballast Compatibility

Can a 30 W lamp be run on a 27 W ballast? What about a 22 W ballast?

The answer is an absolutely possibly qualified maybe. :)

Any fluorescent lamp is expected to run at some specific current to produce its rated light output and life. (There is also the issue of preheat, instant, and rapid start types but that's for another discussion!) At the rated current, there will be a certain voltage across the lamp. The voltage drop is related to tube diameter, length, filament type, and gas fill. It goes up with length but is not directly proportional to length. Being gas discharge devices, the impedance of a fluorescent lamp is negative - its voltage actually goes down with increasing current, thus the need for a ballast to limit the current. Some iron ballasts are rated to handle more than one size lamp maintaining a nearly constant current over a range of lamp voltages - 12, 15, and 20 W, for example. What this means is that the voltage drop across all these lamps is similar enough that the current will be nearly the same and/or the ballast has a magnetic shunt to provide a quasi-constant current characteristic over a range of voltages.

The typical ballast will list compatible lamp types and wattages on its label. Wattage, starting type, and lamp diameter are all critical. With all the variations in lamps, there's no hard and fast rule that will determine whether a non-listed combination will work or even be safe. A higher wattage lamp may run and even be easier on the ballast since with its higher voltage drop, it will draw less current. Of course, there will also be less than rated light output. However, if the incompatibility is great enough, it may flicker, cycle on and off, or not start at all. A lower wattage lamp may burn out quickly and/or cause either type of ballast to overheat and fail.

Where the rated lamp current is known or where the same lamp could be run on a compatible ballast, it might be possible to measure the current with the ballast combination being tested to determine if it is acceptable. However, this is clearly above and beyond what is normally required when changing a light bulb. :)

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Fluorescent Fixture Wiring Diagrams

The following wiring diagrams are typical of fluorescent fixtures using iron ballasts. These do NOT generally apply directly to fixtures using electronic ballasts.

Wiring for Preheat Fluorescent Fixtures

The following is the circuit diagram for a typical preheat lamp - one that uses a starter or starting switch.

```
              Power Switch    +-----------+
 Line 1 (H) o------/ ---------|  Ballast  |-----------+
                              +-----------+           |
                                                      |
                      .--------------------------.    |
 Line 2 (N) o---------|-      Fluorescent       -|----+
```

```
        | )          Tube          ( |
    +---|-   (bipin or circline)   -|----+
    |   '--------------------------'     |
    |                                    |
    |          +-------------+           |
    |          |   Starter   |           |
    +----------| or starting |-----------+
               |   switch    |
               +-------------+
```

Where a three position switch (OFF-ON-START) is used to control the fixture (e.g., those circular magnifier lamps), there will be two pairs of contacts: One pair (Power) is connected in the ON and START positions, and the other (Start) is connected only in the START position. They are isolated from each-other.

```
              Power Switch     +-----------+
 Line 1 (H) o------/ ---------|  Ballast  |-----------+
              Closed for ON    +-----------+           |
                and START                              |
                                                       |
                      .--------------------------.     |
 Line 2 (N) o---------|-       Fluorescent       -|----+
                      | )         Tube          ( |
                  +---|-   (bipin or circline)   -|----+
                  |   '--------------------------'     |
                  |                                    |
                  +--------------o/ o-----------------+
                          Starting contacts (Closed for START only)
```

Here is a variation that some preheat ballasts use. This type was found on a F13-T5 lamp fixture. Similar types are used for 30 and 40 watt preheat lamps. This 3-lead preheat ballast is a voltage-boosting "high leakage reactance autotransformer" used if the voltage across the tube is much over approx. 60 percent of the line voltage. For technical details on why a fluorescent lamp will not work with ordinary ballasts if the tube voltage is only slightly less than the line voltage, look at Don Klipstein's Discharge Lamp Mechanics document.

```
              Power Switch    +-------------+
 Line 1 (H) o------/ --------|A  Ballast   |
                  +----------|B           C|-----------+
                  |          +-------------+           |
                  |                                    |
                  |   .--------------------------.     |
 Line 2 (N) o-----+---|-       Fluorescent       -|----+
                      | )         Tube          ( |
                  +---|-   (bipin or circline)   -|----+
                  |   '--------------------------'     |
                  |                                    |
                  |          +-------------+           |
                  |          |   Starter   |           |
                  +----------| or starting |-----------+
                             |   switch    |
                             +-------------+
```

Fluorescent Starter Operation

Starters may be either automatic or manual:

- Automatic - The common type are called a 'glow tube starter' (or just starter) and contains a small gas (neon, etc.) filled tube and an optional RFI suppression capacitor in a cylindrical aluminum can with a 2 pin base. While all starters are physically interchangeable, the wattage rating of the starter should be matched to the wattage rating of the fluorescent tubes for reliable operation and long life.

  The glow tube incorporates a switch which is normally open. When power is applied a glow discharge takes place which heats a bimetal contact. A second or so later, the contacts close providing current to the fluorescent filaments. Since the glow is extinguished, there is no longer any heating of the bimetal and the contacts open. The inductive kick generated at the instant of opening triggers the main discharge in the fluorescent tube. If the contacts open at a bad time - current near zero, there isn't enough inductive kick and the process repeats.

  Higher-tech replacements called 'pulse starters' may be available for the simple glow tube type starter. These devices are pin compatible devices and contain a bit of electronics that detect the appropriate time to interrupt the filament circuit to generate the optimal inductive kick from the ballast. So, starting should be more reliable with few/no blink cycles even with hard-to-start lamps. They will also leave used-up tubes off, without letting them blink annoyingly.

  A defective or incorrect starter is a common cause of erratic starting and possibly random restarts during operation.

- Where a manual starting switch is used instead of an automatic starter, there will be three switch positions - OFF, ON, START:

  - OFF: Both switches are open.
  - ON: Power switch is closed.
  - START (momentary): Power switch remains closed and starting switch is closed.

  When released from the start position, the breaking of the filament circuit results in an inductive kick as with the automatic starter which initiates the gas discharge.

Wiring for Rapid Start and Trigger Start Fixtures

Rapid start and trigger start fixtures do not have a separate starter or starting switch but use auxiliary windings on the ballast for this function.

The rapid start is now most common though you may find some labeled trigger start as well.

Trigger start ballasts seem to be used for 1 or 2 small (12-20 W) tubes. Basic operation is very similar to that of rapid start ballasts and the wiring is identical. "Trigger start" seems to refer to "rapid starting" of tubes that were designed for preheat starting.

The ballast includes separate windings for the filaments and a high voltage starting winding that is on a branch magnetic circuit that is loosely coupled to the main core and thus limits the current once the arc is struck.

A reflector grounded to the ballast (and power wiring) is often required for starting. The capacitance of the reflector aids in initial ionization of the gases. Lack of this connection may result in erratic starting or the need to touch or run your hand along the tube to start.

A complete wiring diagram is usually provided on the ballast's case.

Power is often enabled via a socket operated safety interlock (x-x) to minimize shock hazard. However, I have seen normal (straight) fixtures which lack this type of socket even where ballast labeling requires it. Circline fixtures do not need an interlock since the connectors are fully enclosed - it is not likely that there could be accidental contact with a pin while changing bulbs.

Wiring Diagram for Single Tube Rapid or Trigger Start Ballast

Below is the wiring diagram for a single lamp rapid or trigger start ballast. The color coding is fairly standard. The same ballast could be used for an F20-T12, F15-T12, F15-T8, or F14-T12 lamp. A similar ballast for a Circline fixture could be used with an FC16-T10 or lamp FC12-T10 (no interlock).

```
             Power Switch    +---------------------------+
 Line 1 (H) o----/ ----------|Black   Rapid/Trigger      |
                      +------|White       Start       Red|------+
                      |  +---|Blue       Ballast      Red|---+  |
                      |  |   +-------------+-------------+   |  |
                      |  |                 |                 |  |
                      |  |        Grounded | Reflector       |  |
                      |  |       ----------+----------       |  |
                      |  |    .-------------------------.    |  |
                      |  +----|-      Fluorescent      -|----+  |
                      +------x| )         Tube        ( |       |
 Line 2 (N) o----------------x|-  (bipin or circline)  -|-------+
                              '-------------------------'
```

Wiring Diagram for Two Tube Rapid Start Ballast

The following wiring diagram is for one pair (from a 4 tube fixture) of a typical rapid start 48 inch fixture. These ballasts specify the bulb type to be F40-T12 RS. There is no safety interlock on this fixture. (A similar scheme could also be used on a dual tube Circline fixture though slightly different ratings may be needed for each tube since they would be of different sizes.)

```
             Power Switch    +--------------------------+
 Line 1 (H) o----/ ----------|Black    Dual Tube     Red|------------+
 Line 2 (N) o----------------|White      Rapid       Red|--------+   |
                       +-----|Yellow     Start      Blue|-----+  |   |
                       |  +--|Yellow    Ballast     Blue|--+  |  |   |
                       |  |  +-------------+------------+  |  |  |   |
                       |  |                |               |  |  |   |
                       |  |       Grounded | Reflector     |  |  |   |
                       |  |      ----------+----------     |  |  |   |
                       |  |    .----------------------.    |  |  |   |
                       |  +----|-     Fluorescent    -|----+  |  |   |
                       |  |    | )      Tube 1      ( |       |  |   |
                       +-------|-      bipin        -|-------+  |   |
                       |  |    '----------------------'          |   |
                       |  |    .----------------------.          |   |
                       |  +----|-     Fluorescent    -|----------+   |
                       |       | )      Tube 2      ( |              |
```

```
                      +--------|-       bipin       -|-------------+
                               '---------------------'
```

Schematic of Typical Rapid/Trigger Start Single Lamp Ballast

This ballast is marked "Trigger Start Ballast for ONE F20WT12, F15WT12, F15WT8, or F14WT12 Preheat Start Lamp. Mount tube within 1/2" of grounded metal reflector". (Note that while labelled "Trigger Start", it does heat the filaments so I assume it is similar or identical to a rapid start ballast.)

Voltages were measured with no bulb installed with safety interlock bypassed.

Internal wiring has been inferred from resistance and voltage measurements.

The lossy autotransformer boosts line voltage to the value needed for reliable starting with the filaments heated. It is assumed that part of the magnetic circuit is loosely coupled so that putting the lamp between Red/Red and Blue/White results in safe current limited operation once the arc has struck.

A complete fixture wiring diagram like those shown in the section: Wiring for Rapid Start and Trigger Start Fixtures will probably be provided on the label.

Numbers in () are measured DC resistances.

```
             Red o---------------------------+
                     8.5 V               (5) )|| Filament 1
             Red o-----------------------+---+ ||
                                         |     ||
                                         +     ||
                                          )||==|| Stepup winding/choke is
                    82.5 V          (37) )||   || loosely coupled to main
                                          )||==|| magnetic circuit
                                         +     ||
                                         |     ||
  +--> Black (H) o-----------------------+---+ ||
  |                                           )|| Primary of starting
                   106.5 V              (31) )|| autotransformer
115 V                                         )||
            Blue o---------------------------+ ||
  |                  8.5 V               (3) )|| Filament 2
  +--> White (N) o-----------o/o-------------+  |
                          Interlock             |
       Green (G) o------------------------------+
```

Schematic for Rapid Start Ballast with Isolated Secondary

As noted, rapid start fixtures do not have a separate starter or starting switch but use auxiliary windings on the ballast for this function. Here is the schematic for a typical 1-tube rapid start fixture including the internal wiring of the ballast.

