The Stage Lighting Technician's Handbook

A compilation of general knowledge and tricks of the lighting trade

Compiled by Freelancers in the entertainment lighting industry

Stage Terminology:

Learning Objectives/Outcomes.

Understanding directions given in context as to where a job or piece of equipment is to be located. Applying these terms in conjunction with other disciplines to perform the work as directed.

Lighting Terms:

Learning Objectives/Outcome

Learning the descriptive terms used in the use and handling of different types of lighting equipment. Applying these terms, as to the location and types of equipment a stagehand is expected to handle.

Electrical Safety:

Learning Objectives/Outcomes.

Learning about the hazards, when one works with electricity. Applying basic safety ideas, to mitigate ones exposure to them in the field.

Electricity:

Learning Objectives/Outcomes.

Learning the basic concepts of what electricity is and its components. To facilitate ones ability to perform the mathematics to compute loads, wattages and the like in order to safely assemble, determine electrical needs and solve problems.

Lighting Equipment

Learning Objectives/Outcomes.

Recognize the different types of lighting equipment, use's and proper handling. Gain basic trouble shooting skills to successfully complete a task. Build a basic understanding of applying these skills in the different venues that we work in to competently complete assigned tasks.

On-sight Lighting Techniques

Learning Objectives/Outcomes.

Combing the technical knowledge previously gained to execute lighting request while on site, whether in a ballroom or theatre. Approaches, to lighting a presentation to aspects of theatrical lighting to meet a client's expectations. Obtain practical solutions and abilities to interact with clients while on-site to satisfy their needs.

Practical skills

Learning Objectives/Outcomes.

Hands on practice using skills learned in the technical section or utilizing theory previously taught. Using supplier or equipment assisted presentations culminating in simple on-site problems to be solved

Industry Links

Stage Terminology:

- **Learning Objectives/Outcomes.**

Understanding directions given in context as to where a job or piece of equipment is to be located. Applying these terms in conjunction with other disciplines to perform the work as directed.

All directions that are given to perform work, place equipment or find and item is based on a person standing on the stage and looking towards the Audience. However they may be times were the house (the audience sites here) or a camera is referenced. Therefore the directions are as follows:

Stage Left or SL, were your left arm is.

Stage Right or SR, were your right arm is.

Prompt, or "P" the European term for Stage Right, typically used to label Theatrical items used in operas form Europe.

Opposite Prompt or "OP" the European term for Stage Left, typically used to label Theatrical items used in operas form Europe.

Down Stage or DS, the area in front of you, sometimes with a orchestra pit in between you and the audience.

Upstage or UP, the back wall of the theatre or the area to the rear of the stage.

Orchestra Pit, the sunken area in the front of the stage in a theatre

Trap Room, the area below the stage that may be accessed directly from the stage using a trap or a hole in the stage to walk down.

Crossover, any area on stage or below the stage used as a walkway between Stage Left and Right.

Cove, a ceiling slot were lighting fixtures are hung in a theatre.

Main floor/ Orchestra level the main seating area of the theatre that is accessible directly from the street.

Dress circle/ Loge, the first area of seating above the main floor / Orchestra level usually under the first balcony.

Balcony, mezzanine, seating area above the main floor.

Balcony rail, the hanging position that is attached and directly in front of any seating area that is above the main floor or dress circle. They can be referred to as the First Balcony Rail and The Second Balcony Rail.

Proscenium opening, the wall and arch that separates the stage from the auditorium (house). Or the opening in the front of the stage that frames the stage.

Plaster line, a line that can be made between the DSL and DSR sides of the Proscenium from the DS edge of the fire curtain/ smoke pocket

Fire Curtain, a batten heavy device that has low melting link that will be broken by heat of a fire and or may be lowered by cutting a rope with a knife or other similar release device.

Smoke pocket, the guide area that the fire curtain travels in that helps form a seal between the stage area and the audience.

Lighting Terms:

- **Learning Objectives/Outcome**

Learning the nomenclature of lightning equipment. Applying these terms, as to the location and types of equipment a stagehand is expected to handle.

Performance Area, the stage and audience seating area associated with a temporary stage structure, whether indoors or outdoors, constructed of scaffolding, truss, platforms or similar devices that is used for the presentation of theatrical or musical productions or for public presentations.

Portable Equipment, Equipment fed with portable cords or cable intended to be moved from one place to another.

Portable Power Distribution Unit, power distributions box containing receptacles and over-current devices.

Overheads, term applied to an electric hung over the stage typically

Electric, were a group of lighting fixtures are hung and flown to a height over the stage. An electric may be hung on a theatres system pipe/ batten; the lighting fixtures may be attached to a piece of uni-strut that is in turn C-clamped to a system pipe. Or it may be a series of trusses that are connected end to end to form a structure that is flown using the system pipe or chain motors.

Box Booms SL and SR referenced from their side of the stage, if shown on a lighting they may be referenced from the house perspective, as such they should be labels HSE L an HSE R. HSE one acronym for House

Torm SL and SR a lighting position that is immediately upstage of the plaster line/ fire curtain.

Truss, a portable structure that has two sides made up of a top cord and a bottom cord that are bound together using vertical and diagonal laces. Each side is then tied together using the same tubing as the top and bottom cords or an end plate using some other stock will be used. Depending on the means to attach them end-to-end, pins or bolts may be used to build a taller or longer structure.

Towers, a lighting position that is attached to the floor, generally using a structure that may be a series of truss structures that are attached end to end and stood up. A tower may be fixed or mobile with wheels, that may have a height or weight that may require a guide track at the top.

Booms, usually a weighted base that is round that has a 11/2" pipe threaded into a flange.

Rolling Boom, These may also be tripod shaped and have wheels attached to them. Usually know more than one or two lights attached to it. They may use a 1" pipe that threads into the middle of the rolling base.

Ladder Hanging structure that is either made of pipes to resemble a ladder, or a vertical truss handing in the air.

Top Hat/ Snoot, Cylindrical extension for the front of the light, which slips into the gel frame holder to eliminate unwanted flare.

Short Top Hat/ *Eye Lash*?, A Top Hat that is half the horizontal height of a standard one.

Half Hat/ Eyelash, A Top Hat that is cut in half along its vertical axis.

Gel Extender, A double-ended Top Hat that slides into the gel holder on a lamp. The front of the Gel Extender has a gel holder to receive gels.

Foots, traditionally a recessed area, at the DS edge of the stage floor before the Orchestra Pit where lights are recessed into the floor, it may be a hidden trough or an open one to contain lighting fixtures.

Lighting Terms Cont:

C clamp, a device used to hang almost anything imaginable on stage to mostly round things. There are numerous types of C-clamps.
Sidearm, a ¾" diameter black pipe that is attached to a C clamp
Cheese burrow, a type of clamp that attaches two round pipes together, that usually is tightened using a wing nut on a threaded stud.
Cross Plug, the act of unplugging one load from a female plug and plugging in an adjoining load to test for voltage.
Twofer, Twin, Rubber Chicken Splitter "Y", a cable that is less than three feet in length that has one male connector and two female connectors and is used to combine two loads into a single branch circuit.
Smart twofer, a device manufactured that will allow two loads to be plugged into the same circuit in a multi-cable. These devices are then used with a lamp that operates at 50V at 550W. The sockets are keyed to allow insertion into one specific type.
Three-fer, "W", a set of three female cables that terminate into a single male connector. Lends the ability to combine three loads into a single cable.
Jumper, a cable that has one male and female at each end.
Multi-cable, a cable that combines typically 6 load carrying cables, that has one hot, one neutral and at least three grounds into a single cable that has a multi-pin male and female on each end.
Breakout or fan-out, an adaptor that uses a group of single cables or branch circuit that has a female on each end that are terminated into a single male multi-cable.
Break-in or fan-in, a group of single cable that have a male on each end and are all terminated into a single female connector.
Mains/ Feeder cable, usually five cables that have colored cam-lock connectors on each end. These colors are typically: Green used to transmit an earth ground to equipment. White used for the common or return in the power circuit. Black, Red, Blue colors used to label phases in a Three-phase power system. For our uses, cable size or AWG is either 4/0 or 2/0. Also an additional neutral may be used for dissipation of unwanted current in the load return, to prevent overload of a single conductor
Bundle, cables or conductors that are physically tied, wrapped, taped or otherwise periodically bound together.
Connector strip, a metal wire-way containing pendant or flush receptacles.
Drop Box, A box containing pendant or flush mounted receptacles attached to a multi-conductor cable via strain relief or multi-pole connector.
Grouped, cables or conductors positioned adjacent to one another but not in continuous contact with each other.
Dead Front, a non-conductive panel that isolates working personnel from conductive electrical surfaces that are also grounded and bonded to the earth ground
Suicide Cable, a cable that has two male ends on it, that will allow contact with hazardous voltages when unplugged from a female receptacle
Dimmer Rack, an enclosure that contains dimmers that control the intensity of lamps, and may contain a patch bay to select what dimmer will control a particular lamp.

Lighting Terms Cont:

ACL whip, four female connectors wired in series that are terminated in a single male. So the combined load of all 24v lamps equal 96v and may be plugged into a 110-120v load plug in a dimmer rack.

Daisy Chain, cables plugged end to end with some type of lighting device as an intermediate termination

Leko, originally a trade name given to a lighting fixture that contained an ellipsoidal reflector and a Plano-convex lens and four shutters. That was able to have a hard edge on the beam of light projected or a soft edge depending on the relationship of the lens to the second focal point. In addition a pattern can be projected from the lighting fixture using the pattern slot.

Gobo or pattern, a piece of stainless steel that has a design cut into it that controls the amount of light passing through it. Which is inserted into the gobo or pattern slot of a Leko

Twin spin, a motorized device that can hold a maximum of two gobos or patterns and spin it in a circle producing movement in the beam of light. Which is inserted into the gobo or pattern slot of a Leko

Scroller, a device that hangs off the front of a lighting fixture that contains a roll of different colored gels that is remotely controlled.

Optimize/ Bench Focus, a term used to fix the lamp source at the focal point to create an even field of light projected from a lighting fixture. This term is used in conjunction with a Leko and a HMI or HTI source.

Stand Lamp (Work Light), a portable stand that contains a general purpose luminaries (lighting fixture) or lamp holder with guard for the purpose of providing general illumination on the stage or in the auditorium.

Fresnel, a lighting fixture that is typically used to flood an area with light that allows for a soft, blend able field of light. It may also have its lamp moved internally via a knob to vary the diameter of light from a spot position to full flood. These types of fixtures range in size from a 3" diameter lens to 16". They will use either an incandescent lamp source of a HMI lamp and ballast.

Beam Projector, a light source usually round that has a small parabolic reflector in it. That reflects the light out through a cylinder held in the middle of the open-faced fixture. It too has a means to give a spot or flood light field on stage. (This usually is tight and less tight). The lamp source may be a 120v or a low voltage lamp source powered by a ballast of some sort.

Ghost Load, a lamp or group of lamps used to create additional resistance when plugged in series with a lamp that has a visible output on stage.

Zip strip/ Mini strip, border light type that uses low voltage MR16 lamps.

Strip Light/ Border Light, a long narrow metal enclosure that ranges in a 3"0" length to 7'-0". May be portable or permanent in installation. It may contain A-lamps, R lamps, Par 56, Par 64 type lamps or "T" type lamps. These also will have either 3 or 4 circuits, which can be determined by the number of whips coming out of either end. They also usually have females on one end to allow plugging in additional units in a daisy chain fashion up to the load limit of the dimmers and connectors.

Lighting Terms Cont:

Par 64, a type of lamp that is used in a lighting fixture that is a sealed beam bulb, much like the old round car headlamps. It is referred to by its various beam sizes: Wide (12 lines across the face), medium (8 lines across the face), narrow (frosted in appearance), very-narrow (clear to see a tubular type lamp inside), and ACL (clear to see a small filament in the center with a half circle wrapped around the filament.

Xenon, a lamp type that is often used in a front follow spot that operates at a high internal pressure, depending upon the lamp, the internal pressure can exceed 10 ATM or 147 PSI, even when not in operation.

HMI, H = Hg = mercury (for arcing) "to create the lamp voltage"
M = metals, to create daylight spectrum
I = iodine, refers to halogen compounds of iodine and bromine

Ballast, A magnetic ballast has an input power that is routed through main breakers, which protect the circuit in the event of a short. From there power is routed to the transformer. The transformer provides the start-up charge for the igniter circuit, and then it acts as a choke, regulating current to the lamp, once the light is burning. Power from the transformer is routed to the main contactors (which are controlled by a low-voltage control circuit) and to the igniter circuit wire

PSI, Bar, Atmosphere, units of measure used to explain the pressure inside a HMI or Xenon lamp.

DMX 512, any lighting equipment that is remote controlled requires this language to receive que information from a control console or test apparatus

Opto-isolator, a device that has an input connector for the DMX signal and multiple outputs. The device is used to electronically isolate the control signal from external noise sources.

DAC, acronym for Digital to Analog Converter, When used in lighting, it receives a DMX signal, then converts the first DMX address as a starting address and then converts the DMX signal into a series of 0-10vdc output voltages for use with a device that requires an analog control signal.

House Snake/ or snake, usually a group cables that are bound together that consists of an ac mains for a control console and typically at least two DMX control cables for data transmission from the console to dimmers and other DMX controlled devices.

5 Pin XLR, a data cable that has 5 conductors that is terminated on each end with a male and female 5-pin connector.

4 Pin XLR, a data cable that is typically used to supply a data signal to a color changer and low voltage power to the color changer, for control circuitry. That is terminated on each end with a male and female 4-pin connector.

3 Pin XLR, typically used for intercom connections between a base station and belt packs in different locations. It may also be used at times for a data run for the DMX 512 protocol. That is terminated on each end with a male and female 3-pin connector.

Lighting Terms Cont:

Stage Pin Connectors, a three-pin connector that has a ground in the center, neutral offset towards the ground and a hot the furthest away from the neutral and ground. They come in three different amperage ratings generally, 20, 60 and 100 amps in an inline male, female and panel mount varieties.

Multi-pin connector, generally a 19-pin connector that has a male/ female cable end connector (inline connector) and panel mount style connectors. May be called by their manufactures names: Soco-Socopax or Mac. Various manufactures make these style connectors, but they are called by the trade name of the original manufacture.

Focus tape, Usually a three inch wide piece of webbing, marked from a center point in one-foot increments.

Trim chain, either a light weight piece of metal or plastic chain that is cut to a specific length to aid in the raising a lighting truss or pipe to a specific height based on its length. It may also be a simple tape measure with the trim heights recorded on its side.

Focusing, not pointing, scopeing or otherwise. The act of placing a beam of light on stage, using the center of a projected light source as a reference centered on a person. Then adjusting the Shutters and image sharpness as directed centered on a person.

Lock it Down, once the lighting fixture that has been focused the nut that attaches the yoke to the C-clamp is tightened using a crescent wrench and the "T" handle on the side is tightened to prevent drift.

Heat Shield, a clear filter that filters out Ultraviolet light and heat to help preserve color media or projection images. Located either in a gel frame or mounted permanently in a special slot. With some types of heat shield, hand protection is necessary to prevent one's skin oil from being burned into the coating on the plastic media.