This ballast includes separate windings for the filaments and a high voltage winding that is on a branch magnetic circuit that is loosely coupled and thus limits the current once the arc is struck. It is not known if this design is common. The isolated secondary and separate high voltage winding would make it more expensive to manufacture.

A complete fixture wiring diagram like those shown in the section: Wiring for Rapid Start and Trigger Start Fixtures will probably be provided on the label.

```
                                     +--------+
          Power Switch ||======||(         |
Line 1 (H) o---/ ----+ ||      ||(   +----+---------o    to both pins
                     )||      ||(  ( filament winding   on one end
                     )||      ||(   +---------------o
                     )||      ||(     HV winding       Grounded reflector
                     )||      || +-----^^^^^^^-------------------------+
                     )||      ||(                                     _|_
                     )||      ||(   +---------------o                  -
                     )||      ||(  ( filament winding   to both pins
Line 2 (N) o---------+ ||      ||(   +----+---------o    on other end
                       ||======||(         |
                                 +--------+

         Loose magnetic coupling in the ballast core results
         in leakage inductance for current limiting.
```

Schematic of Rapid Start Dual Lamp Ballast

This ballast is marked "Rapid Start Ballast for TWO F40WT12 Lamps. Mount tubes within 1/2" of grounded metal reflector". This circuit was derived from the measurements listed in the section: Measurements of a Dual Tube Rapid Start Ballast.

The autotransformer boosts line voltage to the value needed for reliable starting with the filaments heated. The series capacitor of approximately 4 uF is used instead of leakage inductance to limit current to the tubes. Leakage inductance from loose magnetic coupling is used to smooth the waveform of current flowing through the tubes. The .03 uF capacitor provides a return path during starting to the yellow filament winding but is not really used during normal operation.

Numbers in () are approximate measured DC resistances.

```
 Red 1 o---------------------------+
           8.5 V             (.5) )|| Tube 1 Filament 1
 Red 2 o-----------------------+---+ ||
                              _|_    ||
                        4 uF  ---    ||
                               |     ||
                               +---+ ||
                                   )||
                                   )||
                                   )|| HV winding
                                   )||
                                   )||
                   +---------+---+ ||
                   |        _|_    ||
                   | .03 uF ---    ||
                   |         |     ||
Yellow o-----------------------+---+ ||
           8.5 V   |         (.5) )|| Tubes 1 and 2 filament 2
Yellow o---------------------------+ ||
```

```
                             |                ||
                             |                ||
          Blue 1 o-----------+-------------+  ||
                    8.5 V              (.5) ) ||  Tube 2 filament 1
          Blue 2 o--+----------------------+  ||
                    |                         ||
    +--> Black (H) o--+----------------------+ ||
    |                                        ) ||  Primary of
  115 V                                 (13) ) ||  autotransformer
    |                                        ) ||
    +--> White (N) o-----------o/o-----------+ ||
                          Interlock           ||
                                               |
       Green (G) o-----------------------------+
```

Measurements of Dual Tube Rapid Start Ballasts

One is a Universal, the other is a Valmont.

(Measurements made with Radio Shack multimeter)

Resistance:

```
    Measurement                         Universal             Valmont
------------------------               -----------           -----------
  White-Black                              13                    13
  Between blues                            .5                    .55
  Between reds                             .5                    .55
  Between yellows                          .5                    .6
  Black to closer blue                    <.1                   <.1

  Blue-red                                open                  open
  Blue-yellow                             open                   5 M
  Red-yellow                              open                  20 M

Capacitance:

  Blue-red                                 ~4 uF              ~3.5 uF
  Blue-yellow                            ~.03 uF
  Red-yellow                             ~.03 uF

Primary current, (not true RMS), various secondary load conditions:

  Secondary open                          .32 A                 .35 A
  60W 120V incandescent bulb              .75 A                 .63 A
  Short                                   .48 A                 .53 A

Heater voltage:                      not measured    approx. 8 V, unsteady
                                                     surprisingly independent
                                                     of secondary load
```

Open circuit output voltage voltage (from one red wire to one blue one, highest reading of four combinations):

```
  Red-Blue                               270 V                 275 V
```

Fluorescent Lamps in Series?

This is not possible where line voltage is 105 to 125 VAC because this is not sufficient to sustain the discharge where two lamps are in series. Special dual lamp ballasts are required.

However, where the line voltage is 220 VAC, it is possible:

(From: andrew@cucumber.demon.co.uk (Andrew Gabriel))

Here in UK (and probably all 220 to 250 V areas), this is common:

```
            =======
L o---+-----^^^^^^^-------+ +-----+
      |     Ballast       | |     |
      |   (Inductor)     +|-|+    |
      |                  | - |    |
      |                  |   |   +-+
      |           Tube 1 |   |   |S| Glow Starter
      |                  |   |   +-+
      |                  | - |    |
      |                  +|-|+    |
      |                   | |     |
     _|_ Power Factor     | +-----+
     ___ Correction       |
      |  Capacitor        | +-----+
      |                   | |     |
      |                  +|-|+    |
      |                  | - |    |
      |                  |   |   +-+
      |           Tube 2 |   |   |S| Glow Starter
      |                  |   |   +-+
      |                  | - |    |
      |                  +|-|+    |
      |                   | |     |
N o---+-------------------+ +-----+
```

Note that starters for a 230 VAC two tube fixture may NOT be the same as those for a 230 VAC single tube fixture. Installing single tube starters in a two tube fixture may result in no action at all since their breakdown voltage may be too high. Doing the reverse may result in damage.

Fluorescent Lamps in Parallel?

Like most gas discharge tubes, fluorescent lamps are negative resistance devices. Therefore, it isn't possible to put more than one lamp in parallel and get them both to light - additional components are needed. The following applies mostly to magnetic ballasted fixtures. Where electronic ballasts are used, all sorts of games can be played to implement wierd configurations!

Multiple lamp fixtures in countries with 110 VAC power usually have special ballasts with separate windings for this purpose. Where 220 to 240 VAC is available, it may be possible to put multiple lamps in series with individual starters. See the section: Fluorescent Lamps in Series?.

However, there is at least one application where putting two lamps is parallel makes sense: light fixtures in hard-to-reach or safety-critical areas where redundancy is desirable. With only minor modifications at most, a conventional single lamp ballast can be connected to a pair of lamps in such a way that only one will light at any given time. (Which one actually starts could be random without additional circuitry, however.) If either lamp burns out or is removed, the other will take over. The ballast must provide enough power to the filaments for starting but once started, the lamp that is on will operate normally and there should be no degradation in performance or expected lamp life (except to the extent that the unlit lamp's filaments might be kept hot).

The following is just a suggestion - I have not confirmed if or with which model ballasts these schemes will work!

For rapid start ballasts, this could be as simple as wiring all connections to the lamps in parallel - if the ballast has enough current available to power both sets of filaments for starting. For trigger start ballasts, the filament power is not an issue so it should be even easier:

```
             Power Switch   +---------------------------+
 Line 1 (H) o----/ ---------|Black   Rapid/Trigger      |
                      +-----|White       Start       Red|--------+
                      |  +--|Blue       Ballast      Red|-----+  |
                      |  |  +--------------+------------+     |  |
                      |  |                 |                  |  |
                      |  |                 +---------------+  |  |
                      |  |       Grounded  | Reflector     |  |  |
                      |  |       ----------+----------     |  |  |
                      |  |    .-------------------------.  |  |  |
                      |  +----|-     Fluorescent       -|--|--+  |
                      |  |    | )       Tube          ( |  |  |  |
                      +--|----|-  (bipin or circline)  -|--|--|--+
                      |  |    '-------------------------'  |  |  |
                      |  |                 +---------------+  |  |
                      |  |        Grounded | Reflector        |  |
                      |  |       ----------+----------        |  |
                      |  |    .-------------------------.     |  |
                      |  +----|-      Fluorescent      -|-----+  |
                      |       | )        Tube         ( |        |
 Line 2 (N) o---------+-------|-  (bipin or circline)  -|--------+
                              '------------------------'
```

Note: The interlock normally present on most rapid/trigger start fixtures have been removed to permit one lamp to operate if other is removed.

For preheat ballasts, wiring the filaments in parallel would probably result in insufficient current to either lamp for it to start reliably. If the filaments were wired in series, one lamp would probably start, but if the filament of one lamp burned out or the lamp was removed, the fixture would cease to function kind of defeating the purpose of these gyrations!

Wiring Fluorescent Lamps to Remote Ballasts

For reasonable distances, this should work reliably and be safe provided that:

1. This is only attempted with iron ballasts. The fire safety and reliability of electronic ballasts that are not in close proximity to the lamps is unknown. The ballast may fail catastrophically either immediately or a short time later as the circuit may depend on a low impedance (physically short) path for stability.

   In addition, there will almost certainly be substantial Radio Frequency Interference (RFI) created by the high frequency currents in the long wires. The FCC police (or your neighbors) will come and get you! This may be a problem with iron ballasts as well - but probably of less severity.

2. Wire of adequate rating is used. The starting voltage may exceed 1 kV. Make sure the insulation is rated for at least twice this voltage. Use 18 AWG (or heavier) gauge wire.

3. There is no possibility of human contact either when operating or if any connectors should accidentally come loose - dangerous line voltage and high starting voltage will be present with tubes disconnected.

Note: one application that comes up for this type of remote setup is for aquarium lighting. My recommendation would be to think twice about any homebrew wiring around water. A GFCI may not help in terms of shock hazard and/or may nuisance trip due to inductive nature of the ballast (both depend at least in part on ballast design).

Wiring diagram of Low Power 220 VAC Fluorescent Lamp

(From: Manuel Kasper (mk@mediaklemm.com).)

The circuit in Low Power 220 VAC Fluorescent Lamp is from an AC line powered 'light stick'. So there's no fancy inverter circuit inside, but a simple ballast without any nasty coils - just capacitors, resistors, and diodes. A few modifications would probably be necessary to make it operate from 110 VAC. It runs the tube brighter than a similar lamp power from a 12 V inverter. (See the section: "Automotive Light Stick Inverter" in the document: Various Schematics and Diagrams. FWIW, the brand is "Brennenstuhl".

It was damn hard to open up because everything was made out of thick plastic with no screws (no wonder; it cost $6) - but thanks to a huge saw I managed to get at the guts without destroying the tube or the circuit.

Alternatives to Commercial Iron Ballasts?

While the circuit diagrams of iron ballasts may resemble those of common power transformers, I wouldn't recommend attempting to use these as ballasts unless you really know how to implement controlled impedance behavior in a non-current limited transformer. Ballasts are rather special and unless you are willing to blow a lot of fluorescent lamps, transformers, fuses, and circuit breakers, just go with commercial ballasts. :)

Even for small lamps using a glow starter or separate starting switche, while it's certainly possible to use an ordinary inductor rather than something labeled "ballast", it's still probably not a good idea from fire safety and liability considerations.