Rosco, Lee, Colortran, Gam, trade names that refer to color media manufactures whose color catalogs are numbered where on a lighting plot these will serve as reference numbers.

The following are drawn from the National Electrical Code (NEC 2002) that are relevant to describing portions of our trade.

Article 100 generally states:

Ampacity the current in amperes, which a conductor can carry continuously under the conditions of use without exceeding its temperature rating.

Plug attachment plug, Plug Cap, a device that by insertion in a receptacle establishes a connection between the conductors of the attached flexible cord and the conductors connected permanently to the receptacle.

Bonded bonding, the permanent joining of metallic parts to form an electrically conductive path that ensures electrical continuity and the capacity to conduct safely and current likely to be imposed.

Branch Circuit the circuit conductors between the final over- current device protecting the circuit and the outlet(s).

Circuit Breaker a device designed to open and close a circuit by non-automatic means and to open the circuit automatically on a predetermined over-current without damage to itself when properly applied within its rating.

Lighting Electrical Terms Cont:

Dead Front without live parts exposed to a person on the operating side of the equipment.

Continuous Load a load where the maximum current is expected to continue for 3 hours or more.

Energized electrically connected to a source of voltage.

Fuse an over-current protective device with a circuit-opening fusible part that is heated and severed by the passage of over-current through it.

Grounded connected to earth or to some conducting body that serves in place of the earth.

Outlet a point on the wiring system at which current is taken to supply utilization equipment.

Over-current any current is excess of the rated current of the equipment or the ampacity of a conductor. It may result from overload, short circuit, or ground fault.

Overload operation of equipment in excess of normal, full-load rating, or of a conductor in excess of rated ampacity that, when it persists for a sufficient length of time, would cause damage or dangerous overheating. A fault, such as a short circuit or ground fault, is not an overload.

Voltage (of a circuit) the difference of potential between any two conductors of the circuit concerned.

Voltage Nominal a nominal value assigned to a circuit or system for the purpose of conveniently designation its voltage class for example 120/240volts 480/277 volts, 600 volts. The actual voltage at which a circuit operates can vary from the nominal within a range that permits satisfactory operation of equipment.

Voltage to Ground for grounded circuits, the voltage between the given conductor and that point or conductor of the circuit that is grounded; for ungrounded circuits, the greatest voltage between the given conductor and any other conductor of the circuit.

You will also find though out the following document references to the National Electrical Code (NEC 2002).

Electrical Safety:

- **Learning Objectives/Outcomes.**

Learning about the hazards, when one works with electricity.
Applying basic safety ideas, to mitigate ones exposure to them in the field.

Upon completion of the lesson, participants will be able to:

1. Describe four types of injuries that may result from contact with electricity.

Possible responses.

- Electrocution or death due to electrical shock
- Electrical shock
- Burns
- Falls

2. List the three main electrical hazards that may be encountered at a worksite.

Possible responses.

- Inadequate wiring
- Improper grounding
- Overloads

3. Discuss at least three methods of protection from electrical hazards.

Possible responses.

- Use proper sized fuses, circuit breakers, and GFCI's.
- Never disconnect the ground wire from a plug.
- Inspect all flexible cords before use.
- Guard live electrical parts.
- Use proper grounding.
- Train workers, staff, and employees.
- Shut off electricity at the source before doing electrical work.

4. Describe the function of a ground fault circuit interrupter (GFCI).

Possible responses.

- A GFCI detects current leakage rather than an overload and switches off current when leakage is detected.
- A GFCI matches the amount of current going to an electrical device against the amount of current returning. If it detects a difference in current, it switches circuit off.

5. Name at least three warning signs or clues that an electrical hazard exists.

Possible responses.

- A GFCI that shuts off a circuit
- Tripped circuit breakers or blown fuses
- Warm tools, wires, cords or connection boxes
- Worn or frayed insulation around a wire or connection

Interior of the Iroquois Theater after the Fire

Ampacity of Listed Extra hard usage cords and cables as taken from the National Electrical Code, when applied to a multiconductor cable with more than three current carrying conductors:

Table 520.44

	Temp. Rating of Cords & Cables		Maximum rating of Over-current protection
Size (AWG)	**75°C (167°F)**	**90°C (194°F)**	**Device** (Breaker Size)
14	24	23	15
12	32	35	20
10	41	47	25
8	57	65	35
6	77	87	45
4	101	114	60
2	133	152	80

Table 520.44

Number of Conductors	Percent of usable Ampacity
4-6	80
7-24	70
25-42	60
43+	50

The above tables will assist in determining the safe loads of a single cable or circuit but to determine a safe load in a three-phase system the following calculations will need to be done:

Total Watts÷Volts÷number of phases=Amps

An easy example of this is:

10 1000watt or 1K par cans = 10,000 watts

10,000watts ÷ 120 volts = 83.33 amps

83.33 amps ÷ 3 Phases =27.77 amps per phase

The above example assumes the pars are plugged into dimmers spread over all 3 Phases. You should also leave a margin for safety.

In addition to the need to know safe load carrying capacities of cables. There are three fundamental reasons to make sure there is a equipment ground. These are:

1.For protection from overvoltage, should the primary and secondary of the transformer become crossed, or should high-voltage lines cross with low-voltage lines.

2. To dissipate lighting or static charges or any other types of surge voltages.

3. To place non-current-carrying parts of an electrical system at zero potential to ground. Here, when the word ground is used, it may mean earth, concrete, walls, floors, piping, etc.

Electrical Code:

Sections of the Chicago Electrical code that pertain to the theatrical trade.

Chapters 1-4, general sections

Chapter 5: Special occupancies, 518 Places of Assembly, 520 Theatres, Audiences areas of motion pictures and TV studios. 525 Carnivals, Circuses and Fairs. 530 Motion Picture Studios and other locations.

National Electrical Code NEC 2002

Chapter 2 Wiring and Protection, Articles 200, 210, 220, 250.
Chapter 4 Equipment General Use, Articles 400, 410.
Chapter 5 Special Occupancies, Article 520, 530, 540
Chapter 6 Special Equipment, Article 630, 640
Chapter 7 Special Conditions, Article 700, 701

Electricity:

- **Learning Objectives/Outcomes.**

Learning the basic concepts of what electricity is and its components. To facilitate ones ability to perform the mathematics to compute loads, wattages and the like in order to safely assembly, determine electrical needs and solve problems

The law of electrical charges: Like Charges repel, opposite charges attract. So therefore electricity is the flow of these *free electrons* in a wire. This flow is described as *current.* Benjamin Franklin made the designation of *positive* and *negative* with the knowledge of electrons (-) and protons (+).
Is defined using these terms, Coulomb and Electrostatic Field

Sources of Electricity

The three basic sources of electricity that a stagehand deals with are a battery source and generated. The generated may be a field type of generator used on location or the type that is used to generate power for an entire city.
Battery sources are used in a theatrical sense primarily for handheld lighting sources that need illumination.
Most all power that we use is connected to a building service that in turn receives its source for a commercial power provider such as Com ED.
On other occasion when not enough power can be provided by the building or in a remote location were there is no electricity. A portable generator will be brought in to provide electricity to the lighting, and sound packages.

The Electrostatic Field

The fundamental characteristic of an electric charge is its ability to exert a force. This force is present within the electrostatic field surrounding every charged object. When two objects of opposite polarity are brought near each other, the *electrostatic field* is concentrated in the area between them. If an electron is released between these two objects, it will be repelled by the negative and attracted to the positive object.
When a charged object retains its charge temporarily, and there is no immediate transfer of electrons to or from it, it is said to be at rest. Electricity at rest is called static electricity

Conductors

A conductor is a material that easily lets a few electrons move from molecule to molecule (protons/nucleus with and electron orbiting it) to the other molecule.

Inexpensive metals with these properties are copper and aluminum. Copper is the prevalent conductor used in the theatrical trade and used extensively in your homes. Article 110.5 states: conductors normally used to carry current shall be of copper unless otherwise provided in the NEC. Where the conductor material is not specified the material and the sizes given in the code shall apply to copper conductors. Where other materials are use, the size shall be changed accordingly.

Insulators

An insulator does not easily release electrons to move about.

Which is why plastic is used as a typical insulator around copper wire. However, to have a flexible insulator, rubber is one type used, such as the coating on feeder cable.

The Coulomb/Measuring Current

The *Coulomb* is the magnitude or quantity of electric charge a body possesses which is determined by the number of electrons compared with the number of protons within the body. The symbol for the magnitude of the electric charge is Q, expressed in units of coulombs C. A coulomb is the unit for counting electrons, using the coulomb to count for 1 second equals 1 ampere and becomes a multiplier for each second. Therefore 2 coulombs per second equals 2 ampere.
1ampere= 1 coulomb per second

The convention to represent current with a symbol or letter which is *I;* were I designates the units of *ampere,* as in I=1 ampere as in the above example or I=15 *amps* (amperes). An example of current flow is the use of a battery for this. Batteries are devices that demonstrate the flow of current with a positive and negative terminal, which are formed into contacts.
When a wire is connected to each terminal, the positive and negative terminals, a closed circuit is formed causing current to flow. A battery is dead or drained when enough electrons have flowed form the negative to positive terminals, causing the *current* to cease flowing.
Current flow can be described as a potential inducing the free electrons to forcibly move through a copper wire. To do so a batter needs to be connected across the two ends of the wire, an applied voltage of a battery 1.5V forces the free electrons to move. The current is the drift of these electrons moving from the negative charge side of the battery through the wire and back to the positive side of the battery.

Potential Difference/ Measuring Voltage

Because of the force of its electrostatic field, an electric charge has the ability to do the work of moving another charge by attraction or repulsion. The ability of a charge to do work is called its potential. When one charge is different from the other, there must be a difference in potential between them.
The sum of the differences of potential of all the charges in the electrostatic field is referred to as *electromotive force emf.*
The basic unit of potential difference is the *volt*. The symbol for potential difference is V, indicating the ability to do the work of forcing electrons to move in a circuit. If a voltage is applied, and a path is provided which could be a piece of wire, then a current will flow. If you produce a path or wire and do not apply any voltage, then there will be no current. So providing a path will cause a potential difference that is called *voltage* or volt.
The strength of electrons moving through a conductor or from a generating source is measured in voltage. So the higher the pressure to push electrons generates a higher voltage. The lower the pressure, the lower the voltage.

Article 110.4 states: voltages considered shall be that at which the circuit operates. The voltage rating of electrical equipment shall not be less than the nominal voltage of a circuit to which it is connected.

Measuring Resistance

Amperes (current) and voltage (electrical pressure) are related due to the fact the some wires let more current flow than others. A wire that does not let very much current flow has high *resistance.* Resistance has a symbol of R when used to express this quantity. The resistance is related to how much the current *I* we get from a given voltage *E* by "Ohm's Law". Given at least two values the third may be found using this formula:

Ohm's law states: I=E / R or E=I*R and R=E/I

If I is measured in *ampere*, and V *emf* in volts, then we say that R is units of *resistance* "*ohms"*. For example: a 1 volt battery, and a wire with a resistance of 1 ohm, then the current that at the battery's terminal is;

I=E÷R

1 volt-emf (E)/ 1ohm (R)= 1 ampere (I)

Knowing two of the three values, the third may be calculated.

Following are some examples of uses of the above formula:

I=E ÷R = 100V ÷50Ω=2A I=E ÷R =100V ÷100Ω= 1A I=E ÷R =200 ÷50Ω=4A

The following example uses a heater element of 20 and 40ohms:

20 ohms on 120 volts I=V/R= 120V/20Ω=6A

40 ohms on 120 volts I=V/R= 120V/40Ω=3A

20 ohms on 240 volts I=V/R= 240V/20Ω=12A

40 ohms on 240 volts I=V/R= 240V/40Ω=6A

In the event you did not notice there is a correlation between the doubling of resistance on the same voltage halves the current; also, doubling the voltage with the same resistance doubles the current. So the current in any circuit varies in proportion to the voltage and is affected by resistance.

As you see ohms law stated in a circle will give the relationship of each variable and how to solve for one, when two are known.

Voltage = Current × Resistance or I × R = E

Current = Voltage ÷ Resistance or E ÷ R = I

Resistance = Voltage ÷ Current or E ÷ I = R

As seen previously there is a relationship between voltage, current and resistance. Using the following analogy will illustrate the relation ship between a wires size (AWG), and its resistance

Two water pipes are side by side; they are both supplied by the same source. However, one is a 1inch pipe and the other is a ½ diameter pipe. The flow will be far less out of the ½ inch pipe than out of the 1-inch pipe. The same idea works with electrical conductors and resistance. The smaller a conductor is in AWG the more resistance it will have and less current carrying capacity that larger ones of the same type of material.

So therefore, the current through a conductor will have a loss of power and a drop in voltage. One indicator of this resistance is the generation of heat, which is power loss that can be expressed in watts. In some cases we make use of this loss, in incandescent lamps to produce heat-producing light in the visible and invisible spectrum (inferred). Or in the case of a fog machine, the heating element produces heat and caused the fluid to turn into a vapor that is the fog emitted.

The previous two examples illustrate two uses of harnessing this resistance, however for circuits that carry current, resistance needs to be kept to a minimum.

1. The resistance of a conductor is directly proportional to its length.
2. The resistance of a conductor is inversely proportional to its cross sectional area.
3. The resistance of a conductor of a given length and cross sectional area depends upon the material of which its composed.
4. Temperature affects resistance. All pure metals increase in resistance with an increase in temperature, but this increase is not linear.

Watts

Ohm's Law as defined above may also be applied to electric power, which is our primary concern. Defining Ohm's Law when used with electric power is: electric power *P* used in any part of a circuit is equal to the current *I* in that part multiplied by the voltage *V* across that part of the circuit. Its formula being:

P=VI

P= power expressed as W or Watts
V=voltage, V
I =current, A

To express the formula in the other two transpositions:

$$I = P \div E$$
$$E = P \div I$$

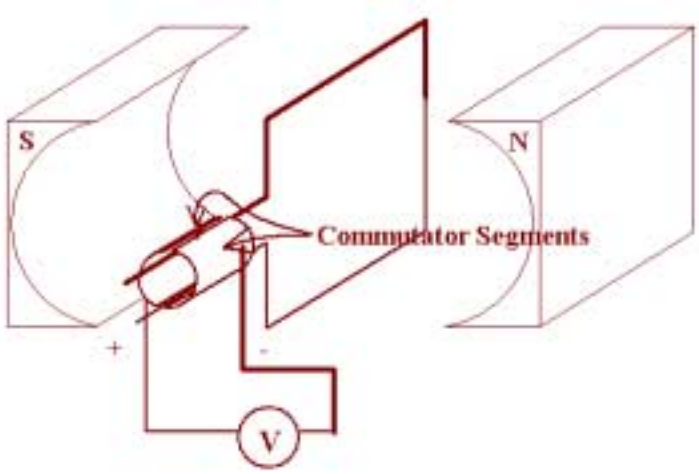
Or stated another way W=V×A substituting Watts for Power and A to express current. This transposition allows one to easily solve for problems using terms that express the ratings that we work with in the theatrical trade. A lamp is given a value in watts, voltage is treated as 110v and a breaker is rated in amperes or amps.