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Specialty Fluorescent Lamp Types

All Sorts of Less Conventional Lamps

In addition to the boring white ones (OK, well 'white' does come in various colors!), other interesting types of lamps include all sorts of real colors (red, green, blue, yellow), blacklight lamps, germicidal lamps in which there is no phosphor coating at all and a quartz tube to transmit short-wave UV light (e.g., EPROM erasers and PCB photoresist activation), sunlamps, plant lights and special purpose specific wavelength lamps such as reprography and copier lamps.

The basic technology is extremely flexible!

(From: Bruce Potter (s602531@aix2.uottawa.ca).)

There are also High Output and Very High Output types of lamps that have a discharge current of 0.8 A and 1.5 A instead of the standard 0.3 A. HO and VHO lamps are used when high light output is desired but are being outmoded by HID lamps like metal halide.

Blacklight Fluorescent Lamps

(From: Don Klipstein (don@misty.com).)

BL in the tube designation (e.g., F40T12BL) means "blacklight", which is a fluorescent lamp with a phosphor that emits the longest largely invisible UV wavelengths that are both efficiently and fairly cheaply possible. This phosphor seems to emit a band of UV mainly from 350 to 370 nanometers, in the UV-A range.

BLB means "blacklight-blue", which differs from "blacklight" only in that the glass tube of this lamp is darkly tinted with something with a dark violet-blue color to absorb most visible light. Most UV gets through this, along with much of the dimly visible deep-violet 404.7 nanometer line of mercury. Most of the violetish-blue 435.8 nanometer line is absorbed, but enough of this wavelength gets through to largely dominate the color of the visible light from this lamp. Longer visible light wavelengths do not significantly penetrate the BLB's very deep violet-blue glass, which is known as 'Wood's glass'. The UV is the same as that of the BL lamp, being mostly between 350 and 370 nanometers.

There is a 350BL blacklight lamp, using a different phosphor that emits a band of slightly shorter UV wavelengths in the UV-A range. The reasoning for this lamp is that it is supposedly optimized for attracting insects. These lamps are one variety of UV lamps used in electric bug killers.

There are other UV fluorescent lamps. There are at least two different UV/deep violet emitting fluorescent lamps used mainly in the graphic arts industry, emitting mainly wavelengths between 360 and 420 nanometers. Possibly one of these is also used in bug killers. I have noticed one kind of UV fluorescent lamp for bug killers with a broadish band phosphor with significant output from the 360 nanometer range (maybe also shorter) into visible wavelengths around 410 to 420 nanometers or so.

There is an even shorter UV-A lamp used for suntanning purposes. I would guess the phosphor emits mainly within the 315 to 345 nanometer range. One brand of such lamps is "Uvalux".

There is even a UV-B emitting fluorescent lamp. Its phosphor emits mostly at UV-B wavelengths (286 to 315 nanometers). It is used mainly for special medicinal purposes. Exposing skin to UV-B causes erythema, which is to some extent a burn reaction of the skin to a slightly destructive irritant. Use of UV-B largely limits this to outer layers of the skin (perhaps mainly the epidermis) and to parts of the body where skin is thinner. UV-A wavelengths just over 315 nanometers can also cause sunburn, but they are more penetrating and can affect the dermis. Please note that the deadliest varieties of skin cancer usually originate in the epidermis and are usually most easily caused by UV-B rays.

There are clear UV-emitting lamps made of a special glass that lets through the main shortwave UV (UV-C) mercury radiation at 253.7 nanometers. These lamps are marketed as germicidal lamps, and ones in standard fluorescent lamp sizes have part numbers that start with G instead of F. These lamps will work in standard fluorescent lamp fixtures.

Cold-cathode germicidal lamps are also in use; these somewhat resemble "neon" tubing.

Be warned that the shortwave UV emitted by germicidal lamps is intended to be dangerous to living cells and is hazardous, especially to the conjunctiva of eyes. Signs of injury by the UV are often delayed, often first becoming apparent several minutes after exposure and peaking out a half hour to several hours afterwards.

Please note that non-fluorescent (high pressure mercury vapor discharge) sunlamps generally emit more UV-B rays rather than the tanning-range UV-A rays. These lamps do have substantial UV-A output, but mainly at a small cluster of wavelengths around 365 nanometers. Tanning is most effectively accomplished by wavelengths in the 315-345 nanometer range. In addition, no UV suntanning is completely safe.

Compact Fluorescent Lamps

These are miniaturized fluorescent lamps that usually have premium phosphors which often come packaged with an integral ballast (either iron or electronic). They typically have a standard screw base that can be installed into nearly any table lamp or lighting fixture that accepts an incandescent lamp.

Compact fluorescent Lamps (CFLs) are being heavily promoted as energy savings alternatives to incandescent lamps. They also have a much longer life - 6,000 to 20,000 hours compared to 750 to 1,000 hours for a standard incandescent. While these basic premises are not in dispute, before replacing all the incandescent lamps in your house with CFLs, that there are some disadvantages and quirks:

1. CFLs are often physically larger than the incandescent bulbs they replace and simply may not fit the lamp or fixture conveniently or at all. However, they are getting smaller as the technology matures.

2. The funny elongated or circular shape may result in a less optimal lighting pattern.

3. The light is generally cooler - less yellow - than incandescents - this may be undesirable and result in less than pleasing contrast with ordinary lamps and ceiling fixtures. Newer models have been addressing this issue and color temperature of some are now very close to incandescent lamps.

4. Some types (usually iron ballasts) may produce an annoying 120 Hz (or 100 Hz) flicker.

5. Ordinary dimmers cannot be used with compact fluorescents and may result in immediate destruction of the CFL.

   In addition, CFLs should not be used with illuminated switches, electronic timers, or any other means of control that results in a small current in series with the lamp when it is supposed to be off. With some electronic ballast designs, the small current will slowly charge a filter capacitor inside the CFL until it reaches a critical threshold, at which point the lamp will flash on momentarily - perhaps every 5 seconds. This may be kind of cool and may not damage the CFL (at least not immediately) but probably isn't the intended effect in your home. :) For illuminated switches, the switch won't be affected (though it may pulse synchronously with the cycle of the flashing CFL), but for timers and the like, the non constant current is likely to result in erratic behavior if not actual damage to the control device.

6. Light output may depend somewhat on mounting orientation.

7. Some CFLs come on instantly while others may have a delay of a up to a second or more where nothing appears to happen. They generally go off instantly. There characteristics may be annoying to anyone used to normal incandescent desk lamp behavior where which has a small but noticeable (and expected) delay as the filament heats or cools.

8. There will usually be a warmup time of a few seconds to a minute or more before full light output is produced even in warm temperatures.

9. Light output will decline slightly over the course of the life of the CFL.

10. Like other fluorescents, operation at cold temperatures (under around 50 to 60 °F) may result in reduced light output. Starting may also be erratic, although most compact fluorescent lamps seem to start OK at temperatures near freezing. Many types start OK near zero °F. Operation in an enclosed fixture often results in full light output in cool surroundings after the lamp warms up for a few minutes, as long as the initial temperature is high enough to permit a good start. However, enclosing compact fluorescents often impairs their ability to work well at higher temperatures.

11. CFLs should not be use in an unenclosed fixture outdoors unless the package states that this is acceptable since the electronics are really not always well protected. There may be additional specific environmental limitations listed as well.

12. Similarly, operating in enclosed fixtures or various orientations may result in reduced reliability, despite what the package claims. The only failures of GE-branded CFLs I've seed were for 2 samples run in a semi-enclosed ceiling fan fixture base-up due to fractured solder joints, and one sample in a sideways position in a ceiling fixture due to a blown resistor. Two of these three were repairable but one of those with the bad solder joints blew the MOSFETs making repair more trouble than it was worth.

13. There may be an audible buzz from the ballast, especially the iron type.

14. CFLs may produce Radio Frequency Interference (RFI).
15. While their rated life may be 6,000 to 20,000 hours, a wayward baseball will break one of these as easily as a 25 cent incandescent as I've found out - but that's how I was able to trace the ballast schematics!

The prices of CFLs are dropping and $5 or $6 for one that does a decent job of replacing a 100 W incandescent lamp (in terms of color, light output, and fit) is now common. Depending on the cost of electricity in your area, these should pay for themselves over the number of hours equivalent to the lifetime of 1 to 2 incandescent lamps.

As an example, in 750 hours, a typical 26 W (consumed) CFL with a light output of 1,700 lumens (similar to a 100 W soft white incandescent) will use 19.5 kWh, compared to 75.0 kWh for the incandescent. At 10 cents/kWh, this represents a saving of $5.55. Add in $0.50 for the cost of the incandescent lamp and it's already just about break-even for a $6 CFL. And, most of the life of the CFL and continued savings on electricity lies ahead. With special discounts and promotions, CFL prices may be even lower resulting in quicker pay-back periods.

Identify locations where lamps or fixtures are left on for a significant number of hours on average per day. Or equivalently, where it seems you are always replacing bulbs (but they are actually lasting for their rated life, not burning out due to vibration or bad connections). It doesn't make sense to put a CFL in a closet or attic which isn't used much. Even a bathroom is typically a marginal location. Go for CFLs that will fit physically and and where their color and appearance is acceptable. Home centers may have better prices than corner hardware stores but not always. Shop around before buying (or at least before buying a bushel).

For more information, see the separate document on Compact Fluorescent Lamps.

If you're into recycling electronics to other uses, see Andrew Gabriel's D.I.Y. Electronic Gear Page for taking the electronic ballasts from compact fluorescents that died due to lamp failure and using them to drive normal fluorescent lamps as well as remotely connected CF lamps.

(From: Victor Roberts (Vic@RobertsResearchInc.com).)

One big difference between the low cost electronic ballasts designed for integral CFLs and the higher cost ballasts designed to be used with plug-in CFLs or linear fluorescent lamps, is that the former are usually not designed to survive if the lamp does not light or is not present. After all, for an integral system, once the lamp dies there is no reason why the ballast cannot also burn out. One reason external electronic ballasts are more expensive than the electronic ballasts used in integral CFLs is that external ballasts are designed to survive if the lamp does not light or is not present.

If you "harvest" an electronic ballast from an integral CFL, in addition to making sure you know what you are doing so you don't kill yourself or someone else, make sure that you never operate the ballast without a operating lamp attached. If you do, the ballast will most likely burn out in less than a few seconds.

Cold Weather Fluorescent Lamps

(From: Bruce Potter (s602531@aix2.uottawa.ca).)

There are special lamps with heavy glass jackets and/or with krypton gas filling for cold weather/freezer applications. They work best at below room-temperatures. It really annoys me when I go to the grocery store or see outside installations with dim, flickering tubes! What a waste of electricity!

Fluorescent Lamps which Operate from Low Voltage DC

These are now found in all sorts of equipment including laptop computers and all many other portable high tech devices to camping lanterns, boats, and RVs, All are based on an electronic ballast that converts the low voltage DC (anywhere from 3 V to 24 V depending on application) to high frequency high voltage AC to operate the fluorescent tube(s). Laptop computers and similar devices use special narrow tubes designed specifically to be run without heated filaments (cold cathode operation) and very narrow envelops to fit into very thin spaces. :) Most of the others use conventional fluorescent tubes and may or may not drive the filaments during starting or at any other time.

The ballasts for these lamps must generate the required voltages to start and operate the lamps reliably as well as to assure long life. See the section: Electronic Ballasts for more info and some links to sample circuits.

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Troubleshooting of Fluorescent Lamps and Fixtures

Problems with Fluorescent Lamps and Fixtures

In addition to the usual defective or damaged plugs, broken wires in the cord, general bad connections, fluorescent lamps and fixtures have some unique problems of their own. The following assumes a lamp or fixture with a conventional iron (non-electronic) ballast. Always try a new set of fluorescent tubes and starter (where used) before considering other possible failures.

If two tubes dim or flicker in unison, this means that both are powered by the same ballast. Often this means that one tube has failed, although the other tube may also be in poor condition or approaching the end of its life. Both tubes must be replaced with known good tubes in order to rule out a defective ballast.

1. Bad fluorescent tubes. Unlike incandescent lamps where a visual examination of the bulb itself will often identify a broken filament, there is often no way of just looking at a fluorescent tube to determine if it is bad. It may look perfectly ok though burned out fluorescents will often have one or both ends blackened. However, a blackened end is not in itself always an indication of a bad tube. Blackened ends are a somewhat reliable means of identifying bad tubes in 34 or 40 watt rapid start fixtures. Blackened ends are not as reliable an indicator in preheat or trigger start fixtures, or for tubes of 20 watts or less.

   Failure of the electrodes/filaments at one or both ends of the the fluorescent tube will usually result in either a low intensity glow or flickering behavior, or sometimes in no light at all. A broken filament in a fluorescent tube used in a preheat type fixture (with a starter) will almost always result in a totally dead lamp as there will be no power to the starter. A dim glow is rare in this case and would probably be confined to the region of the broken filament if it occurs. The best approach is to simply try replacing any suspect tubes - preferably both in a pair that are driven from a single ballast.

One end glowing bright orange means the tube is dead - the filament has lost its electron-emitting coating. A working filament at that temperature will emit enough electrons to cause a discharge around it which will make the phosphor glow at that end (even without any voltage across the tube). The electron-emitting coating is normally to be found at this stage coating the inside of the glass, resulting in black tube ends.

Before such complete failure, while the coating on one filament is much less effective that the other, this results in asymmetric current flow and 50/60 Hz flicker. This can have a bad psychological effect on people (even if they are not actually aware of the flicker), and is very bad news for anyone susceptible to epilepsy (50 Hz supplies are probably worse in this respect).

In fixtures where a rapid start ballast runs two tubes, both tubes will go out when one fails. Sometimes one or both tubes will glow dimly and/or flicker. If one tube glows dimly and the other is completely dead, this does not indicate which tube has failed. The brighter tube may be the good one or the bad one. The bad tube usually has noticeable blackening at one end. It may pay to replace both tubes, especially if significant labor costs are involved. Also, prolonged dim-glowing may degrade the tube that did not initially fail.

In trigger start fixtures that use one ballast to power two 20 watt tubes, sometimes both tubes will blink or intermittently dim. Replacing either tube with a known good tube may fail to fix this. The tubes may continue blinking or intermittently dimming until both are replaced with brand new tubes. This sometimes indicates borderline low line voltage ("brownout", etc.), nonideal temperatures, or a borderline (probably cheaply designed) ballast.

A simple test that will confirm that a tube is bad is to check the continuity between the pair of pins at each end. If either set are open, the tube is guaranteed bad if used in a preheat or rapid start fixture. It might still work in an instant or trigger start fixture, or one with an electronic ballast, since these do not depend on heating the filament via current through the two pins. However, if there is continuity, the tube could still be bad as noted above.

2. Bad or incorrect starter (preheat fixtures only). The little starter can may go bad or be damaged by faulty fluorescent tubes continuously trying to start unsuccessfully. It is a good idea to replace the starter whenever tubes are replaced in these types of fixtures. One way that starters go bad is to "get stuck". Symptoms of this are the ends of the affected tube glowing, usually with an orange color of some sort or another but sometimes with a color closer to the tube's normal color if arcs form across the filaments. Occaisionally, only one end arcs and glows brightly, and the other end glows dimmer with a more orange color. This is hard on both the tube and the ballast. The defective starter should be immediately removed.

A starter that is rated for a different wattage lamp can result not only in starting problems, but erratic behavior if the lamp does successfully start. For example, a starter rated for a lower wattage or shorter lamp (lower voltage drop) may be randomly activated resulting in flickering as it attempts (incorrectly) to restart.

Should one or both ends glow with a bright yellowish orange color with no sign of any arc discharge surrounding each filament, then the emissive material on the filaments is probably depleted or defective. In such a case, the tube should be replaced regardless of what else is wrong. If both ends glow a dim orange color, then the filaments' emissive coating may or may not be in good shape. It takes approximately 10 volts to form an arc across a healthy fluorescent lamp filament.

3. Defective iron ballast. The ballast may be obviously burned and smelly, overheated, or have a loud hum or buzz. Eventually, a thermal protector built into many ballasts will open due to the overheating (though this will probably reset when it cools down). The fixture may appear to be dead. A bad ballast could conceivably damage other parts as well and blow the fluorescent tubes. If the high voltage windings of rapid start or trigger start ballasts are open or shorted, then the lamp will not start.

   Ballasts for fixtures less than 30 watts usually do not have thermal protection and in rare cases catch fire if they overheat. Defective fixtures should not be left operating.

4. Bad sockets. These can be damaged through forceful installation or removal of a fluorescent tube. With some ballasts (instant start, for example), a switch contact in the socket prevents generation of the starting voltage if there is no tube in place. This minimizes the possibility of shock while changing tubes but can also be an additional spot for a faulty connection.

5. Lack of ground. For fluorescent fixtures using rapid start or instant start ballasts, it is often necessary for the metal reflector to be connected to the electrical system's safety ground. If this is not done, starting may be erratic or may require you to run your hand over the tube to get it to light. In addition, of course, it is an important safety requirement.

WARNING: Electronic ballasts are switching power supplies and need to be serviced by someone qualified in their repair both for personal safety as well as continued protection from electrical and fire hazards.

Causes of Short Lamp Life

The following directly addresses issues with the common 4 foot 34 to 40 W fluorescent lamps and fixtures. However, most will apply to other wattages.

(From: Don Klipstein (don@Misty.com).)

There are two likely reasons for short lamp life:

1. **Bulb-ballast mismatch:** There are several different wattages of 4-foot fluorescent bulbs, two of which are called F40. The "energy saver" F40 is usually 34 watts but sometimes 35 watts but treatable as a 34. F40 with no mention of "energy saver" or "energy saving" is a true 40 watt.

2. **Subtle partial ballast failure:** Sometimes, usually in a 2-bulb magnetic rapid start ballast, a capacitor in series with the transformer's secondary winding fails. Excessive current flows through the lamp and the ballast can overheat. If you have or can borrow one of those "clamp-on" AC ammeters, clamp it around the black lead or the white lead (but not both, for a 120 VAC USA-usual ballast of this sort). A good ballast will draw approximately 0.8 A. A bad one will draw around 1.5 A.

Some less likely reasons:

3. **Excessive cycling:** You turn the lamps on and off a lot.

4. **The ballasts are cheap junk:** Replace them with "commercial grade" ballasts.

5. **Corroded contacts in the sockets:** Try twisting the bulbs around. Slight chance you need to clean the socket contacts with sandpaper (WITH POWER OFF - 280 volts is a popular output voltage of a 2-bulb F40 rapid start ballast.) Slight chance you need a new fixture - and then replace the cheapo-junko ballast with a proper "commercial grade" one, if the usually 2-inch-longer-length of the proper ballast is something the fixture will accept.

6. **Bulbs need to be cleaned:** More likely in humid coastal areas - a slightly conductive film of dust/salt/dirt on the bulbs can affect electric field distribution within bulbs that have not yet started and that can impair starting.

7. **The fixture may not be grounded:** It should be connected to the grounding conductor of the cable feeding it. This sometimes affects starting and sometimes unpredictably or in a manner varying with bulb age, temperature and humidity.

   But if the bulbs always start until some time when they act up and never start again, then grounding is probably not the problem.

Comments on Black Bands and Other Fluorescent Failure Issues

(From: Don Klipstein (don@Misty.com).)

Fluorescent tubes failing in this manner normally draw reduced current. The voltage across the tube is higher and the tube will sometimes draw more power, but the current flowing through the ballast is less.

Since the ends of the bulb usually burn out unequally, some "net DC" may try to flow through the ballast. My experience is that the feared core saturation effects do not occur. Furthermore, the common rapid start ballasts have a capacitor in series with the secondary windings which would block any DC.

There is a different problem that I once knew of causing a fire: Starters getting stuck in the "closed" state. The symptom is the ends of the tube glowing brightly, either yellow-orange or a color closer to the normal tube color, sometimes even one end glowing yellow-orange and one end glowing a more normal color. Excessive ballast current flows in this case. This is not a problem with "instant start", "rapid start", or "trigger start" fixtures. It is only a problem where there are starters.

A dim orange or red-orange glow more likely indicates dead tubes on a rapid start or trigger start ballast. If the fixture is a preheat type, dim orange end glow indicates less current than a brighter yellow-orange, and the ballast is less likely to overheat. Different brands of ballasts are designed a little differently.

If a preheat fixture has the tube glowing only in the ends, it is recommended to immediately remove the tube to stop the ballast from possibly overheating. You should replace both the tube and the starter. The starter is bad if this occurs, and the tube is usually bad also. Typically, the starter goes bad after too much time trying to start a bad tube. In the unlikely event the starter had the initial failure, the tube will be damaged by prolonged excessive end glow.

Why is a Grounded Fixture Needed for Reliable Starting?

Many fluorescent fixtures will not start reliably unless they are connected to a solid earth (safety) ground. This is most likely the case with rapid or trigger start magnetic ballasts. These will usually state on the label: "Mount tube within 1/2 inch of grounded metal reflector". If this is not done or if the entire fixture is not grounded, starting will be erratic - possibly taking a long or random amount of time to start or waiting until you brush your hand along the tube.

The reason is straightforward:

The metal reflector or your hand provides a capacitive path to ground through the wall of the fluorescent tube. This helps to ionize the gases inside the tube and initiate conduction in the tube. However, once current is flowing from end-to-end, the impedance in the ballast circuit is much much lower than this capacitive path. Thus, the added capacitance is irrelevant once the tube has started.

The reason that this is required is probably partly one of cost: it is cheaper to manufacture a ballast with slightly lower starting voltage but require the fixture to be grounded - as it should be for safety anyhow.

(From: Don Klipstein (don@Misty.com).)