Direct and Alternating Current and Voltages

Direct current (*DC*) is current that moves through a conductor or circuit in one direction. The reason for the unidirectional current is that voltage sources such as cells and batteries maintain the same polarity of output voltage. The voltage supplied by these sources is call direct current, or simply *DC voltage.* A DC voltage source can easily change the amount of its output voltage and maintain is direction of current flow assuming it polarity stays the same.

If you need to know more about DC

Direct current can be generated using the same basic components as found in a DC motor. A motor converts electric energy into rotary mechanical energy. While a generator, converts rotary mechanical energy into electric energy. The mechanical energy used to generate a DC voltage may be a waterfall, steam, wind, gasoline, diesel fuel or even an electric motor.



In a generator, an external mechanical force as those above rotates the armature; the voltage generated is connected to an external load. In an alternator, the stator supplies

the field of the magnetic lines of force. The *rotor*, or *armature*, as it is called in a DC generator is the part that the emf is generated. Also in a DC generator a means is needed to collect the emf from the generator in one direction only. This is accomplished by the means of a commutator, which is split lengthwise and the two halves are insulted from each other.

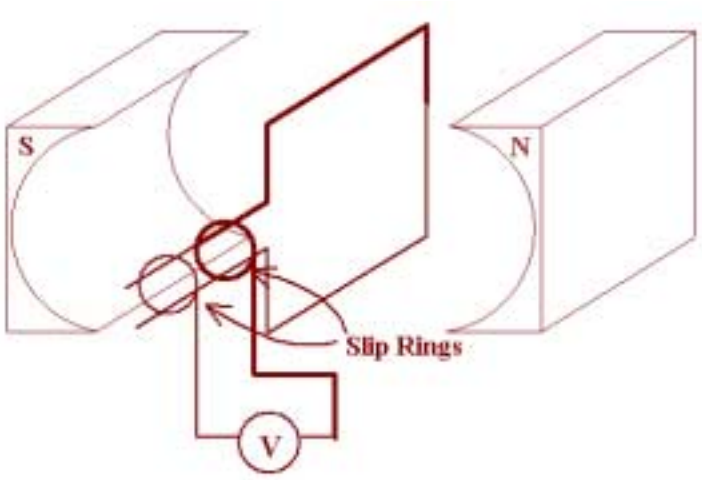
The commutator consists of copper segments, on pair for each armature coil. Each commutator segment is then insulated from the other and from the armature shaft. These commutator segments make contact with two stationary brushes. These brushes are then spring-mounted to slide or brush against the commutator as it rotates. Which in turn provide a connection between the armature coils and the external load. Much like a common DC motor used in various toys.

When the armature coil cuts across the magnetic field it produces voltage, if a complete path is present. Current will move through the armature coil through to the commutator to a segment that is in contact with each of the brushes. Because of the constant contact between a segment of the commutator and the brushes the armature coil is always cutting across the magnetic field in the same direction. Therefore both brushes have a constant polarity and a pulsating direct current is delivered to the external load and zero volts will be reached more than once for each revolution. By using a higher number of armature coils a smoother waveform can be obtained for the DC voltage.

Alternating current

Alternating current (*ac*) is voltage source that periodically reverses or alternates in polarity. Therefore, the resulting current also periodically reverses direction. In terms of current flow, it flows from the positive terminal of the voltage source (generator) through the circuit, and back to the negative terminal, but when the generator alternates in polarity, the current must reverse it direction. These voltage and current reversals happen many times a second in these systems. Obviously the power line used in homes is a common example of this.

Alternating-current generators are commonly knows as *alternators*, are used to generate AC voltage. As a rule an alternator has the winding stationary termed *stator***.** The rotating portion or *rotor* is the DC part of the alternator and receives it voltage from an exciter that is mounted on the alternator and the armature of which is driven by the rotor shaft of the alternator. The DC portion of the alternator will be stationary with only the AC portion rotating, this simplifies the explanation to follow. The AC voltage is transmitted using slip rings and brushes.

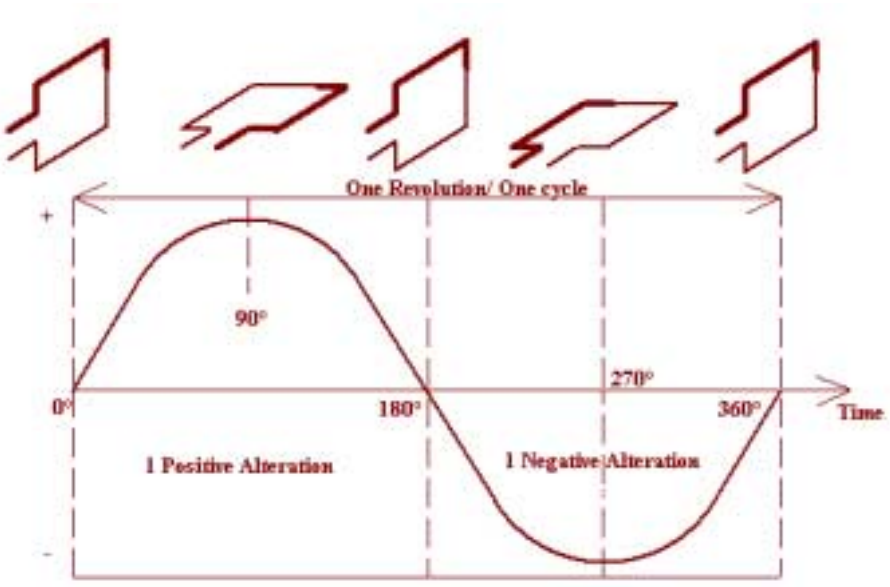


The advantage that AC current has over DC current is the ease of transmission. When there is a need of a higher or lower voltage, simple step-up or step-down transformer is used. To do the sample with DC a motor generator set is need to change voltages or to convert to AC. If it is necessary to convert back to DC rectifiers are needed to do so.

If you need to know more about AC

A device called alternators typically does generation of Alternating current . An AC voltage is one that continually changes in magnitude and periodically reverses in polarity. If one draws a horizontal line and calls it the Zero axis and then strikes one vertically and calls it the Voltage + above the Zero axis line, and – below the Zero axis. Then overlay the Alternating waveform on this you can see the vertical variations of the voltage waveform illustrating the changes in magnitude. The voltages above the horizontal axis have positive polarity and those below negative polarity, See Fig .

If one rotates a conductor loop between a magnetic field with a northern and southern orientation, then the loop rotates through the magnetic field and cuts lines of force to generate an induced as voltage across its terminals. One complete rotation in relation to an AC sine wave or loop around the circle is a *cycle.* The number of armature coils determines how many cycles will generate voltage when rotating. In a two pole generator, when the armature is at 90° to the magnetic field is when it will generate voltage, twice every 360°. If a four pole generator is used every 180° voltage will be generated. Placing the conductor loop at a 12 O'clock position will generate a positive polarity, while at 6 O'clock will generate a negative polarity using a circle or clock as a simile. Therefore viewing the AC waveform, as a sine wave will show the 12 O'clock peak above the zero axis and the 6 O'clock peak below the zero axis, connected by a lazy sideways S.

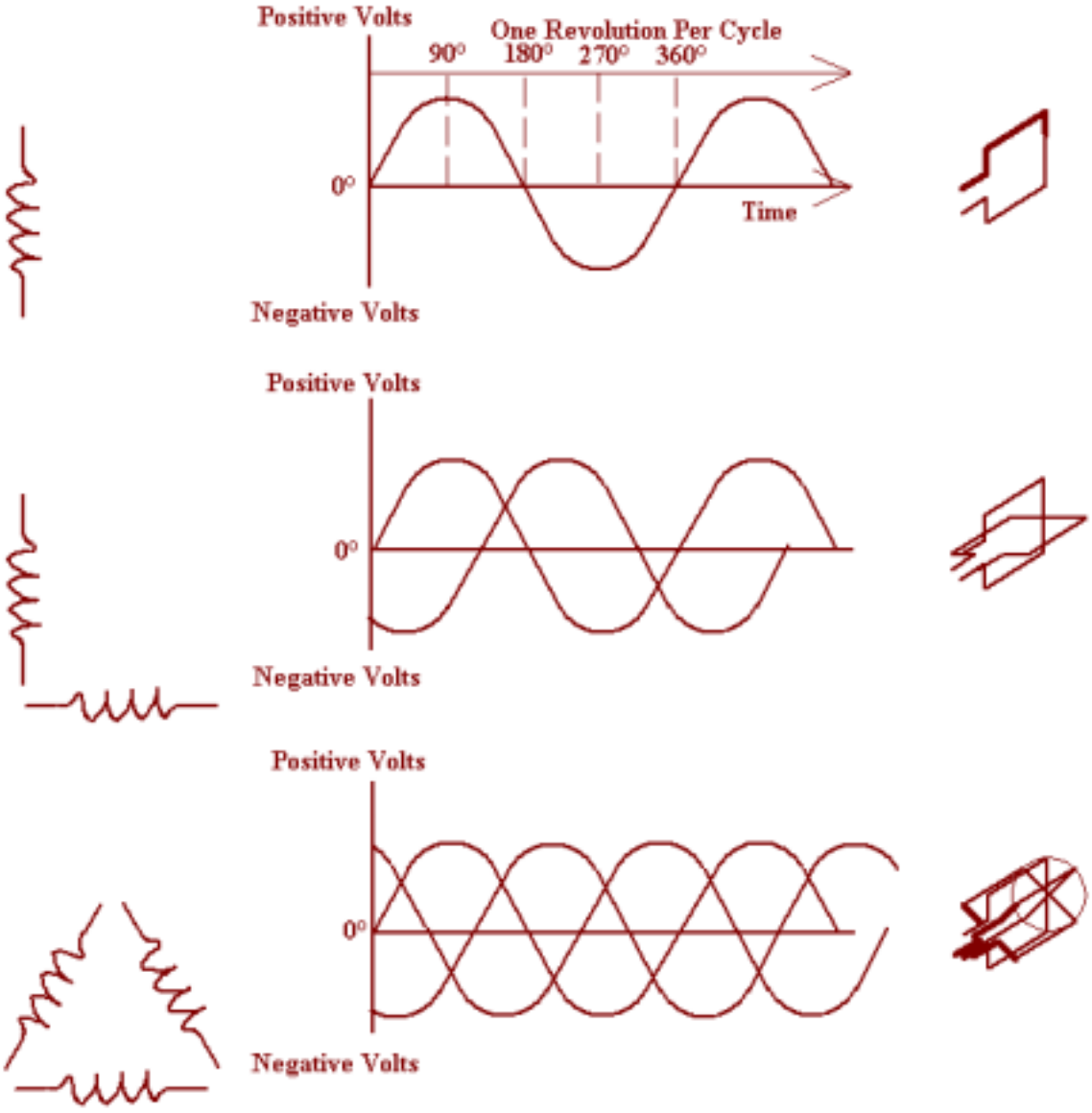


Looking at the example at 0° there is no induced voltage at 90° the maximum is generated. At180° a reversal and no induced voltage at 270° generates the maximum voltage and again at 360° no voltage generated and the cycle starts again. Note, 0 AC volts is reached twice for each complete revolution of the armature. Therefore, frequency can be defined as the number of cycles per second *hertz*

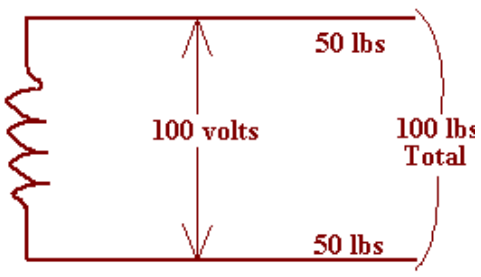
Polyphase Power Types Single and Three Phase

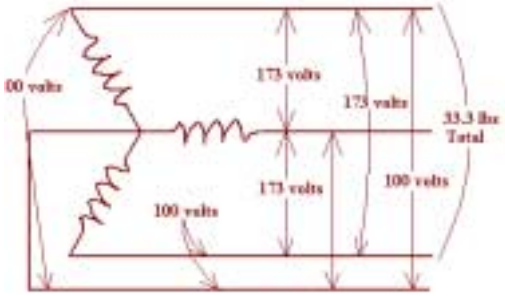
Three-phase (3-∅) system is a combination of three single-phase (1-∅) systems. In a 3-∅ balanced system, the power comes from an ac generator that produces three separate but equal voltages, each of which is out of phase with the other voltages by 120°. It may be thought of each of these generators are mounted to a common shaft or one alternator (generator) has three different windings on the stator or rotor. These are then connected so they are 120° apart and configured as either a wye or delta voltage output, see the wye and delta drawings to follow.

Below is a drawing of all three phases on a graph that demonstrates the relationship of each generator to the other and the phase it generates.



Although 1-∅ circuits are widely used in electrical system, most generation and distribution of alternating current is 3-∅. Three-phase circuits require less weight of conductor than 1-∅ circuits of the same power rating; they permit flexibility in the choice of voltages, and they can be used for single- phase loads. Also, 3-∅ equipment is smaller in size, weight and more efficient than 1-∅ machinery of the same rated capacity.





At a substation or the destination transformers supply the power stepped down from the high-voltage transmission to three sinusoidally varying electric current of 120V. This is then delivered to a breaker or disconnect panel through four conductors. One conductor is neutral or ground at the power source, the other three lines or phases carrying electrical power to the destination.

The three phases of a 3-∅ system may be connected in two ways. If the three common ends of each phase are connected together at a common terminal marked *N* for neutral, and the other three ends are connected to the 3-∅ line, the system is a *wye* or Y-connected, Fig 1. Connecting between one-phase and neutral will supply 120v, Fig 2.

Fig 1

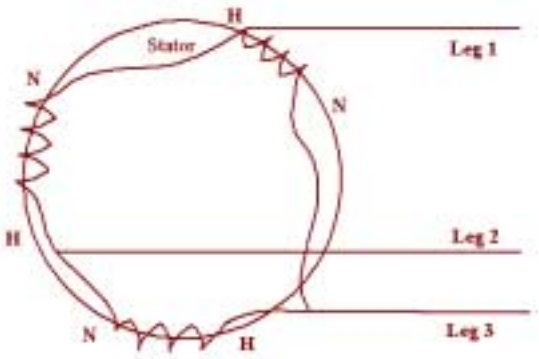
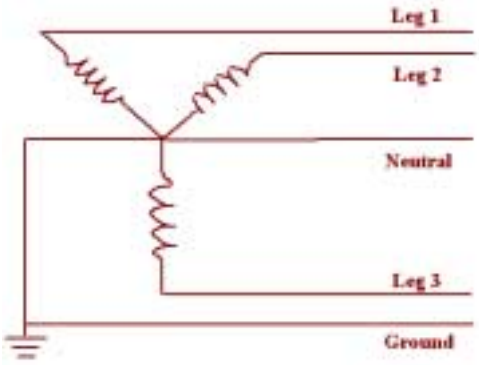


Fig 2



If the three phases are connected in series to form a closed loop, the system is delta or Δ-connected, Fig 3 and 4.

Fig 3.