Should one or both tubes glow dimly, then ionization is not the problem and poor grounding isn't the cause. In such a case, the problem is poor contact with the pins of the tubes, one or both tubes are bad, insufficient voltage, bulb/ballast mismatch (wrong bulbs may fit but not work especially for 4-footers which come in many wattages), or possibly just a bad case of the bulbs being much too cold. Wire or foil or other attachments to change the electric field distribution will not help dim glow make the transition to arc - only help with the tubes ionizing and glowing at all.

Why Do Fluorescent Lamps Buzz and What to Do About It?

The buzzing light is probably a mundane problem with a defective or cheap ballast. There's also the possibility of sloppy mechanical construction which lets something vibrate from the magnetic field of the ballast until thermal expansion eventually stops it.

First check for loose or vibrating sheetmetal parts - the ballast may simply be vibrating these and itself not be defective.

Most newer fixtures are of the 'rapid start' or 'warm start' variety and do not have starters. The ballast has a high voltage winding which provides the starting voltage.

There will always be a ballast - it is necessary to limit the current to the tube(s) and for starting if there is no starter. In older fixtures, these will be big heavy magnetic choke/transformer devices - hard to miss if you open the thing. Cheap and/or defective ones tend to make noise. They are replaceable but you need to get one of the same type and ratings - hopefully of higher quality. A new fixture may be cheaper.

The starter if present is a small cylindrical aluminum can, approximately 3/4" x 1-1/2" in a socket, usually accessible without disassembly. It twists counterclockwise to remove. They are inexpensive but probably not your problem. To verify, simply remove the starter after the lamp is on - it is not needed then.

The newest fixtures may use totally electronic ballasts which are less likely to buzz. Warning: electronic ballasts are basically switching power supplies and are maybe hazardous to service (both in terms of your safety and the risk of a fire hazard from improper repair) unless you have the appropriate knowledge and experience.

Where the buzzing started after replacing the ballast, assuming the replacement is of the same type as the original and it is tightly mounted, there is probably nothing really wrong - it is just not as quiet as your previous ballast. Make sure it is the ballast and not its mounting sheet metal vibrating. If the sound is coming from the ballast, there really isn't a lot that can be done other than to try another manufacturer or sample. Also see the section: Why do Fluorescent Lamps Buzz and What to Do About It?.

(From Brian Beck (jrdnut@utah-inter.net).)

There are 2 main types of ballasts; those for 'home' use and those for commercial use. The commercial type will last longer and the lamp life is better as well.

There are three sound ratings

- A - extremely quiet (e.g., libraries, churches).
- B - somewhat noisy (e.g., work areas, shops).
- C - outdoor noisy (e.g., 60 foot poles in parking lots).

My guess is you got a home rated ballast with a 'B' sound rating. There is nothing wrong with the ballast - it is just noisy. If the buzz bothers you, return it to the store you bought it and go purchase one at an actual electrical parts supplier (home centers and hardware stores may not have the highest quality components). For a 2 lamp F40/T12/CW/SS lamp fixture, you want an R2S40TP ballast.

Why Fluorescent Lamps are Sometimes Dimmer than Expected?

> "I recently replaced a kitchen overhead fixture with two 75 watt bulbs with a fluorescent one having two 20 W bulbs. Guess what? Not enough light!"
>
> Somehow I was under the impression that a watt of fluorescent lighting produced many more candles than a watt of incandescent lighting, but obviously, I

overestimated the ratio."

A 20 watt fluorescent bulb of a higher light output color should make as much light as a 75 watt incandescent (1170 to 1210 lumens), BUT:

1. A few fluorescent lamp colors are dimmer, such as Deluxe versions of cool white and warm white, and a few others.

2. Fluorescent lamps only make full light output in a somewhat narrow temperature range. The fluorescents will probably not make full light when they first get started. They typically make more light after warming up for a few minutes, then may lose a bit of light output if they warm up past optimum temperature.

3. Some ballasts do not make fluorescent lamps produce full light. Some 20 watt fixtures use a multi-purpose ballast designed to be usable with a few different wattages of lamps, and which typically sends about 16 watts of power to a 20 watt tube. A few other ballasts send an inferior current waveform to the tube, impairing efficiency. I have found some fixtures by "Lights of America" to suffer slightly impaired efficiency from a less smooth current waveform generated by an instant-start ballast system that starts "preheat" tubes instantly without a starter. Some cheaper rapid start and trigger start ballasts produce slightly inferior current waveforms.

   Some of the slightly popular 2-tube 20 watt "trigger start" ballasts are cheap and "fussy", and only work well if everything is optimum. These ballasts often don't work well with cool temperatures, slightly low line voltages, or slightly weak lamps. Their best may not be too great anyway. The same may be true of some cheaper two-tube 40 watt "shop light" ballasts. Also, some "shop light" fixtures that you may think are dual 40 watt are actually dual 25 watt 4-foot fixtures.

4. Some fluorescent lamp colors (especially warm white, white, and cool white) have a spectral distribution that dims most reds and most greens. This may make things look dimmer. For details of this effect, look for the appropriate section in Some Bits of Discharge Lamp Theory andOther Technical Information!, (a web document related mostly to discharge lamp mechanics).

   "What will happen if I replace the two T20s with higher powered lamps? (If some will burn out, can I replace it as well?"

The ballasts in nearly all 20 watt fixtures will not send much over 20 watts of power to any size tube. Sometimes even not much over 16 watts to any size tube. You need a different fixture, more fixtures/tubes, or possibly tubes of the same wattage but better brightness and/or color brightening (more modern '3000', 'D830', '3500', 'D835', '4100', or 'D841' tubes with higher lumen ratings but of wattage and size for the fixture).

Replacing fluorescent lamp or fixture components

Most of these parts are easily replaced and readily available. However, it is usually necessary to match the original and replacement fairly closely. Ballasts in particular are designed for a particular wattage, type and size, and tube configuration. Take the old ballast with you when shopping for a replacement. There may be different types of sockets as well depending on the type of ballast you have.

It is also a possible fire hazard to replace fluorescent tubes with a different wattage even if they fit physically. A specific warning has been issued about replacing 40 W tubes with 34 W energy saving tubes, for example. The problem is that the ballast must also be correctly sized for the new tubes and simply replacing the tubes results in excessive current flow and overheating of the ballast(s).

Rings or Swirls of Light in Fluorescent Lamps

Complaints are generally of the following form:

> "I just replaced my bulbs because they had the black bands at the end and finally went out altogether. The new bulbs light fine but they have subtle rings of light running down the inside of them."

or

> "My fluorescent tubes look like a they have a writhing snake inside trying to get out."

(From: Don Klipstein (don@Misty.com).)

The rings sometimes happens. I forget the name of this, but it is a sometimes normal feature of the main discharge column in low pressure lamps. In fluorescent tubes, it is more common if the bulb is cold or not fully warmed up, brand new or not-yet broken in, or if the ballast is of poor quality or there is a bulb/ballast mismatch.

Double check the label on the ballast and the lamp type to be sure they are compatible with each other.

If the bulb is an "energy saver" 34 or 35 watt model (part number usually begins with F40, which is the same for a normal 40 watt bulb), be sure the ballast is compatible with that bulb. If it is compatible with both 34's and 40's, it is compatible with 35's. Matching bulbs/ballasts is important for these models mainly to ensure long bulb life and to avoid overheating the ballast. 34 and 35 watt bulbs are prone to rings and flickering and being dim and being unusually sensitive to cold because of the nature of these bulbs and can do so no matter what ballast you use. They will normally behave properly after warming up, especially in ceiling fixtures where heat builds up.

Fluorescent tubes sometimes also "swirl" before being broken in, or if they are underpowered by an incorrect or low quality ballast.

Comments on Instant Start/Rapid Start Compatibility

(From: Ken Berg (goken@inreach.com).)

The problem with premature lamp failures using Instant Start ballast lies in the fundamental difference in the basic operating principles between Rapid Start and Instant Start lamps. It has really nothing to do with whether the ballast is magnetic or electronic. Instant Start ballasts are really designed to be used with the standard T12 single pin Slimline lamps. Instant Start ballasts deliver a higher striking voltage on starting than Rapid Start ballasts do. Slimline (the single pin) lamps have a slightly heavier cathode to tolerate the starting cycle. With Instant Start, the lamps are really started "cold cathode" style, and then they of course run as hot cathode.

On occasion, even the standard T12 Slimlines refuse to "die like gentlemen" and flash and swirl wildly. Maintenance guys have known for decades that they need to replace Slimlines promptly if they start doing this. They will need to keep this in mind when dealing with the F32T8 lamps as well. Even though the lamps are bi-pin, and so look like the old Rapid Start T12's, they are more than likely running on an Instant Start circuit, and will sometimes go like this.

The cathodes in most bi-pin lamps are made for Rapid Start, which is a starting method that is easier on the filaments. The lamp manufacturers are supposed to have already taken the starting characteristics of the new F32T8 Instant Start ballasts into account, but some might just be going on the cheap, and skimping of the lamp filaments.

Premature Cathode Failure in Dimmed Fluorescent Lamps

> "I have been experimenting with 15 W T8 lamps running from a dimmable electronic ballast. I have found that if set to a low light level after a few days of being left on, one of the cathodes in the tube often goes open circuit."

(From: Clive Mitchell (clive@emanator.demon.co.uk).)

The only explanation that I can come up with is that there isn't enough current flow to keep the cathodes warm and this is causing the discharge to be concentrated on a small point. The discharge will tend to stay on that point since it's the only warm bit, and as such is emitting electrons, making it the easiest path for current flow.

The voltage drop across this point will be higher than normal since the heat being generated is being dissipated by the rest of the cathode and this means that more power than normal is being dissipated from that point causing sputtering. This could be causing the early burn-out.

The best way to validate this would be with a clear tube to see the cathode discharge activity.

I've seen a phenomenon like this when I've lit a halide lamp at low level with a small voltage multiplier circuit. The glow discharge led to a white hot point on the electrode that caused sputtering.

If this is the case, then the cure is to use a ballast that can supply a continuous heating current to the cathodes.

Replace Preheat Ballasts with Rapid or Trigger Start Type?

When a ballast fails in a preheat fixture, should the bad preheat ballast be replaced with a more modern type? Advantages of a rapid or trigger start ballast are that the starter (a high failure part) is eliminated and the fluorescent lamps may last longer as a result of less stress during starting. Disadvantage include cost of the ballast and possibly space limitations inside the fixture. However, since a defective starter may ruin the lamp controlled by it, the potential cost of replacement lamps may offset the additional cost of the ballast. All in all, this is probably not a decision affecting the future of the Universe but in certain cases, changing ballast types may make sense.

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Items of Interest

All Those Different Wattage 4-Foot and F40 and "Shop Light" Lamps?

The original 4-foot fluorescent lamp was the F40T12, which is 47.75 inches (approx. 121.3 cm) long from pin tip to pin tip and 1.5 inches (approx. 4 cm) in diameter and designed to consume 40 watts. Not too many years ago, this was the most common and least expensive fluorescent lamp.

There is the "HO" (high output) 4-foot tube and the "SHO" (super high output) 4-foot tube. These are not common and are only used where there is not enough room to fit enough standard F40 tubes to make enough light. These lamps are slightly less efficient than standard fluorescent lamps. These tubes require more current than standard 4-foot tubes and require special ballasts. These tubes should only be used with their respective ballasts, and these ballasts should only be used with the tubes they were designed for.

In response to the energy shortages of the 1970's, the 34 watt lamp with the same physical dimensions was introduced. It works in most 40 watt fixtures and draws 34 watts in these fixtures. However, some 40 watt ballasts can overheat with this lamp. The ballast should say that it is rated for use with 34 watt lamps.
Please note that a 34 watt tube can say F40 and still be a 34 watt tube and not be a 40 watt tube. It will in some way say near the F40 designation that it is an energy-saving tube. There have also been a few 35 watt tubes, which are similar enough to 34 watt tubes to work anywhere both 34 and 40 watt tubes can work. 34 watt lamps sometimes produce noticeably less light than 40 watt lamps, especially in cooler environments.

Nowadays, there is the 25 watt "shop light" lamp. The 25 watt tubes should only be used with appropriate 25 watt shop light ballasts, and these ballasts should only be used with these tubes. Please do not confuse these with other wattage tubes/fixtures of the same physical dimensions which are also sometimes called "shop lights".

A more recent development is the 32 watt T8 lamp, which is 4 feet long but only one inch (2.5 cm) in diameter. These require ballasts made for them. Many of the ballasts made for these lamps are electronic ballasts.

The confusion has increased in recent years now that the USA has an energy-conservation law against manufacturing and importing standard 40 watt white fluorescent lamps. Specialty lamps and white ones with a color rendering index of at least 82 (out of a maximum of 100) are exempt and are still available in the USA as true 40 watt lamps.

Again, be sure that you are not mismatching the bulb and the ballast. If the ballast is not rated to operate the bulb type being used, the bulb life will probably be shortened and the ballast life may be shortened. In a few cases, the ballast may catch fire after failing.

What's with All Those Different Shades of White?

At one time, most fluorescent lamps were "cool white" which is a plain-old white with a color like that of of average sunlight.
One bad thing about "cool white" is that the spectrum of "cool white" has a surplus of yellow and a shortage of green and red. Since mixing red light with green light makes yellow, the white light of a cool white lamp still looks white. Since yellow objects usually reflect green through red, they look yellow as usual in this light.
But red objects reflect mainly red light and green objects reflect mainly green light, and look dim and dull due to the shortage of red and green wavelengths in "cool white". Impure reds and greens will look less red and less green as well as darker - making them look more brown.

Other early whites were "warm white" and "daylight". Warm white is a color similar to that of incandescent lamps, although it usually looks slightly less yellow and more white-pink. A warm white lamp's spectrum has a surplus of yellow and violet-blue, and a shortage of red, green, and green-blue. Like cool white, warm white can distort colors in unflattering ways.
Both "warm white" and "cool white" are obtained using "halophosphate" phosphors. The surplus of yellow and shortage of red and green is a general characteristic of halophosphate phosphors.
"Daylight" is a bluish white, and does not have as bad a surplus of yellow as the other halophosphate whites. But it is also slightly dimmer.

Next were the "deluxe" versions of cool white and warm white. These have "improved" halophosphate phosphors and are sometimes known as "broad spectrum" lamps. They have a less severe yellow surplus and red/green shortage than standard halophosphate lamps. They also produce slightly less light.

Another slightly common halophosphate white is "white", which is between "cool white" and "warm white" in color.

Other halophosphate whites, whether of differing spectral quality or different shade of "warmth/coolness" include "supermarket white", "sign white", "north light", "merchandising white", etc. Please note that some of these are not made by all fluorescent lamp manufacturers, and some of the less standard color names are trademarks of their respective manufacturers.

One earlier fluorescent lamp color with enhanced red spectral content is the "natural". This lamp has "cool white" halophosphate phosphor with a red-glowing phosphor of a different type added in. These lamps look slightly pinkish in color, sometimes purplish when compared to warmer colored light such as incandescent light. "Natural" fluorescent lamps make skin tones look pinkish, unlike the usual halophosphate types which make skin tones look green-yellowish. Some meat displays have "natural" fluorescent lamps to make the meat look more red.

Nowadays, there are "triphosphor" fluorescent lamps. These have a spectrum very different from that of the halophosphate lamps. Triphosphor lamps have their spectral content mostly in distint bands and lines: Orangish red, slightly yellowish green, green-blue, and violet-blue. For cooler color lamps, there is an additional band in the mid-blue. Triphosphor lamps do not distort colors as badly as halophosphate lamps, and triphosphor's color distortions are usually not as unpleasant as those of halophosphate. Also, triphosphor lamps often make reds and greens look slightly brighter than normal, unlike halophosphate lamps which usually make these colors look dimmer than normal.

Most compact fluorescent lamps and most 4-foot T8 (1-inch diameter) lamps are triphosphor lamps.

Triphosphor lamps come in various warm and cool shades, usually designated by "color temperature". This is the temperature that an ideal incandescent radiator would be heated to in order to glow with a similar color. Color codes on fluorescent lamps may include the color temperature or 1/100 of the color temperature. Osram/Sylvania brand lamps often have D8 immediately preceding the color code.

2700 or 27 - orangish shade common for compact fluorescent lamps, similar to many incandescent lamps.

3000 or 30 - "warm white", similar to whiter shades of incandescent.

3500 or 35 - between warm white and cool white, similar to the whitest halogen lamps and projector lamps.

4100 or 41 - "cool white" or the color of average sunlight.

5000 or 50 - an icy cold pure white like that of noontime tropical sunlight.

6500 or 65 - slightly bluish white or "daylight".

There are still other specialty whites, including ones with a mixture of "broad spectrum" and "triphosphor" phosphor formulations to get a spectrum more like that of daylight. Some others have particularly good "broad spectrum" phosphors, sometimes mixed with other phosphors for a tailored spectrum. Many of these, like most triphosphor lamps, have color temperature designations.

Why Small Fluorescent lamps Cost More than 4-Foot Ones

Can you say 'supply and demand' and 'economies of mass production'. You are comparing the price of the common F40CW-T12 lamp manufactured by the zillions and sold in home centers for about $1 with specialty bulbs used in a relatively few devices like battery powered fluorescent lanterns and makeup mirrors. These little bulbs may indeed cost up to ten times as much as the much larger ones.

By any measure of materials and manufacturing cost, the 4 foot bulb is much much more expensive to produce. There is nothing special involved.

Energy Consumption and Wear-And-Tear due to Starting

(From: John Gilliver (g6jpg@gmrc.gecm.com).)

The amount of energy used in starting isn't worth worrying about. However, in addition to the turn on/off deterioration, there is also the steady-state `on' deterioration (they don't last for ever even if left on), so...

As far as turn-on deterioration:

I can't give it as a percentage, but for ordinary striplights I heard a figure of 15 minutes (about 15 years ago), i. e. turning it on stresses it as much as leaving it on for that long. Things have perhaps changed by now (and there are so many kinds these days as well).

For low-energy use, I'd go for fluorescents any day, unless size is a major factor (Bosch [I think] and others have been trying to get some sort of discharge lamp for headlights for some time, but I haven't seen any yet). You might also look into LEDs, but I doubt they will match the efficiency; certainly only the high-effificiency types (all seem to consume about 10, 20, or 30 mA, but the output power in light seems to vary widely, from a few millicandelas to about three candelas!). They are narrow band (i. e. coloured) as well of course.

What Happens when Fluorescent Lamps Wear Out?

(From: Charles R. Sullivan (charless@crissy.EECS.Berkeley.EDU).)

The usual failure mode is depletion of the emission mix on the filaments. Then they do not emit electrons, and the arc can't be sustained. Unless the ballast supplies a high enough voltage that very high field can be set up near the electrode. Then the ions bombarding the electrode have a high enough energy to knock electrons out of the metal even with no emission mix, or to heat the metal to the point it emits electrons. The high field is also sufficient to ionize the argon fill gas---normally only mercury is ionized. The argon radiation is of a more purple color. That is probably what you see.

Blackening at Ends of Fluorescent Tubes

This is a common phenomenon with most common fluorescent tubes as they age. However, frequent or repeated starting can accelerate the process. The black areas in themselves don't affect operation except to slightly reduce the amount of light available since the phosphor in that area is dead. However, they do represent a loss of metal from the electrodes (filaments).

The cause is sputtering from the filaments, mostly when cold. Thus. this happens mostly when starting or with a defective rapid start ballast which doesn't heat the filament(s) or a ballast or starter that continuously cycles. When the filament is cold and is the cathode (on the negative half of the AC cycle for that end of the tube), the work function is higher and ions have a higher velocity when impacting, knocking off metal atoms in the process. This is greatly reduced once the filament is up to normal operating temperature (though even then, some sputtering is inevitable).

(From: Greg Grieves (ggrieves@home.com).)

Lamps with the longest lifetimes typically use the heavier noble gasses as the buffer gas, (Xenon or Krypton instead of Argon) because the sputtering that occurs at the cathode is due to fast ion bombardment from the ionized gasses in the tube. the heavier atoms have a smaller velocity for a given kinetic energy of acceleration. its not the total energy of the ion that sputters but its the momentum at impact that knocks other atoms loose. I presume thats why Kr and Xe bulbs can run brighter, because they can crank up the power and still have about the same lifetime. Some tubes use a "hollow cathode" design in which the shape of the cathode is designed to deflect impacting ions rather than be sputtered by them. That's my understanding, anyway, theres much more to the story...

(From: PBerry1234 (pberry1234@aol.com).)

I recall one brand of lamp that positioned shields around the electrodes to prevent the blackening. I suppose this improved the appearance in exposed lamp applications, but don't know of any other benefits.

Hot Cathode Versus Cold Cathode Operation

The cathode is the negative electrode of a vacuum tube or gas filled discharge tube. Current flows by way of electrons emitted from the cathode and attracted to the positive electrode, the anode.

A hot cathode is one which must be heated to operate properly - to emit sufficient electrons to be useful. Examples: TV and monitor CRTs, most vacuum tubes (or valves), vacuum fluorescent displays (like those on your VCR). This is called thermionic emission - the boiling off of electrons from the surface of the cathode. Normal fluorescent lamps are hot cathode devices - partially maintained by the discharge current itself. They all have some sort of warmup period (though it can be quite short).

(From: Phil Rimmer (primmer@tunewell.com).)

A cold cathode is one where operation takes place without depending on heating of the surface above ambient. There are all sorts of devices that use 'cold' cathodes - neon lamps and signs, fluorescent backlight tubes, and helium neon laser tubes. Naturally, cold cathode devices don't have much of a warmup requirement.

The purpose of a cathode is to feed electrons into the negative end of the positive column (the discharge) so they can variously excite and ionise gas or vapour atoms.

Electrons are released from cathodes by the action of the positive ions being accelerated towards them due to an electric field in the vicinity of the cathode.

Electrons are broadly released in two ways: Thermal emission and secondary emission.

- Thermal emission is the primary process used in "hot cathode" lamps which include standard fluorescent tubes. The ions are accelerated towards the cathode through a small cathode voltage (less than 10 volts) and gain just enough energy to heat a small part of the very fine wire electrode when they collide with it. They heat it until it glows dully and electrons are "boiled off", liberated by the thermal energy. This process is very efficient in producing lots of electrons and results in efficient lamps.