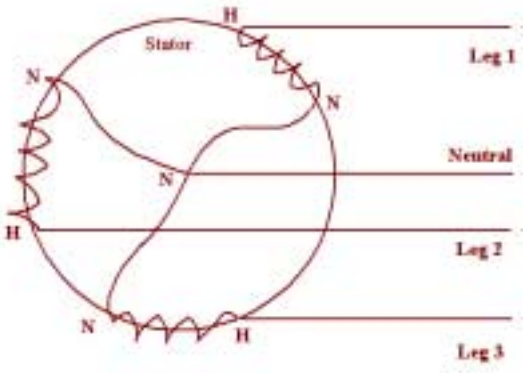
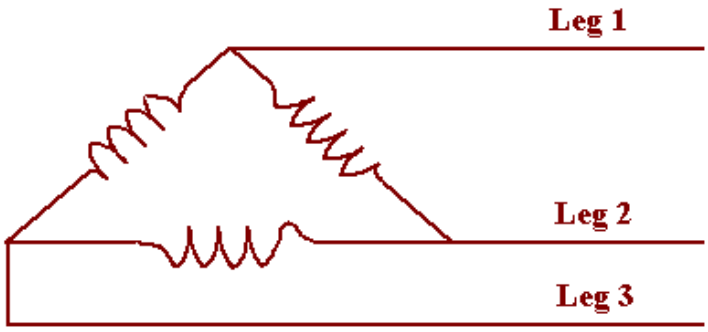
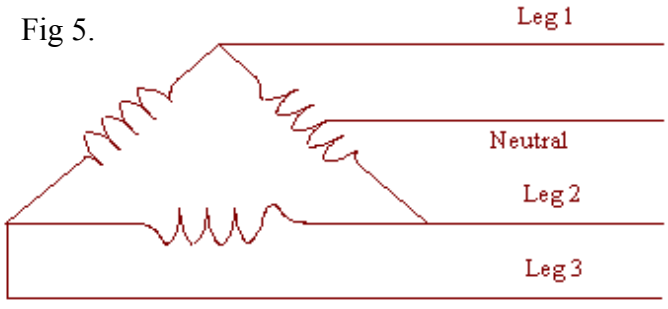


Fig 4.



If you look at Fig 3, you will see a neutral lead coming out. Fig 5. illustrates an alternate means of wireing delta. When the phase is split and metered to any other phase you will see 120 volts. This may also be known as Flying-Leg Delta

Fig 5.



Batteries

Volta, a professor created a *voltaic cell* by using discs of copper and Zinc and alternating them, placing a felt discs between each of the metal discs. The felt was saturated with vinegar or other diluted acid, as a result a current is created and will continue as long as the felt is moist.

A battery is a combination of materials used to convert chemical energy into electric energy. The chemical cell consists of two electrodes made of different kinds of metal or metallic compounds and an electrolyte, which is a solution capable of conducting and electric current. A battery is formed when two or more cells are connected.

An example of electrodes is, zinc and copper. Zinc contains and abundance of negatively charted atoms, while copper has an abundance of positively charged atoms. When they are immersed in an electrolyte, chemical action between the two begins. The zinc electrode accumulates a much large negative chare since it gradually dissolves into the electrolyte. The atoms that leave the zinc electrode are positively charged. They are attracted by the negatively charged ions (-) of the electrolyte while they repel the positively charged ions (+) of the electrolyte toward the copper electrode. This causes electrons to be removed from the copper, leaving it with an excess of positive charge.

If a load, such as a light bulb is connected across the terminals connected to the electrodes, the forces of attraction and repulsion will cause free electrons in the negative zinc electrode, connecting wires and light bulb filament to move toward the positively charged copper electrode. The potential difference permits the cell to function as a source of applied voltage *V*.

If the electrolyte is a liquid, the cell is called wet, like a car battery. If the electrolyte is in a paste form the cell is referred to as a dry cell.

Batteries may be used in three basic ways; the first is a battery with a voltage that is what is needed, such as a car battery at 12v. Or in two other ways: the first is to use multiple batteries in a *series circuit*. This consists of connecting at least two batteries terminals together, positive to negative, leaving a positive one on a battery and a negative terminal on the other open. If one were to do this with two 1.5v batteries then their sum would equal 3v, because the current flowing through one cell flows through all the batteries in the series circuit. An example of this is a double C cell flashlight.

The third means to use a battery is in a *parallel circuit*. Utilizing batteries in this fashion allows for greater current to be sustained, so one battery will last longer. To create a parallel circuit, all the batteries will have their positive terminals and negative terminals connected together. However, the voltage output of the batteries in the parallel circuit is the same as a single battery, but the current available is the multiple of the quantity of cells combined in parallel.

Knowing this allows one to understand why a selection was made when looking at a battery powered product, in theatre this is most likely applied to hand held lanterns or battery powered particles.

The duration that a battery will produce current is expressed in *ampere-hours* (*ah*), this tells you the theoretical amount of time it will last. However, the time period that it will produce current may be calculated as well, using a simple formula and knowing a couple variables. The first is to know the voltages of the battery used in our case 24v. The second the load it will be placed under, we will use a 250w light bulb. 250/24=10.41 amps. We will round it down to 10 amps though. The other item that we need to know is how many ampere hours is the batter rated for, usually the battery will tell you this in documentation provided with it. Our particular battery has a life of 7-Ah.

Lighting Equipment

Portable Cord Designations

In the entertainment industry portable cable is often used, to connect loads to dimmers. Or from service disconnects, to provide power to the dimmers and other auxiliary loads. When the cable is manufactured there a number of different coatings applied to the copper wire to insulate from ground and from the end users. Two of these are Thermoset, which is extruded onto the wire and cured and Thermoplastic, which is melted and once again extruded onto the wire and water-cooled. When the cable is manufactured a service designation in either imprinted into the cable or printed onto the cable typically white. The following are typical designations:

Portable cable types

S Service 600v
O Oil Resistant Jacket
OO Oil Resistant Jacket and Oil Resistant conductors
W Weather Resistant Jacket
J Junior Hard Services 300v
V Junior Light Duty Vacuum
E Elastomer
T Thermoplastic
P Parallel
A Meets Canadian Standards

Portable Feeder Cable Types

SC Entertainment Cable
SCE Entertainment cable extra hard usage 600v 6awg – 4/0
W Industrial power feeder cable double jacket, for extra hard usage at 600v/2000v 8awg-500MCM. This not welding cable!

AWM

Portable cable types either a single wire/conductor or when woven into a group of cables is expressed as an AWG. Article 110.6 defines this as: conductor's sizes are expressed in American Wire Gage (AWG) or in circular mills. The circular mils are used to state the conductor size for cables that are larger than 4/0, which is normally the largest portable cable that is used in the theatrical industry.

CIRCUIT NUMBER	HOT	NEUTRAL	GROUND
Circuit 1	pin 1	pin 2	pin 13
Circuit 2	pin 3	pin 4	pin 14
Circuit 3	pin 5	pin 6	pin 15
Circuit 4	pin 7	pin 8	pin 16
Circuit 5	pin 9	pin 10	pin 17
Circuit 6	pin 11	pin 12	pin 18

Pin 19 is a blank in this configuration.

The standard wiring of 12-circuit cables using "Pyle" type 37-pin, 20 Amp connectors is:

CIRCUIT NUMBER	HOT	NEUTRAL	GROUND
Circuit 1	pin 1	pin 2	pin 3
Circuit 2	pin 4	pin 5	pin 6
Circuit 3	pin 7	pin 8	pin 9

Circuit 4	**pin 10**	**pin 11**	**pin 12**
Circuit 5	**pin 13**	**pin 14**	**pin 15**
Circuit 6	**pin 16**	**pin 17**	**pin 18**
Circuit 7	**pin 19**	**pin 20**	**pin 21**
Circuit 8	**pin 22**	**pin 23**	**pin 24**
Circuit 9	**pin 25**	**pin 26**	**pin 27**
Circuit 10	**pin 28**	**pin 29**	**pin 30**
Circuit 11	**pin 31**	**pin 32**	**pin 33**
Circuit 12	**pin 34**	**pin 35**	**pin 36**

What is the pin out on a 7-pin Socapex?

There is no standard wiring on a 7-pin connector for motor control. Normally the center pin, (#7), is used for the ground. However, the pins used for control and the pins used for power vary from Rental Company to Rental Company. Usually they are in groups - [1,2,3, control], [4,5,6 power], or [1,2,3, power], [4,5,6 control]. There is no industry standard, so you should always double check the wiring of any equipment that is sub rented and used with your gear. The reason to double check your gear is that 7-pin connectors carry power and control together and there is a potential for harming the equipment or the operator if the wiring configuration is not confirmed

Coloram cable

The Coloram cable uses 4-pin XLR connectors on either end and consists of two -14 AWG conductors and a 22 AWG twisted, shielded pair.

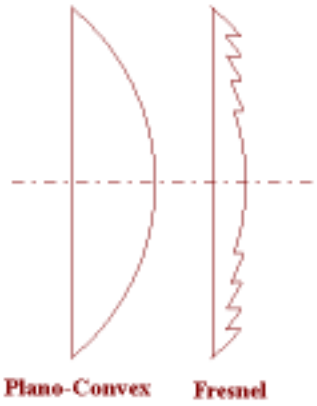
XLR Pin #	Wire Color	Function	Size
1	White	24 Volts DC	14 AWG
2	Green	Data -	22 AWG
3	Red	Data +	22 AWG
4	Black	Ground	14 AWG

LIGHTING FIXTURE TYPES

As a theatrical electrician you will need to identify and use various types of lighting fixtures that are manufactured specifically for the theatrical trade. Along with theatrical fixtures, you will also use others that are borrowed from the display, commercial and residential uses when they fit the particular need of the show. We will concentrate on those that are manufactured for theatre for our purposes.

There are two types of lighting fixtures now infrequently used in American theatres. The first is an open faced lighting fixture that contains multiple lamps in a rectangular enclosure, mounted on a stand to flood an area with light; as seen to the right. There are however, modern smaller replacement fixtures that will resemble it in operation, which will be seen later.

Another fixture that gets little use today is the Plano-Convex Spot or PC Spot. It uses a single Plano-Convex lens on its face to focus the light output. Some of the manufactures included the ability to focus from a spot to flood beam pattern. On the left, a modern example of the PC can be seen. The improvement made to the lamp has been the inclusion of a stippled or pebbled finished to the convex side of the lens. This acts as a diffuser and makes a PC Spot behave more like a Fresnel. The major difference between the PC Spot and a modern Fresnel fixture is the different lens and their finish, to further contrast the two fixture/ lens types the Fresnel has concentric rings of glass removed in steps, from a Plano-Convex lens.



Ellipsoidal Spots

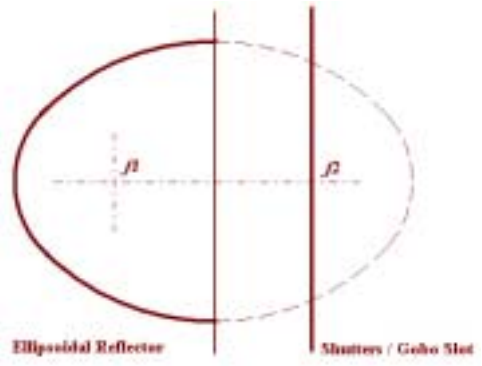
Contemporary Theatrical lighting fixtures fit broadly into four categories: spot, wash, scenic projectors and automated.

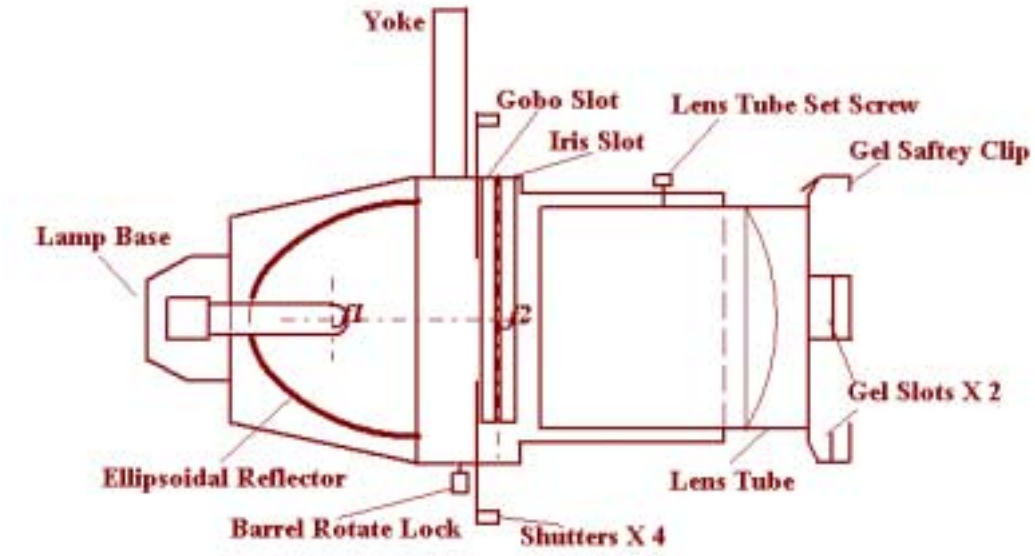
The first type, generally called a Leko, Profile spot, or Ellipsoidal Reflector Spot (ERS). The Leko was invented in about 1928 or 1933 depending on which side of the Atlantic you were on. In 1928 Strand applied for a patent for the Stelmar ellipsoidal spot which was for a 1K and 500 watt ellipsoidal profile spot. Also in 1932 Century developed a Leko and 1933 Kliegl Bros. Lighting Co, the fixtures are seen in their 1936 catalog. The Kliegl luminaire, utilized an off axis lamp, Alzak metal ellipsoidal reflector and framing shutters. Their general outward appearance has changed little over time. However, there have been modifications to the design to aid in increasing the footcandles produced. The first change was the addition of trapezoidal facets to the reflector to eliminate the projection of the lamp image when brought to past sharp edge (barrel run all the way in). The trapezoids cause the image to fuzz out and produce a more even field of light. In addition to the previous improvement there are three recent changes to the Ellipsoidal Reflector Spot light that has greatly improved the luminaire. These are: the addition of a rotate-able shutter pack/ lens barrel from a fixed one, the change from a Alzak metal reflector to a glass dichroic reflector and a more compact lamp source that contains more filaments that generate more (footcandles) lamp output.

A further change that has been made to this type of lighting fixture has been the addition of the 77-volt lamp source, previously all lamps made use of 110 volts. Using this lamp source allows for dimmer doubling, which uses a special twofer that load patches two lamps into a single circuit that allows for independent

control of each lamp. The twofer allows one to use both the positive and negative sides of an AC sine-wave split between two multiplexed dimmers.

Leko's are often used, were a controllable field of light is needed when light is projected onto the stage or scenery. In order to accomplish this, a Leko typically has one or two Plano-convex lenses that allows for a sharp or soft edged image to be projected. An ellipsoidal reflector, with the illumination source placed at the first focal point ***f1,*** centered in the ellipse is used to project the light generated by the lamp filament. Using this type of reflector in conjunction with shutters, gives one the means of controlling the amount of light projected. Shutters are located in the second focal point ***f2***, or gate area and mounted on the top and sides of the fixture. They are used singularly or together to remove an unwanted portion of the projected light, "a shutter cut" is the term used for this. The "gate" area is typically at or near the second focal point of an ellipse. Which may also contain a gobo and iris slot. Refer to the generic sectional view of a Leko for its parts and their location on most all manufacture shells. Some older lekos will lack some of the features found on newer luminaries, but the location of the lamp base, shutters and lens tube will remain the same.