- Secondary emission is a more brutal process for generating electrons. It requires an accelerating voltage drop of 130 to 150 volts. It is used in cold-cathode lamps that have relatively huge cylinders of iron for electrodes. These massive electrodes require much too much energy input to make them into thermal emitters. The energetic ions simply "knock" electrons off the metal surface. In so doing they also knock some of the metal off as well, a process called sputtering. The big electrodes have enough material to last before other effects cause lamp failure.

Hot cathode lamps operate in cold cathode mode if the cathode receives too little energy to keep it glowing. The colliding ions are thirty times more energetic than usual and soon sputter enough metal off the tiny electrodes to destroy them.

Moral: Pre-heat the electrodes before starting the discharge and maintain auxiliary current in the electrodes if the discharge current is low (e.g, when dimming).

Failure Mechanisms of Cold Cathode Fluorescent Lamps

(Portions from: Victor Roberts (Vic@RobertsResearchInc.com).)

- All fluorescent lamps, be they hot cathode, cold cathode or electrodeless will suffer from phosphor degradation. The rate of this degradation is a function of the type and amount of phosphor, the type of glass used for the tube, the temperature of the phosphor & glass and the intensity of the UV flux from the discharge. If these parameters are the same, then the type of electrodes does not make any difference, except perhaps at the ends of the tube.

- For heated filament lamps (which means most of those in residential and commercial lighting), the usual failure mode is depletion of the emission mix on the filaments. Then they do not emit electrons, and the arc can't be sustained.

- Many hollow cold cathodes contain a coating on the inner surface to improve operation. When this coating is degraded the lamp will be harder to start and therefore might not start if the starting voltage is not high enough.

- Due to their high cathode fall voltages, there will often be significant sputtering of cathode material from the surface of a cold cathode. Depending upon the design of the lamp and cathode, this sputtered material can end of up the walls of the lamp where it is unsightly at best, and may absorb significant light at worst.

- Cold cathodes tend to "consume" the active gas in a discharge. Due to the reasonably high cathode fall voltages, ionized gas atoms get buried in the surface of the cathode at a slow rate. In fact, this phenomena is used to make a very effective high vacuum pump. Also, in many HeNe lasers that use cold cathodes, a gas reservoir was added so that the loss of Ne, the dominant excited species, would not significantly change the He:Ne balance which is essential for proper laser action. In a modern fluorescent lamp, where the amount of excess mercury is reduced to prevent disposal problems, consumption of mercury by a cold cathode could be another life-limiting factor.

Comments on Small Inverter Powered Fluorescent Lamps

(From: Paul Bealing (paul@pmb.co.nz).)

Many small low cost inverters use a 2 transistor (one quite small) self oscillating circuit. Simply minimum function, low cost. These circuits can be quite efficient at low power levels. I have seen them used up to 50 watts.

Losses are usually in the transformer and the switching transistors. As the currents increase, the losses usually increase for a given power output.

The lamp requires a high voltage, usually 300 to 500 V, to strike. The voltage depends on the length/wattage of the lamp. Once struck, the current through the lamp is limited to achieve the wattage. The voltage across a small running lamp will be in the order of 60 to 100 volts AC.

Many simple inverters use a series resonant circuit to generate the high strike voltage, which is disabled by the run current.

A couple of years ago I designed an inverter for a PL11 11 Watt lamp based on a switchmode power supply controller IC, 2 power mosfets, and a push-pull transformer, running at about 200 kHz. The main application was in diesel locomotives running from 75 V DC. I've had the circuit operating down to 10V DC (different transformer winding). The primary current rises and the dissipation increases.

Fluorescent Lamp Voltage and Frequency Considerations

For those using iron ballasts, both voltage and frequency will be significant. Though it may be possible to come up with a formula which incorporates both, the best thing to do is to only use the line voltage for which the unit was designed.

Where the frequency isn't the same, the current through the lamp may differ, most likely too high in going from 60 Hz to 50 Hz, too low the opposite way. If the current is too high, there could be shortened lamp life at the very least or even a serious fire hazard. If the current is too low, the lamp may not remain on in a stable manner, flickering, or constantly restarting. Initial starting could also be affected.

If they use electronic ballasts, the frequency probably won't matter. Some "universal" types, can accommodate an input voltage from 90 to 250 VAC up to 400 Hz or even DC.

In all cases, it is best to consult with the manufacturer if the product label doesn't explicitly indicate "50/60 Hz" operation. When in doubt, leave them behind since there is really no way to be sure of the safety issues.

Operating a Fluorescent Lamp on DC

> "I have a application in mind that will use a DC power source around 100 volts and fluorescent lighting. What kinds of voltage do I need to sent the fluorescent? Are there any good sources of info. for the circuitry I would need?"

(From: Don Klipstein (don@Misty.com).)

If it is a preheat tube of 22 watts or less, the cheap-and-dirty way to do it is to use a normal preheat fixture. The only change is to add a resistor in series with the ballast. This resistor should be maybe 100 ohms for 20 and 22 watt lamps, slightly higher for lower wattage ones. It should be able to safely dissipate a wattage comparable to that of the lamp. Of course, you are now wasting significantly more power as heat.

The above includes most simple "PL"/twin-tube compact fluorescent lamps with removable bulbs with two pins, as well as most compact fluorescent bulbs with "choke" type ballasts running from 120 volts AC.

Should you need anything more energy-efficient than this, then there is the world of electronic ballasts.

BTW, most low-power-factor screw-in 120 VAC compact fluorescent lamps with electronic ballasts work fine "as-is" with about 160 volts DC or squarewave.

Ballasts and PCBs (The Hazmat Type)

(From: David Morris (allane@ix.netcom.com).)

Ballasts that were made after the late 70's do not contain PCB's. I spoke with an Advance and GE ballast rep. a few years ago about this and I was told the only sure-fire method to tell that there are no PCB's is if the ballast says no PCB's. Any ballast that doesn't say that has a better than 80% chance of having it. The amount in the ballast is VERY minute. Less than a thimble full. It is used to cool a capacitor in the ballast. Since he said the light is about 12 years old, I am quite certain that the ballast does not contain PCB's. In our state, it is legal to dispose of these ballasts in a limited quantity in your local landfill or throw them in the trash. Larger quantities require Hazmat disposal methods. Our company policy is to leave any old ballasts that is not marked 'no PCB's" with the customer for their disposal.

As a side note, I read in one of the Electrical trade rags that the liquid that replaced PCB's is testing out to be more dangerous than PCB's themselves. Go figure!! :-)

As for catching fire, ballasts contain a thermal protector that will cut the power if the ballast gets too hot. Only real old ballasts do not have this feature. Ballasts marked Class P have this protection. It is very rare for one of these ballasts to actually catch fire, although it does happen. More often, they will smoke up the house if they overheat and the thermal protector fails.

Driving Cold Cathode Fluorescent Lamps

(From: David VanHorn (dvanhorn@cedar.net).)

Linear Technology has several extremely detailed app notes written by Jim Williams on this topic. It's more complicated than you might imagine to do it right. Just making the tube light is perhaps only 10% of the job. The rest includes keeping it running a long time without blackening, providing the ability to set the brightness, not loosing all your energy to wiring capacitance, and not creating an EMI nightmare.

Definitely read and understand those app notes, even if you go to another vendor! The good news is that the actual circuit isn't that bad!

What is the E-Lamp?

The E-Lamp is one of those inventions that sounds like a really good idea but still hasn't (as far as I know) made it into wide scale production. In essence, it is an RF excited compact fluorescent lamp. Some of the E-lamp's basic characteristics include.

- Fits into standard household light bulb bases.
- Radio frequency radiation was emitted, then converted to light.
- Dimmable using standard phase control dimmer - no special devices needed.
- Very efficient so runs cool and consumes much less power than incandescent lamps (don't know how it compares to compact fluorescents).
- Desirable white spectral characteristics.
- No filament to wear out (and no wires through glass) so potentially very long life.

Aside from cost issues, there could also be concerns with respect to RF emissions effects on health and interference with other household appliances and electronics.

(Victor Roberts (Vic@RobertsResearchInc.com).)

E-lamps are electrodeless fluorescent lamps. They use a high frequency or RF magnetic field to create a time varying electric field which in turn drives a discharge which is very similar to the discharge in an ordinary fluorescent lamp. Except for the means by which the discharge is created, these E-lamps and identical to all other fluorescent lamps. There is no magic other than the fact that electrodeless excitation allows for the elimination of the electrodes, so electrode failure and wear out are no longer a problem. Also, electrodeless excitation removes the requirement that the lamp be long and thin to achieve high efficacy. Proof of this is beyond the scope of this note. :) Hence, an electrodeless fluorescent lamp can be more easily made in the shape of an incandescent lamp.

There are also electrodeless metal halide lamps and, of course, the electrodeless sulfur lamp.

Notes on Dimming of Fluorescent Lamps

The following provides a variety of dimming methods, some better than others.

Sam's dimming experiments:

OK, I did some experiments using both a dual-lamp Circline fixture and a typical dual-40 W bulb shop light - both with magnetic (rapid start probably) ballasts.

The common wisdom is not entirely correct. You can dim fluorescents. I do not know about the long term reliability or stress on the ballasts but I could achieve dimming down to around 30 to 50 percent brightness (using my standard-issue eye-balls, calibrated annually) with a relatively stable light output - no excessive flicker and no tendency to go out (though to get down to the low end requires starting high and backing off).

I tried both a Variac and a cheap light dimmer with similar results.

(If you want to go below the 30 to 50 percent threshold reliably, however, some means must be provided to keep the filaments hot.)

How about long term reliability?

This was a 'quick' experiment. All I did was observe the light output. A cheap light dimmer just means the kind you get at a home center for $4 or so. Long term reliability is certainly not known. The purpose was simply to show that just because something is stated to be impossible does not always mean that it is - not a suggestion that it is.

Dimming fluorescents 1:

(From altavoz@azstarnet.com).

48" tubes can glow at microamps if fired with 400 volts and require no heater current at all. The mercury is still probably 99% liquid!! I did this with a 9 V transistor battery and an inverter. As you fire them from lower impedances, still using 400 volts and no heaters, you'll see that you can turn down the current and get a better efficiency (output doesn't drop) but you reach a threshold and it drops light output suddenly. When I was working with 12 VDC ballasts, and 24" tubes I had to fire them at 0.65 amps then drop that to 0.4 A. But below 0.4 A they would dim suddenly to a less efficient point.

Of course this is at warm temperatures. At cooler temps you must have the heaters drawing current to boil the mercury.

I have used the cheap dimmers on many inductive loads and as long as you derate them, they will work fine.

I disassemble standard dual 48" fixtures and put the tubes in line to make a 96" fixture that puts out more light! you only need to put the ballast close to one end of the "starter" tube (the one that always starts first) or put the line Neutral close to the tube (they hook together at the ballast).

Dimming fluorescents 2:

(From: John Shotton (J.A.Shotton@bnr.co.uk)).

I have been running four 5 foot (1.5 inch diameter) tubes like this for 15 years.