In addition to focusing lekos, you will be called upon to bench focus or optimize the lamp field that is projected from the lamp. Each manufacture has chosen a different way to accomplish this. One of the first ways was the use of four screws as seen on a cap from an Altman Q-Leko. Three screws are arranged in a triangular pattern, to enable the lamp base to swivel left to right and up to down. The fourth screw is used to push the lamp base in or out of the first focal point ***f1***. When you come upon this method of bench focusing/ optimizing an easy way to get a ruff idea of were; the lamp is in the reflector is to take the following steps: First loosen the cap set screw and them move the cap around to change the relationship to the reflector. Once loosened you can easily move the lamp around in the reflector in a circular motion and get an idea of which screws to tighten or loosen and whether the lamp needs to move in or out of the reflector's focal point. The Selecon Pacific uses a variation on this them as seen in the picture.

Altman Q-leko Bench Focus

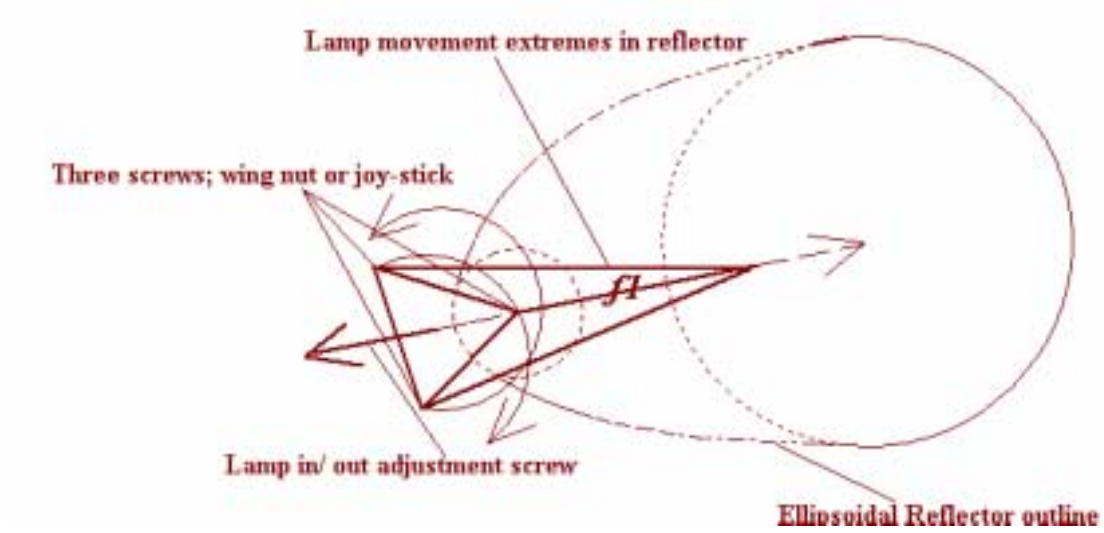
Selecon Pacific Bench Focus

Another popular method was a joystick; it usually consists of a single knob that is loosened, with the lamp base attached to it. In the case of the Strand, the joystick is triangular and it was moved around until the lamp output increased. This was done in conjunction with a second setscrew that held the base onto the lamp unit; the secondary setscrew moved the lamp in and out of the first focal point ***f1***. When the brightest output reached, both setscrews are tightened down to hold the new bench focus.

Strand Bench Focus

The most prevalent way to do the bench focus is the use of two different knobs as seen on the ETC Source Four. The center-knurled knob, controls the in/ out movement of the lamp in relation to the focal point ***f1*** or the Peak/ Flat adjustment. The other, which looks like a wing nut, moves the lamp in a circular pattern within the reflector to help center the lamp. If this method is used either the in/ out or the left to right will need to be checked once the other is tightened to assure a good bench focus.

ETC S4 Bench Focus



Looking at the drawing at left will clarify the general motion that is made by all the systems to optimize the quantity of light emitted from an Ellipsoidal Reflector Spot light or Follow Spot. The three points of the triangle represent the following extremes of movement: Altman and Selecon method of using the three screws for *X* and *Y*. The same principals apply when using a joystick or the ETC Source Four lamp optimization system. The axis point, labeled in/ out or *Z* demonstrates the movement by the Altman center screw, Selecon, ETC center knobs and the Strand Lamp base set screw.

Above is a good bench focus, with a relatively flat field (even & bright).

Above is a bad bench focus; note the hot spot in the upper right corner of the field.

In the gate area the following devices may also be used to modify the appearance of the light projected. A single gobo inserted, using a holder or a gobo changer to remotely select a gobo for projection onto the stage or scenic elements for texturing those surfaces. A Beam Iris to reduce the beam diameter. Motorized devices may be used to animate gobo's, such as "Twin Spins™" that holds two gobos and rotates them in a circular motion. In a heavily modified Leko, EFX2™ animated scenic discs, may be mounted to turn two different animation discs, and DMX controlled beam Iris's, On the front of the barrel using the color frame slots, either single or color mixing color changers may be used. Image Multiplexer™ a multi-prizimed device to project multiple gobo's from a single source, or a DMX controlled mirror or simple animation disk that rotates and blocks a portion of the projected light for a short period of time. Any of the previous attributes or accessories may be modified in appearance by running the lens tube/ barrel to a soft or hard edge by moving the barrel in or out as needed.

Below are illustrations of the different manufactures products.

Altman Shakespear

Altman Q Leko

Altman31/2" Leko

Colortran

ETC Source Four

Strand SL

Selecon Bottom Axial

Mounted EFX 2 Disc

Beam Iris

DMX controlled Iris

Image Multiplexer

DMX Mirror Gobo Changer

Leko's are sized either by their beam spread or by the lens focal point. When you are looking at a lens from unit that is older unit the focal point of the lens may be measured using a ruler. To do this, simply hold the lens under a light and measure the flat side of the lens to a tabletop. This measurement will give you the approximate focal length of the lens in the event you need to match it. Such as used in an Altman Q light that uses a double Plano-convex lens tube. In newer units made by ETC and Altman they have adopted a color code system for their lenses, examples of this are seen above.

Beam Size	**Equivalent 6 X**	**Color Code**
19°	6 X 16	Red
26°	6 X 12	Black/Blue
36°	6 X 9	None/White
50°	4.5 X 6.5	Yellow
10°	6 X 22	Large Lens
5°	None	Really Large Lens

Manufacture/ Name	Fixture Type	True Field Angle	Beam Angle	Lamp	Weight
Altman Q 360	4.5 X 6.5	55°	22°	GLC 575	13.5
Altman Q 360	6 X 9	37°	16°	GLC 575	14
Altman Q 360	6 X 12	26°	11°	GLC 575	15
Altman Q 360	6 X 16	19°	8.5°	GLC 575	15
Altman Q 360	6 X 22	11°	8°	GLC 575	15
Altman Shakespear	50°	50°	23°	GLC 575	15
Altman Shakespear	40°	38°	20°	GLC 575	15
Altman Shakespear	30°	28°	13°	GLC 575	15
Altman Shakespear	20°	20°	13°	GLC 575	15
Altman Shakespear	12°	12°	7°	GLC 575	21
Altman Shakespear	10°	10°	7°	GLC 575	16
Altman Shakespear	5°	6.9°	5°	GLC 575	16
Colortran 5/50	15°	15°	6.8°	FLK 575	19.3
Colortran 5/50	20°	20°	8.3°	FLK 575	19.7
Colortran 5/50	40°	40°	15°	FLK 575	20.3
Colortran 5/50	50°	50°	17.5°	FLK 575	20.9
Colortran 5/50	10°	10°	5.8°	FLK 575	20.9
Colortran 5/50	5°	5°	3.3°	FLK 575	30.1
ETC Source 4	19°	18°	15°	HPL 575	14
ETC Source 4	26°	25°	17°	HPL 575	14
ETC Source 4	36°	35°	25°	HPL 575	14
ETC Source 4	50°	51°	33°	HPL 575	14
ETC Source 4	10°	11°	9°	HPL 575	15
ETC Source 4	5°	7°	6°	HPL 575	19.2
Strand SL	19°	-	-	GLC 575	15.0
Strand SL	26°	-	-	GLC 575	15.0
Strand SL	36°	-	-	GLC 575	15.0
Strand SL	50°	-	-	GLC 575	15.0
Strand SL	10°	-	-	GLC 575	15.0
Strand SL	5°	-	-	GLC 575	17.6
Selecon Pacific	50°	-	-	GLA 575	18.8
Selecon Pacific	40°	-	-	GLA 575	18.8

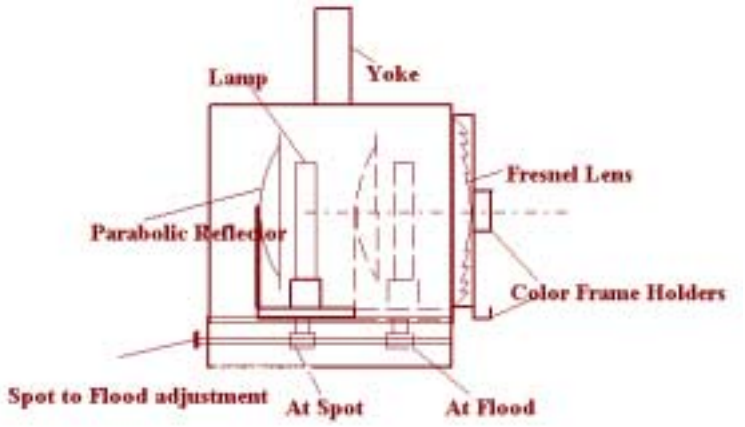
Selecon Pacific	30°	-	-	GLA 575	18.8
Selecon Pacific	20°	-	-	GLA 575	18.8

Fresnels

As seen previously, a Fresnel lens is the subtraction of material from a Plano-Convex lens. The reduction of material reduces the weight of the lens by breaking the lens into concentric circles. To the left, is a Fresnel lens, with an a overlay of a comparible Plano-Convex lens of the same focal length.By doing this, the image quality is reduced. However, in a stage lighting application its negative attribute of the lens is used to our advantage by providing a soft non-directional light source.

Augustin-Jean Fresnel was resonsible for the development of this type of lens for use in French light houses in the 1800's. Augustin- Jean Fresnel received credit for the lens, the lens and was first utilized in a theatrical fixture circa Ninteen Twenty's by of course, the Kleigle Bros.

The Fresnel lighting fixture is primarily used to day as a back-light luminare with either a simple color and frame or used in conjuction with a color scroller for changeable back light color. In a TV studio they are the fixture of choice due to the ease of blending of one light into another.



Wattages for these fixtures as an incandescent lamp source will typically range from 150 watts to 2000 or 2K. As an HMI lamp source they will range from 200 watts to 12,000 watts. When a Fresnel is used with a HMI lamp source, head cable is used in conjuction with a ballast, which usually has a remote strike feature and circuit breaker for protection. They usually use 208 volts for lamp supply rather than 110 volts for an incandscent lamp source.

In addition to the differing lamp sources, the Fresnel has an adjustable field of illumination from spot to flood. The adjustment is made by turning a knob or a set screw on the bottom of the fixture. Turning the knob will vary the position of the lamp and reflector from closest to the lens (Flood) to farthest from the lens (Spot). Unlike a Leko that has built in shutters, to trim unwanted light; a Fresnel requires barn doors to accomplish the same

Turning your attention above, to the sectional view will illustrate the main components of the Fresenl lighting fixtures, and below are some examples of comercail products. A further example may be seen in the 1936 patent 2,057,278 and the 1932 patent1,854,214.

6" Fresnel

8" Fresnel

8" Fresnel

8" Fresnel

3" Fresnel "Inky"

Parnel

HMI Fresnel

HMI Fresnel

Manufacture/ Name	Fixture Type	Full Spot (dia@dist) .36 x dist	Full Flood (dia@dist) 1.25 x dist	Lamp	Weight	Color Frame Size
Altman 100 aka INKY	3" Fres	2'@ 5'	12.5'@13'	ERS	2.2	3¾" x 3¾"
Altman 65Q	6" Fres	2.8'@10'	42'@30'	BTL, BTM, BTN, BTP	9	7¼" x 7¼"
Altman 75Q	8" Fres	4.2'@20'	33.1'@40'	BVT	14.5	10 ⅛" x 10 ⅛"
Altman 2500SE	10" Fres	1.6'@10'	46.2'@40'	2.5 HMI	36	
Strand Fresnelite	8" Fres	4.9'@35	54'@40'	CYX	17	10 ⅛" x 10 ⅛"
Colortran 5kw	10" Fres	4.2'@20'	47.6'@50'	DPY	37	
ETC Parnel						
Mole-Richardson						

Par Lamps

Grand Stage Lighting Sealed Beam Spot

The Par fixture was first seen in the early 60's as an easily used and serviced lighting fixture that did not require any focus adjustment. The early "Par Cans" lacked the rear opening to enable the beam pattern to be adjusted. These same qualities that the lighting fixture possessed, developed it into a lighting fixture that could be rapidly focused and stored in cases for touring Rock and Roll acts in the early 70's. One of the first companies, to develop this technology was Showco. The lamp housing has typically been one of three shapes, a box, hexagon or more prevelant a round cylinder. Each shape had an access opening in the back of the lighting fixture to enable the lamp to be "spun" for a horizontal or vertical lamp beam. The materials that these have been made from are typically of steel or aluminum. RA Roth toured with square Par Cans due to their appropriate size for containerization in a truss. The Octagonal Par Cans were made by Strand Lighting in 1977 and called Parblazers. The more common shape of the circle, has been made by Altman Stage Lighting for 20 +years. The Par Cans are of a simple design and usually have three gel clips and a spring retainer clip on the top. The spring clip usually determines the fixtures orintation for the top of the lamp. Making gravity help keep the gel frame in place. There also is normaly one or two focus locking T handles on either side of the yoke. The Par fixture derives its name from the lamp that it houses, a Par 64 sealed beam lamp. Which is a combination of a extended Mogul End Prong base, a Parabolic Reflector, lamp envelope and lens.

Strand "Parblazer"

Following the text will be a pictoral of the lamps that are described here. The Par lamp is manufactured as as ACL (Air Craft Landing Landing Light), Very Narrow, Narrow, Medium, and Wide lamp varities. The lamps are named for their Beam Spread which is determined by their lens face. A clear lamp face will either be a ACL or Very Narrow. The difference between the two lamp types are the following:

An ACL has a very small lamp filament surrounded by 180° of reflector, a clear lamp face and it is a 24 volt lamp.

A Very Narrow (VN) has a clear lamp face and contains a double ended lamp in a sealed envelope that may be seen.

A Narrow lamp (N) has stippled face on it that provides a minimum of diffusion.

Medium (Med)lamps have 10 ten lines runnin through to provide an average amount of disperson for most uses. While a Wide flood (Wide) has 13 thirteen and provides for the widest coverage possible from a Par type lamp. The Altman Star Par and the ETC Source 4 Pars both make use of interchangeable lamp faces on a common housing and reflector assembly. The Altman and ETC Par Lenses arer avaiable in the following lens faces: VN, N, Med, Wide and Xwide (Buxom). They are not however interchangeable. A hybrid design of the ubiouqis Par Can is the HMI Par. It uses a HMI lamp source in combinaton with interchangeable lenes and an optional dimming shutter for intensity control. In addtiona to the accessories for the head, a ballast is necessary to fire this type of lamp. This is done either locally with a switch located on the ballast or remotely using a DMX address. This funtion is chosen on the ballast itself, and is done to usually make the operation of the unit less noticeable to the audience.

Altman Par Can

Thomas Par Can

TMB Par 46 Can

Altman Star Par

"Birdie" Par Can

ETC S4 Par Can

Arri HMI Par Can

Lamp/ Lens	Manufacture	Beam Angle	Field Angle	Distance @ 10'	Distance @ 20'	Distance @ 30'
ACL						
Very Narrow						
Narrow						
Medium						
Wide						
Very Narrow	Star Par	6 x 6	14 x 14	2'x 2'	5' x 5'	7' x 7'
Narrow	Star Par	7 x 7	16 x 16	3' x 3'	6' x 6'	8' x 8'
Medium	Star Par	9 x 19	19 x 29	5' x 3'	10' x 7'	16' 10'
Wide	Star Par	17 x 40	32 x 56	11' x 6'	21' x 11'	32' x 17'
Very Wide	Star Par	53 x 53	77 x 77	10' x 10'	20' x 20'	30' x 30'
Very Narrow						
Narrow						
Medium						
Wide						
Very Wide						

Wide Flood, abbreviated WFL has thirteen lines of beam dispersion

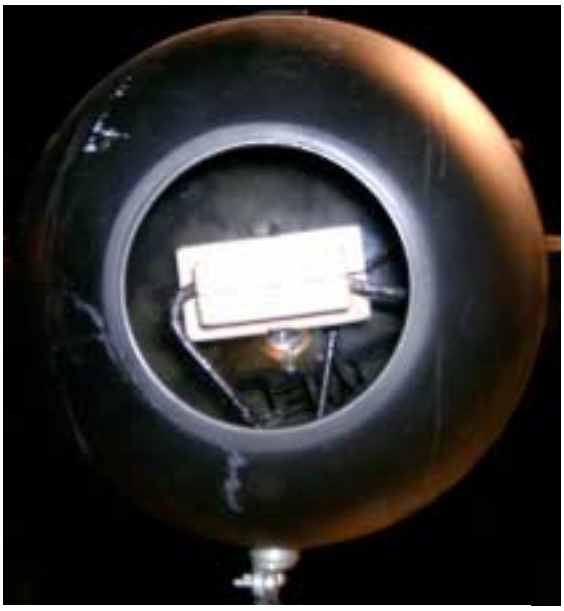
Medium Flood, abbreviated MFL has nine lines of beam dispersion

Note the difference in appearance of the Medium and wide Par Lamps. It is a subtle one, but important to know!

Aircraft Landing Light, abbreviated ACL, note filament and reflector

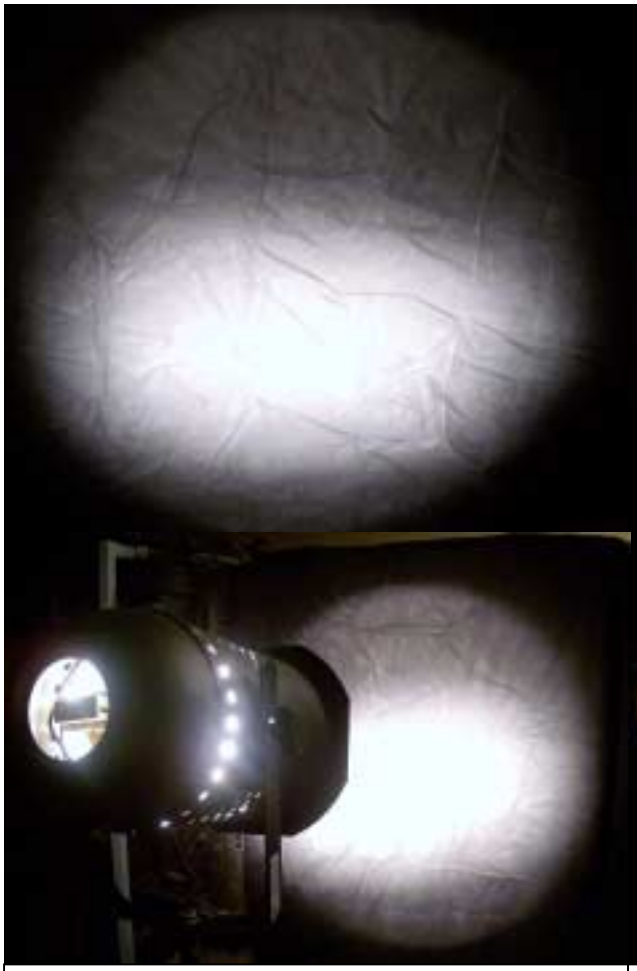
Very Narrow, abbreviated VN has a clear lens but with a double ended lamp

Narrow, abbreviated N; note the frosted lens face.

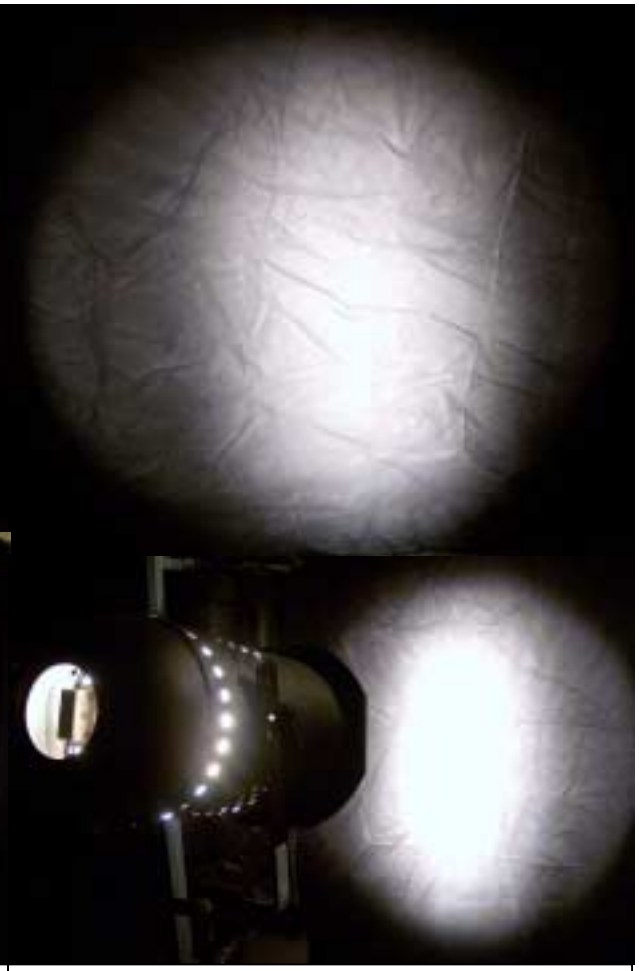


Rear of Par Can showing the porcelain

Focusing a Par Lamp is not unlike any other fixture, however unlike other fixtures the lamps in a standard “can” may be spun. To do so, you grasp the porcelain lamp base and turn the bottle as desired. There is one type of lamp that you don not want to do this, and it is an ACL. ACL’s have screw terminals and you will receive a shock. By spinning the lamp the beam pattern may be changed from a horizontal orientation to a vertical one. In addition the lamp may be stopped, at any position in a 360 turn to give a diagonal appearance to the beam. These types of lamps are held in place by a large snap ring with tangs on the end to facilitate the removal of the lamp for replacement or to increase pressure on the lamp to enable it to hold the lamp in after it is spun.



Above demonstrates a steel Par Can with its lamp spun horizontally.



Above demonstrates a steel Par Can with its lamp spun vertically.

Cyc Lighting

15" Scoop

Open face lighting fixtures are typically used to light a backdrop or cyclorama. These lights lack any sort of lens and are higher lamp wattage from 500 to 2000 watts.

Scoops may be as simple as the ellipsoidal shaped scoop light or may have the additional functionality to focus from a spot to flood setting. Scoops are typically defined by their diameter measured in inches, i.e. 14" Scoop

Scoop lighting fixtures retain color using a round or square gel frame. If neither is available using quickie clamps or clothespins will hold the color in place.

Scoop with Spot to Flood adjustment

When either type is used, the blending of each individual unit is necessary to create a uniform wash of light, whether a single color or multiple unit's, circuits/ colors are used. Whether one uses scoops or multi-cell fixtures each is used to create a soft wash of light on a backdrop or bounce.

The Multi-cell fixtures are typically used today and fit into three categories the first is known as a strip light and use either a PS lamp with a screw base, a Par flood lamp, Par 56 or 64's as a lamp source. Strip lights may use a roundel which is a round color filter made from high temperature glass or color media used in other types of lighting fixtures. When used in an overhead application they are called border/ strip lights or on the floor as a ground row.

The second category uses double ended lamps and are typically used in the newer "strip lights". These lamps are tubular in description and due to their physical design assist in blending multiple units together. This type of fixture is broadly called cyc strips. However, they may also be called Far Cyc's that are typically flown from a line set to illuminated a bounce or cyc from an overhead position. Floor mount cyc units may also fit into the same category but for clarification they are called generally called a ground row. All of these fixtures use a color frame, which are loaded with high temperature color media or make use of glass filters that receive a coating on one side.

R 40 Strip Light with hanging Irons

Far Cyc with hanging hardware.

T3 Cyc Strip with floor trunions.

MR 16 Strip Light with floor trunions.

The third type of strip light in use is the Zip or Mini Strips. These fixtures are approximately a quarter of the size of their larger counter parts. They are used inter-changeably with their larger counter parts. Their diminutive size is attributed to the use of MR 16, 12-volt lamps that are wired in series. These fixtures make use of color frames and also use standard

Economy Strip Light.

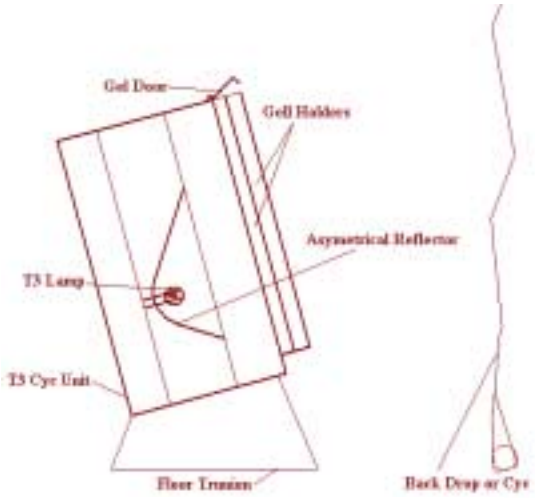
color media or glass filters for color longevity may be inserted into one of the two color slots. Usually, the first slot, closest to the lamp will contain a heat shield. The second slot will have the color media inserted.

Mini Strips used as down stage footlights

Economy Strips used as a Ground Row UPS

Economy Striplights barrel bolted together to from a five-unit strip. Note the letter "G" that indicates it is the seventh unit from SL and the "fist" space between the units

In addition to the previous striplight types, a variant exists. These strip lights are the "economy" Strip Lights by Altman. The distinctive feature of these is the ability to use them, singularly or barrel bolted together to form a traditional multi-color/ circuit strip light. These fixtures use a lightweight color frame that is bent into an arc and fitted over the lamp, as seen in the Ground Row photo.



Basic Cross Section of Far Cyc

As you can see in the Far Cyc Cross section, the units contain an asymmetrical reflector. The units have specific orientations when they are hung as and overhead cyc wash and as a ground row. When they are hung from a line set, the shortest leg of the reflector will be hung closest to the top of the Cyc/ drop or bounce. If they are used as a ground row, the shortest leg of the reflector will be closest to the ground. The reasoning for this is the maximum amount of light will be projected onto the background.

When using any type of Strip light or Far Cyc type unit special attention needs to be paid to circuiting these types of units in order

not to exceed the load capacity of the dimmers they are patched into. Typical dimmers are 2.4K each; one of these units can be up to 2000 watts per cell, a cell being one color. So the ability to twofer them are limited to two maximum units when each lamp is 1000 watts. When strip lights are used to light a cyc or backdrop, these units are hung spanning the width of the stage. Each unit has a specific color in each cell. Each one of these cells are then paired up through a combination of load patching with twofers and control patching to form a controllable color wash on the backdrop or Cyc.

When using these fixtures vigilance is necessary in checking for color that has been punched out when hanging the fixtures, due to the large size gel some of these units use. In addition, light leaks in some types of Cyc units maybe problematic. To correct this problem, Black Tac or Gaffers tape is used to form a seal around the gell frame and the gell holder.

Mazda Open Face Lights c1926

Twin Flood Light c1926

Other Open Face Fixtures

In addition to the fixtures used to illuminate Cyc's, general backdrop and down lighting Open face lighting fixtures are also scaled down in size and wattages to provide a large areas of soft diffused light.