The circuits (4 off) are resonant start - i.e., there is a second winding on the ballast which connects across the tube in series with an 8 uF capacitor (remember in the UK the supply is 230 VAC). Thus the heaters are energised at all times.

I originally experimented with a moving iron wattmeter (measures true RMS power), a photodetector, and a variac. Allowing for ballast loss (computed from current and resistance), the light output was directly proportional to power consumption. The lamps would dim to around 10% but they wouldn't start at this level.

The permanent installation used a mains transformer connected as an autotransformer with several taps so that I can get around 6 light levels, though they will not start on the two lowest settings and is slow at starting on the next two settings. I can't remember offhand what light output they will self start on, but it must be around 30 to 40%.

As for tube life, the lights are on most of the time when it is dark - from around 5 pm till 1 am. I fitted my third set of tubes about two years ago, and this was not because the second set had failed but because we wanted a change from daylight color-matching to tri-phosphor 2700 °k - I've still got the second set should we decide to revert to the daylight effect.

When I did my original experiments I also tried it with normal ballast circuits, i.e., with a starter across the tubes. I can't remember the results, but I didn't pursue it so they can't have been good. I believe it would work if the heaters were energised at all times from a separate winding.

Dimming fluorescents 3:

(From: David Gibson (dgibson@microconsultants.com)).

My company designed a fluorescent dimmer some years ago. It dims 40 x 40W tubes fitted with high power factor inductor/capacitor control gear as used in Australia and other 220 to 240 VAC countries. Its main claim to fame is that it can cope with the highly capacitive nature of power factor corrected luminaires, and is hence easily retrofitted. A number of large office buildings in Australia are fitted with our/my dimmer.

Unfortunately, the standard ballast used in the U.S.A. (and I presume other 120 VAC countries) uses, I believe, a resonant circuit which cannot be dimmed with our design.

The luminaires it does work with contain basically a tube/choke series combination across the line, plus a power factor correction cap also across the line. The lamp filaments are heated only during turn-on by a starter switch that completes an additional circuit at startup.

The purpose of these dimmers is energy saving. A photocell measures the ambient light, and maintains a reasonable constant light level in the office. Energy saving is possible because lighting systems must be overdesigned to allow for lumen depreciation due to lamp aging, plus the fact that daylight allows lower levels of electric light.

Performance is as follows:

Dimming range: We budget for 40% of light output (60% reduction). In the lab we have achieved down to 26%.

Power saving: At 40% light power is about 35% (yup, you win twice)

Lamp savings: In a 26 story building in Sydney, for which good figures are available, lamp replacement rate was reduced to about 40%, i.e., we more than doubled lamp life.

Overall power savings: Same building, independently audited figures, lighting bill was reduced by 45%. This included secondary savings from reduced air conditioning and a time switching system integral to our design which ensures lights are off at night etc.

Power factor improvement. Undimmed tubes have a power factor of typically 0.85 to 0.9. At 40% light this is 0.99. This is true power factor (see article on power factor on our Web site, URL below).

Line harmonics: During dimming the percentage of harmonics increases as current drops, but the absolute level (total amps) decreases.

(The power companies love it!).

Our design uses a hard-won, patented proprietary dimming method which has nothing to do with triacs. It uses high frequency switching and some very fast and smart firmware.

The same lamps can be dimmed using triacs, but the power factor correction caps must be removed from every fitting. The required triac circuit is slightly modified; the patents belong to a competitor. Its power factor is lousy.

Dimming fluorescents 4:

(From: Andrew Gabriel (andrew@cucumber.demon.co.uk)).

I have made a dimming fluorescent fitting out of a standard fitting (which started out as a switch-start series ballast), and an ordinary phase control (triac) dimmer.

My only reservation is that this is all for standard 200-250 V switch-start fluorescents - when I've seen American books describing fluorescent lamp control gear, it is quite different, presumably because of the lower mains voltage being unsuitable without more complex control gear.

There are three significant things you have to do:

1. The lamp extinguishes at around half power because the filaments at each end are no longer heated sufficiently during one half cycle's bombardment with electrons to emit electrons in the following half- cycle. I overcame this by supplying the filaments with a few volts from a miniature mains transformer with a pair of isolated low voltage secondaries, around 4 volts IIRC for a 5 foot 80W fitting (it doesn't need to be anywhere near enough voltage for a visible glow from them). Also, with this transformer fitted (and the switch- starter removed), the tube actually fires up all by itself without flashing, since it is now really rapid start fitting.

   I also have a switch to disable the dimmer, and when disabled, it also switches the filament transformer's primary to be across the tube rather than the mains. Thus initially when the tube is non- conducting and the tube voltage is 240 V, the filaments are heated, but as the tube starts up and its voltage drops to its running value of around 100 V, the additional filament heating provided by the transformer, which is unnecessary when the lamp is running normally, is all but disabled.

2. The second problem is that all cheap triac dimmers fire the triac with a pulse and expect the triac to continue conducting until the zero crossing point (or more strictly, zero current). However, an inductive load takes time to start conducting, and at the end of the triac firing pulse, the current through the triac will not have reached the minimum holding current when the dimmer is set low, which also results in sudden extinguishing of the tube when dimming down. To overcome this, I added a small incandescent lamp to the

output load on the dimmer, in my case it's a 40W spotlight pointing at a painting, so it's a useful additional feature.

This also allows the lamp to be dimmed completely down to zero. At very dim levels just above zero, some tubes exhibit Faraday rings, rings of alternate light and dark along the tube which might remain still or move along the tube.

I was expecting the current phase shift due to the inductor to be a problem with a cheap dimmer, but it wasn't.

3. Ensure the power factor correction capacitor is before the dimmer, or you'll destroy the triac. In a commercial environment, I think I would also include some protection against typical triac failure modes of a one-way open or short, which would result in high levels of DC through the inductor which will overheat it and/or destroy the lamp.

BTW, I did all this 20 years ago as a teenager. However, the fitting in question is still running, and has never required a lamp change in that time, nor is there any blackening at the ends of the tube. It is normally run at full brightness with the dimmer disabled.

Dimming fluorescents 5:

(From: Peter Miller (p.miller@elec.gla.ac.uk)).

I've tinkered a bit... the trick is to keep the filaments at the ends of the tubes warm. You will NOT be able to dim down to zero - probably about 25% at best.

Here is a possible circuit:

```
                        Dimmer
                         +--+  Choke
    AC Live/hot o--------|  |--^^^^^^^^--+--------------+
                         +--+            |              |
                                         |              |
                   +---------------------+              |
                   |                     |              |
                   +-+   +----------------+ +-------+   |
                      )|(                   |       |   |
        Filament      )|(                   |      -|---|-
      Transformer     )| +------------------+     |  ^^^  | Tube
      2 * 6.3V 2A     )|                          |       |
                      )|                          |       |
                      )| +------------------+     |  ^^^  |
                      )|(                   |      -|---|-
                      )|(                   |       |   |
                   +-+   +----------------+ +--------   |
                   |                     |              |
AC Neutral/cold o--+---------------------+--------------+
```

The lamp must be in a earthed / grounded reflector fitting. The metal end caps of the tube must be connected to the reflector. The dimmer MUST be a 'hard fired' dimmer capable of operating an inductive load. The choke is a standard type for the tube in use. Play with an inexpensive everyday tube before using expensive aquaria ones. with a 240 VAC supply a 4 foot 40W tube operates ok. The main difficulty with this circuit is in getting the tube to start - starting is greatly helped by a grounded reflector fitting and connecting the metal end caps of the tube to the reflector (Don't ask - it works!). The transformer can be a standard valve filament transformer - use a separate transformer for each end of the tube if you are unsure of the insulation between the secondaries of any transformer that you buy. As the tube draws less current the voltage across it rises, turning up the heat in the filaments. At start up, maximum voltage is across the lamp and so the filaments are fully on. All dimming ballasts/chokes use some scheme to add extra heat to the filaments at dim running. An undimmed tube draws enough current to keep the filaments warm by itself. There is no glow starter or other starting device in the circuit, so the lamps tend to come on smoothly with no flickering. Shorter tubes are easier to start. New slimline tubes are a real pain to start.

Dimming fluorescents 6:

(From: Bruce G. Bostwick (llbgb@utxdp.dp.utexas.edu)).

This applies to rapid start fixtures.

If the fixture says "RAPID START" somewhere on it or on the package it came in, the internal schematic will be roughly as follows:

```
                      || +-------+---------o
AC line H o---------+ ||(   +----+            to both pins on
                     )||(  (  <-6.3VAC        one end
                     )||(   +--------------o
                     )||(
                     )|| +=---- 2kVAC* -------------------------+
                     )||(                                      _|_
                     )||(   +--------------o                  ///
                     )||(  (  <-6.3VAC        to both pins on
AC line N o---------+ ||(   +----+            the other end
                      || +-------+---------o
```

*The high voltage winding of the secondary is on a branch magnetic circuit that limits the output current to the mercury discharge. Most of the 48" 40W "shop light" type of bulbs use this. Open circuit voltage will be in the kilovolt range, while the voltage across a lighted tube will be somewhat less than that and *exceedingly* non-sinusoidal.

If you're using the big bulbs (F96T12's for example) the ballast will only have the high voltage winding and the cathodes are heated by ionic bombardment from the mercury arc. These take a bit longer to light up when the power is turned on.

If you want instantaneous on/off control, I'd suggest using 4-footers and linking up two ballasts in such a way that the cathode heaters are driven from one which is always on, and the arc is driven from the other which is turned on and off as you desire. They won't last too long that way, but it will work better for show effects. The cathodes could be driven from a pair of low-voltage filament transformers, but be sure to isolate them well -- or you could use a ballast with a blown HV secondary ...

Another suggestion: Use solid-state relays to drive the ballast primaries. These are fairly cheap and provide clean current-zero-crossing switching even with very reactive loads (I've used them for such! ;-) and provide a neat and rugged way to connect the lights to logic controls such as your computer -- great for light sequencing.

Dimming fluorescents 7:

(From: a-freak@freenet.de.)

The magazine "Elektor" developed a dimming circuit for fluorescent lamps running at 230 V which is wired in *parallel* to the lamp at the place where usually the glow starter is located. I tried it and it works well for short lamps of the 18W-type but very unstable with the large ones.

In my opinion this circuit is especially nice if you want to dim up a lamp from zero brightness (lamp shorted, full preheating and maximum current) to full operation (usual values), for example to simulate a sunrise.

Dimming fluorescents 7:

(From: Charles R. Patton (patton@dt.wdc.com)).

Advance (and probably others) made special ballasts for 60 Hz (non-electronic such as with a Variac) dimming. One of the main characteristics was the extra wire for the Variac (or symmetrical electronic dimmer) input. The trick was to keep the filaments warm on the tube, therefore the separate filament power which doesn't get varied so that a larger dimming range was possible. This also makes for much longer lifetimes for the tube because cold electrodes are subject to heavy ion bombardment until they heat up from the normal current (which doesn't exist on a dimmed tube.) As I understand it, some electronic ballasts will power the filament separately for a period of time to get it to temperature, then apply high voltage excitation to light the tube.

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