Like the larger lighting fixtures these have a color frame on their face. The Broad and Runts are able to do so with a higher degree of success due to the distance between the lamp and color holder. The Mini 10's and stick-ups burn the color up almost immediately because the color is so close to the lamp source. These fixtures are generally used were there is limited space to install a lighting fixture. These areas may be backing lights for doorways, multi-level sets and even inside bars

Stick-Up

Mini 10 or Mini King

Runt

Broad Light

Audience Blinder

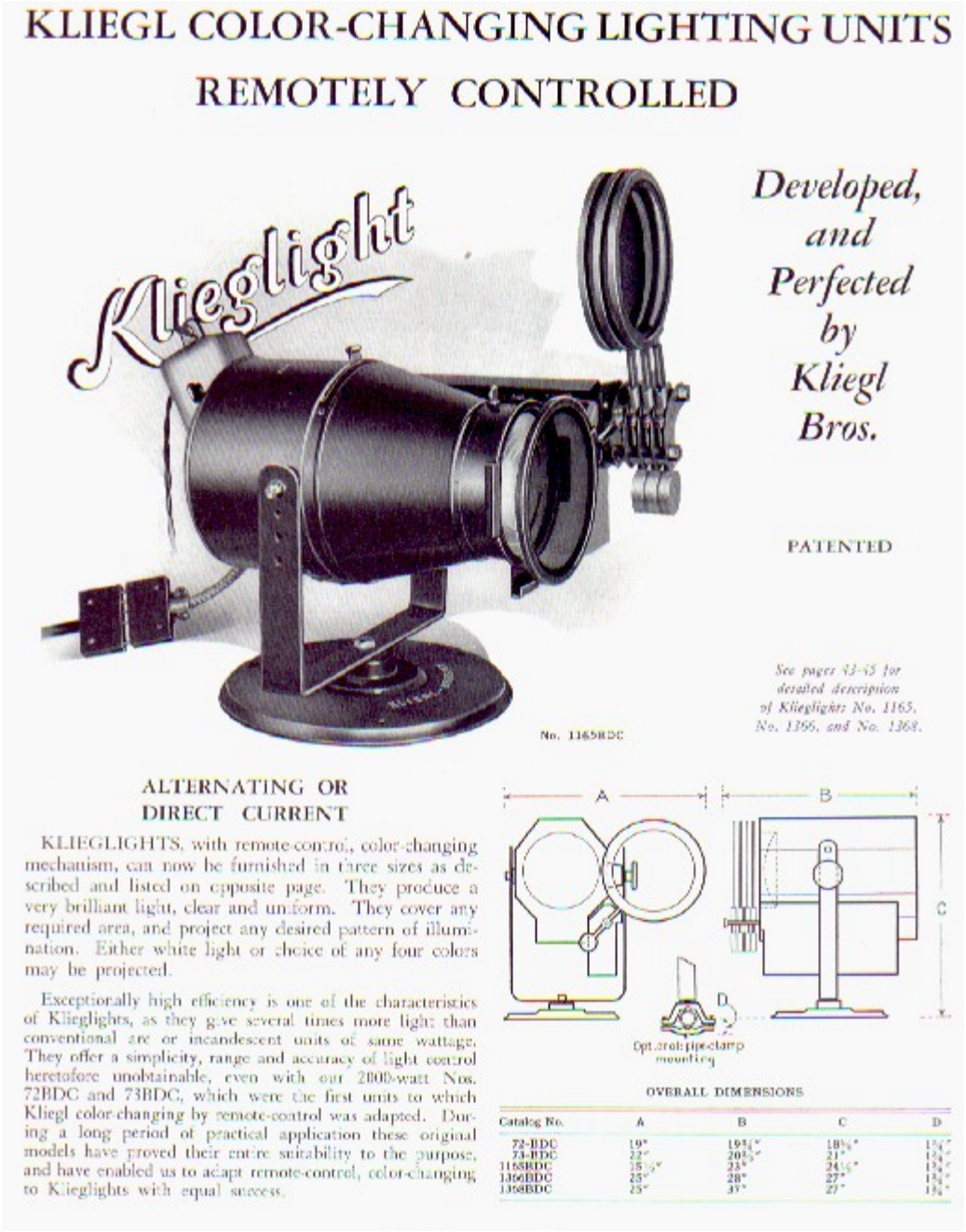
In addition to the lens-less open face fixtures that use tubular lamp sources, there are others developed to illuminate large areas of an Arena hosting Rock and Roll shows and events of the like. These are commonly known as Audience Blinders or as Eight Lights (the number of bulbs forming the name). These use Par 36 lamps and the type of lamps will vary depending on coverage needs or the "look required". These types of fixtures have the normal Pan and tilt associated with other types of fixtures. They may also have the additional ability to focus banks of light to specific areas instead of only

Audience Blinder or Eight Lights

panning in one direction. Color is generally limited to white, unless an adapter ring is used to hold color media or color changers.

Low Voltage Beam Projector

Finally, there is one last type of Open Faced light; it is a Beam Projector. The beam projector is a lamp that projects a beam of light. In this particular fixture there are two different reflectors in use. The first is a spherical reflector located like others at the back. In addition there is parabolic reflector located immediately in front of the lamp. In addition, there may be is a series of rings which concentrically get smaller as their location becomes closer to the center. This ring of baffles takes advantage of the Fresnel Effect. However with out lens, these rings simply help focus the bean of light into a concentrated source. These fixtures typically have a “spot” to “flood” adjustment, which generally has minor affect on the size beam projected. The same bean pattern can be realized by using a Par 64 ACL or Rain Light reflector in a Par fixture.



KLIEGL COLOR-CHANGING LIGHTING UNITS

REMOTELY CONTROLLED

Kliegl light

Developed, and Perfected by Kliegl Bros.

PATENTED

No. 1165BDC

See pages 43-45 for detailed description of Klieglights No. 1165, No. 1366, and No. 1368.

ALTERNATING OR DIRECT CURRENT

KLIEGLIGHTS, with remote-control, color-changing mechanism, can now be furnished in three sizes as described and listed on opposite page. They produce a very brilliant light, clear and uniform. They cover any required area, and project any desired pattern of illumination. Either white light or choice of any four colors may be projected.

Exceptionally high efficiency is one of the characteristics of Klieglights, as they give several times more light than conventional arc or incandescent units of same wattage. They offer a simplicity, range and accuracy of light control heretofore unobtainable, even with our 2000-watt Nos. 72BDC and 73BDC, which were the first units to which Kliegl color-changing by remote-control was adapted. During a long period of practical application these original models have proved their entire suitability to the purpose, and have enabled us to adapt remote-control, color-changing to Klieglights with equal success.

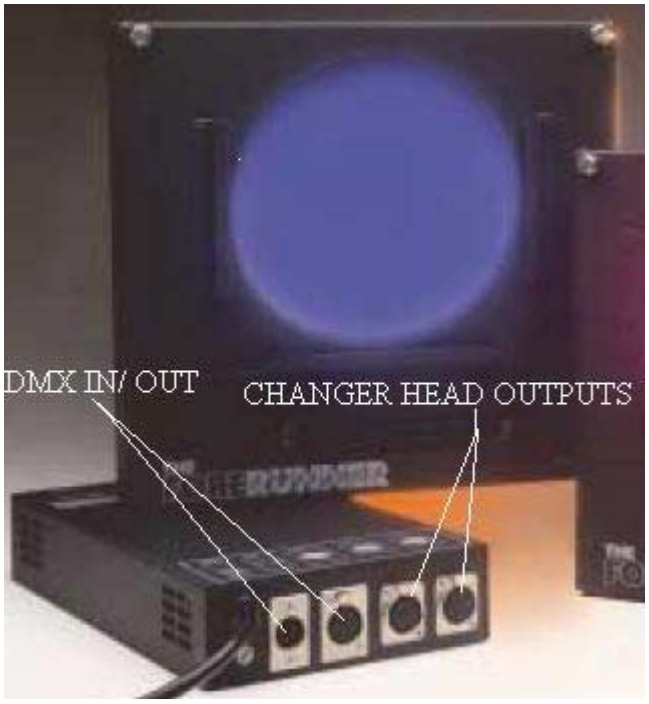
OVERALL DIMENSIONS

Catalog No.	A	B	C	D
72-BDC	19"	19¾"	18⅝"	12¼"
73-BDC	22"	20⅝"	21"	12¼"
1165BDC	15½"	23"	24⅛"	12¼"
1366BDC	25"	28"	27"	12¼"
1368BDC	25"	31"	27"	12¼"

The need to remotely change color has been around for the last 50 years. Early color changers where made to employ a small number of colors and used the then standard “Gels”. As in previous years the need to remotely scroll through a series color still exits. Wybron electronics was one of the first to perfect a method to remotely change colors using the DMX protocol.

Most color changers employ a system of two rollers that are pushed or pulled through their range of colors. Each color is tapped together using high temperature clear tape to create a scroll. These are then loaded into each unit, and depending on the model a tensioner built into one-roller holds the gel taut as it moves through the colors. The other roller is connected to a motor, to drive the gel around the rollers.

These units are plugged into each other in “daisy chain” fashion. The starting point for these units is always a power supply. These power supplies, take line voltage and convert 110 vac into a 24-vdc voltage, to supply various voltages to the electronic components. In addition to the low voltage DC, they also pass the DMX signal to each unit. The power supplies typically have DMX in and out and additional outputs to distribute low voltage DC and DMX through a single four-pin cable that is daisy chained between units.



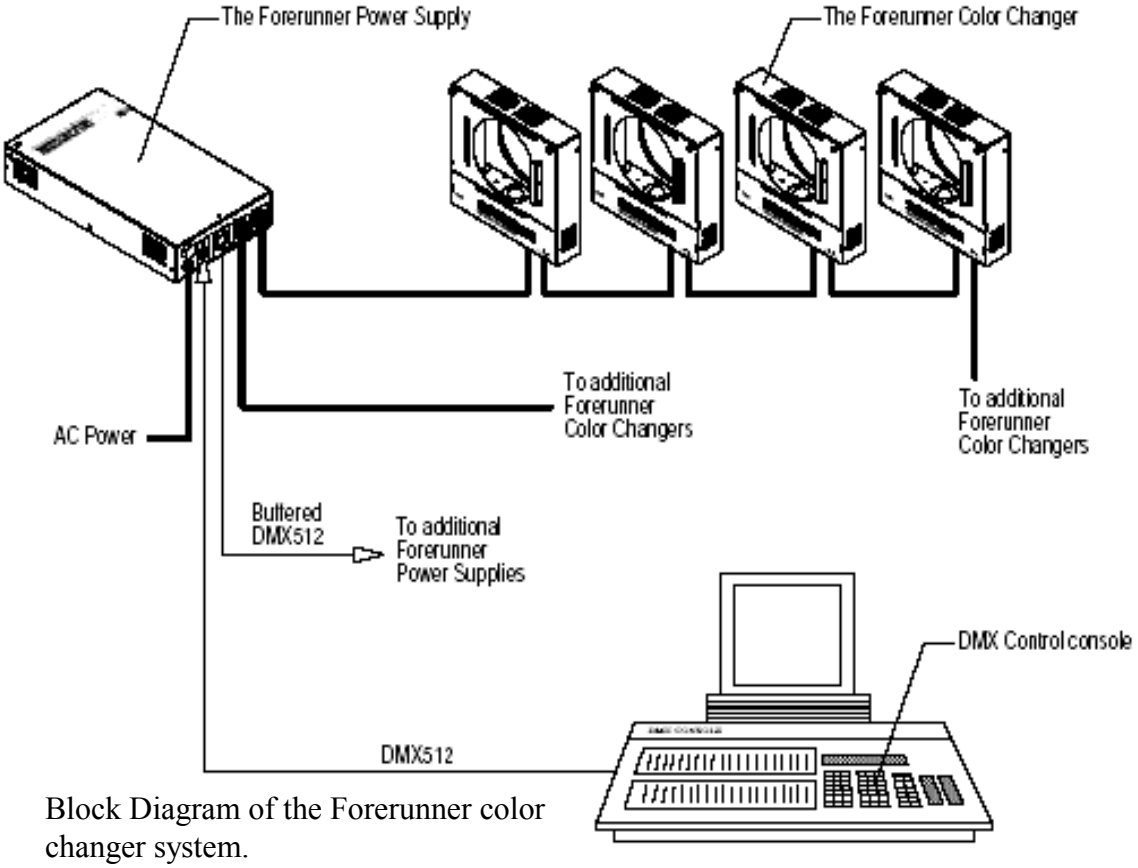
Forerunners are a system employing, a power supply capable of powering sixteen head units as a single daisy chain or two different branches for no more than sixteen. Forerunner color changers have a maximum cable length (Daisy Chain) of 350 feet.

Each changer holds sixteen colors plus a leader and an ending frame. The units must hold sixteen color frames to function properly. Color position is set using a board channel percentage, 0 being frame 1, full or 100% frame 24. There are also two LED's that indicate the presence of power and DMX. You must not mix the Coloram and Forerunner changer heads or power supplies, because either one will damage the other. In the event of a miss-plug or head failure they take a 2-amp slo-blow fuse.

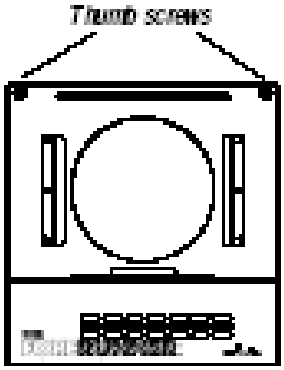
The Forerunners have optional mounting plates that allow them to mount different lighting fixtures. These plates are 6.25", 7" and 10". The different plates are replaced by removal of four Phillips head screws and re-installation.

Addresses for each unit are assigned on each changer head, from 1-512 using a thumb wheel and screwdriver to make the address changes. You may assign the same addresses for groups of lights or use a different address for each changer head.

The power supplies and color changer heads have their own terminators built in and do not require any others.



Block Diagram of the Forerunner color changer system.

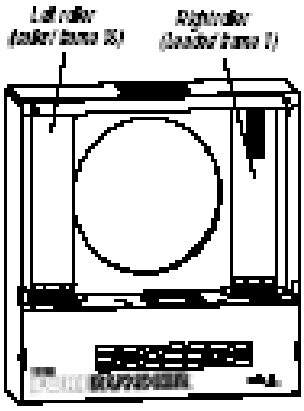


At some point in the service life of the color changers, replacement of the color is necessary to do so:

1. Roll the gel string onto the roller, exposing the clear leader taped on the right roller.
2. Untape the leader from the right roller and remove the tape.
3. Roll the gel string up, until the clear trailer is reached and remove the tape.

Once the color is removed the color changer is ready for new color.

Note: Use gaffer's tape to attach the gelstrings to the rollers. Do not use duct tape or masking tape.



1. Apply power to the Color Changer.

2. Press the recessed "Load Gel" button located in the lower right hand corner of the Color Changer. The rollers will rotate to the trailer load position. The rapidly flashing "DMX" LED indicates the rollers are
either moving toward the trailer load position or are at the trailer load position.

3. Put a strip of gaffer's tape on the edge of the gelstring trailer. Holding the trailer, let the rest of the roll hang off the right side of the Color Changer.

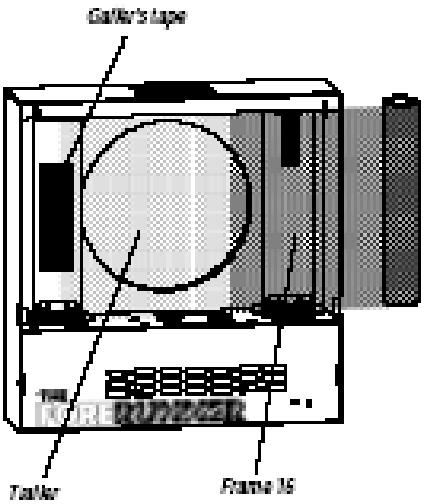
4. Center the edge of the trailer between the two ends of the left roller as shown to the left. Tape the trailer along the top of the roller as shown.

5. Hold the gelstring loosely in your right hand and press the "Load Gel" button again. The rollers will rotate to the leader load position. This will wind the gelstring onto the left roller. The "DMX" LED will flash slowly to indicate the rollers are either moving toward the leader load position or are at the leader load position.

6. Turn the "Adjust Gel" trim pot to bring the leader end of the gelstring to the top center of the right roller. Gel material of different thickness will cause variation in the leader end position. This is normal.

7. Put a strip of gaffer's tape on the gelstring leader.

8. While holding the end of the gelstring, turn the spring roller 3.5 turns toward the drive roller. The sticker at the bottom end of the roller has a black line on it to help you judge the number of turns

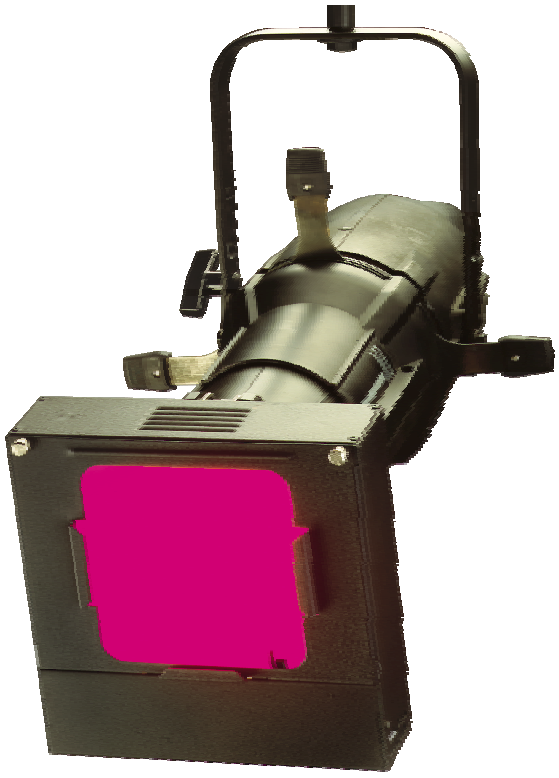


9. Tape the gelstring to the spring roller.

10. Press the "Load Gel" button once again. The gelstring will now move to the first frame if no DMX signal is present or to the commanded DMX level if it is.

11. Replace the front panel and tighten the thumb screws securely.

Note: As the gelstring becomes worn, you may find it necessary to adjust the position of frame 1. This is normal and is done by turning the "Adjust Gel" trim pot.



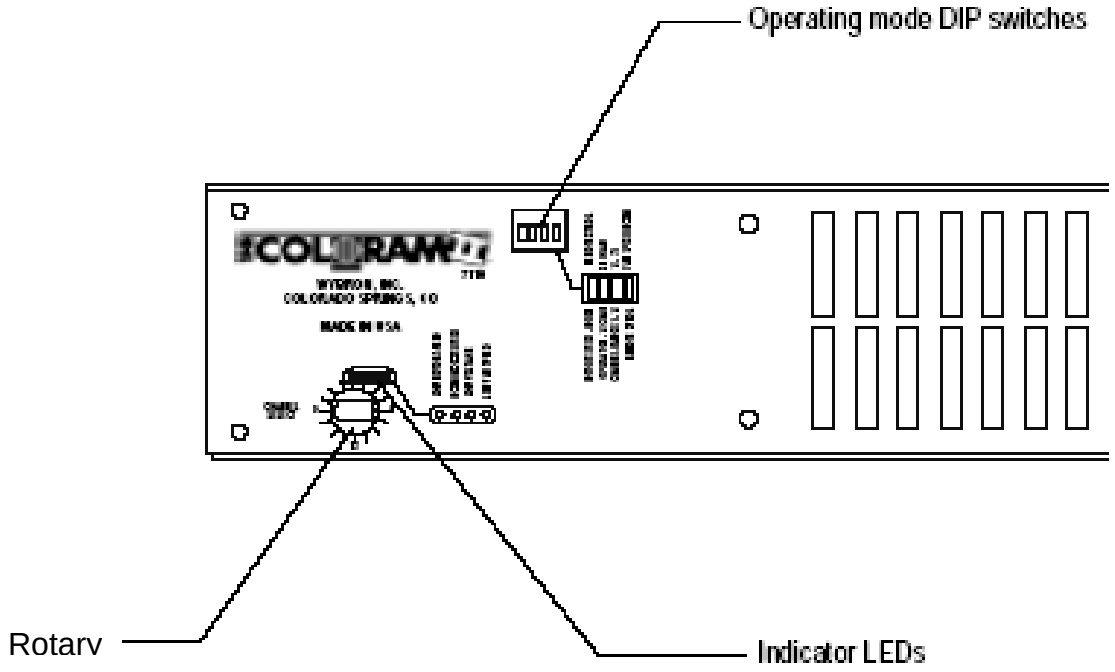
Coloram with 6.25” mounting plate attached to a Source Four Leko.

Colorams are another version of color changers. An immediate difference between these and the Forerunners is the addressing means. Their addresses are set in two places. One is on the power supply for setting a starting address. Then on each head there is rotary switch for each unit’s channel and a dipswitch for 12 (older rams) or 24 for newer units. The 12/24 mode sets the range of addresses from the starting address (set on the power supply).

Colrams may hold up to 24 colors on a conventional console and on a moving light console, 32 colors may be used, due the higher accuracy a moving light console offers (resolution of the encoders may be set to fine).

Cable lengths on the Colrams are also extended: the 4” and 7.5” has a maximum of 1500’. While the balance of the color changers have a maximum of 1000’. These like the Forerunners are daisy chained together for power and control.

The physically smaller Colorams, which are used on Lekos and Pars, draw 1.5 amps. While the larger ones, Far Cyc and Eight Light, draw 2.0 amps. Both fuse types are slow-blow fuses.



Located on the bottom of the unit are four LED’s that indicate Dipswitch settings. When all these same LED’s are all illuminated, they indicate unit shut down.

There is an additional feature that may be implemented on the Colorams, which is control of the fans. Their control from the console is useful when one wants to lower the noise level from the power supply fans. In addition there is a setting for changing the motor speed as well. These features are usually set in advance if used.

When a show has been shop prepped, most all of the settings and address's will have been preset. Typically the user settable dipswitches and addresses are recorded on a label stuck to the unit. This enables a spare to be substituted easily without looking for paper work. However, on a show site you may be required do addressing and dipswitch setting when assisting swapping units for show maintenance. Addressing Scroller's, is one of the most frequent tasks you will be asked to perform on these units

The necessary instructions to address the Power Supplies are included, for a complete copy of these; consult printed or downloaded instructions from Wybron. One item to be aware of is the ease in getting lost in the menu commands to do the setup and start addressing. Following are excerpts to cover the two tasks.

The three different Coloram power supplies require the following fuses: 24 way 7 amp, 12 way 4 amp, and 6 way 2 amp. All three use slow-blow fuses.

Front View of Power Supply

Rear View Showing DMX and Coloram outputs

SETUP

This menu is used to display and select the starting DMX channel as well as other operating modes.

Pressing [▼-] at any of the following options will bring up a question mark (?) behind the option. Pressing [▲+] and [▼-] will increment and decrement numbers such as channels or toggle options such as on or off. Pressing [►/Enter] will confirm your selection and the question mark will go away.

[▼-]

Chan 001 - This allows you to select the first of 48 DMX channels which the Power Supply will respond to and then send out to the Color Changers or Gobo Changers.

[►/Enter]

Mode 24 - This selects original Coloram 12 channel mode or Coloram II 24 channel mode. This option must be set to 12 to work with original Coloram Color Changers which have not had the Coloram II software upgrade.

[►/Enter]

Tbck OFF - This option turns talkback to a remote status monitor on or off. Status of the Color Changers or Gobo Changers will still be displayed in the status menu.

Jttr OFF - This option turns the jitter filter on or off. This option may be necessary for AMX to DMX converters which can have LSB jitter.

[⇤/Enter]

DMXF OFF - DMX fan on or off. This enables or disables the lighting console fan speed control.

[⇤/Enter]

The following options will be displayed only if the DMX fan option is turned on.

FChn 025 - This allows you to set the DMX fan control channel to any channel between, and including, 001 and 512.

[⇤/Enter]

Foff OFF - When turned on, this feature allows you to turn the fans in the Color Changers off from the lighting console. This is done by sending a level of 8% to the fan control channel.

COMMANDS

This is the menu you use to send basic commands to the Color Changers and Gobo Changers.

Pressing [▼-] at any of the following options will bring up a question mark (?) behind the option. Pressing [▲+] and [▼-] will increment and decrement numbers or toggle options. Pressing [⇤/Enter] will confirm your selection and the question mark will go away.

[▼-]

DMX ALL - This will send commands to all Color Changers or Gobo Changers connected to this Power Supply. Pressing [⇤/Enter] allows you to select the DMX channel of the individual Color Changer or Gobo Changer which you wish to send commands to. Channels with Color Changers or Gobo Changers set to them will be indicated by an asterisk.

[▼-]

Re-Init - This will cause the Color Changers or Gobo Changers to re-calibrate their gelstrings or gobo carriers

[⇤/Enter]

Commands Continued:

Shutdown - This will shut down motor drive in the selected Color Changer or Gobo Changer.

[⇤/Enter]

Pos - This allows you to move the gelstring or gobo carrier independently from the lighting console.

[⇤/Enter]

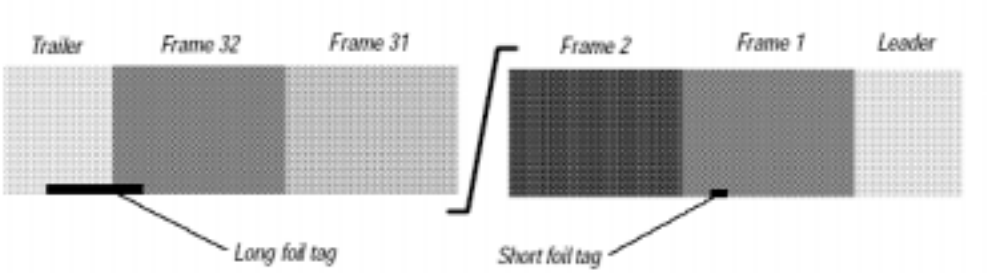
Fan - This allows you to change the fan speed independently from the lighting console.

[⇤/Enter]

Mtr - This allows you to limit the top speed at which the motor will run.

Changing the color scrolls used in the Colorams is another necessary skill to have. Unlike the Forerunners that use a set length color scroll, which determines its position within the scroll. Colorams use a tag system to define the length of the color scroll, without them the color changer will roll to the very end.

To the left is a picture of a color scroll, which shows the foil tags and location of the first and last color frames.



Install the new gelstring

Note: Use gaffer's tape to attach the gelstrings to the rollers. Do not use duct tape or masking tape.

1. Put a strip of gaffer's tape on the edge of the gelstring trailer. Holding the trailer, let the rest of the roll hang off the right side of the Color Changer.
2. Center the edge of the trailer between the two ends of the left roller as shown to the left. Tape the trailer along the top of the roller as shown.
3. Roll the gel string onto the left roller until the end of the leader is directly above the right roller.
4. Put a strip of gaffer's tape on the gelstring leader.
5. While holding the end of the gelstring, turn the right roller toward the left roller. The sticker at the bottom end of the roller has a black line on it to help you judge the number of turns.

Note: Use maximum number of spring roller turns for gelstrings with maximum number of frames. Use less turns for shorter gelstrings. Refer to the gelstring tension chart below for the exact number of turns for your Color Changer/gelstring combination.

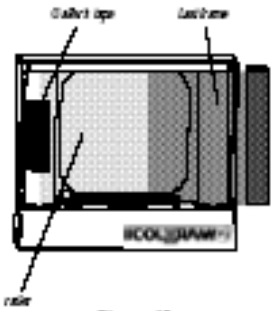


Figure 15

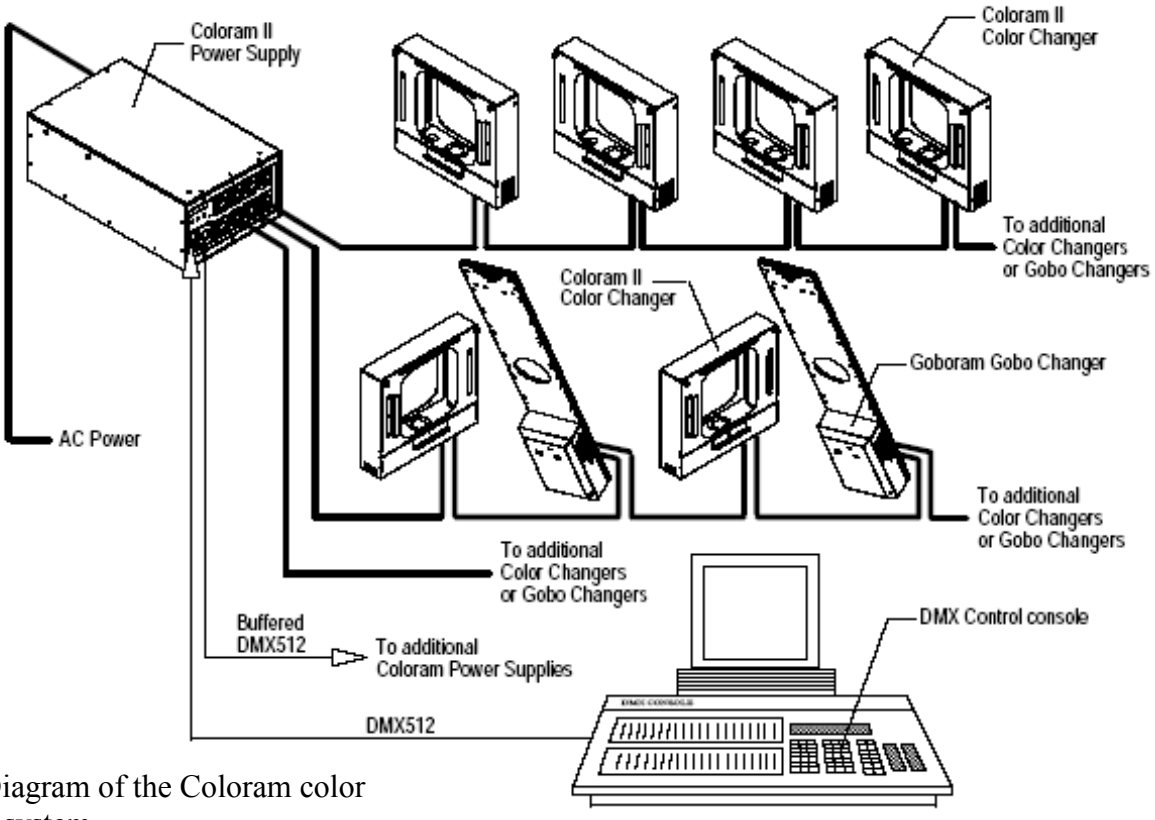
6. Tape the gelstring to the right (spring) roller.

Following are the number of turns that should be placed on the right roller; these turns tension the gell string to prevent sag in the middle of the scroll.

Models: 4520, 7110, and 7080	Number of Turns
2 - 10 frames	5
11 - 18 frames	6
19 - 26 frames	7
27 - 32 frames	8

Model: 10100	Number of Turns
2 - 5 frames	5
6 - 10 frames	6
11 - 17 frames	7
18 - 24 frames	8

Models: 15010, 16080, 16090, 16100, and 5000	Number of Turns
2 - 4 frames	8
5 - 8 frames	9
9 - 12 frames	10
13 - 16 frames	11
17 - 20 frames	12
21 - 24 frames	13



Block Diagram of the Coloram color changer system.

CXI color changers are two roll color scroller that the operator has independent control of each scroller using two different Board control channels. The independent control of both color scrolls in the CXI unit allows for color mixing.

The CXI color changers are compatible with any of the Coloram products including the power supplies. The CXI color changers may be daisy chained with Colorams or eclipse dimming shutters. Like the Colorams the fans on the CXI color changers may be controlled from an additional console channel to remotely turn the fans on or off.

In addition to the previous features, there is a watchdog feature that monitors the CXI's and the feedback may be monitored on a PC.

Like the Colorams, the CXI's cannot be co-mingled with the Forerunner type color changers. In the event they are one or the other may suffer damage.

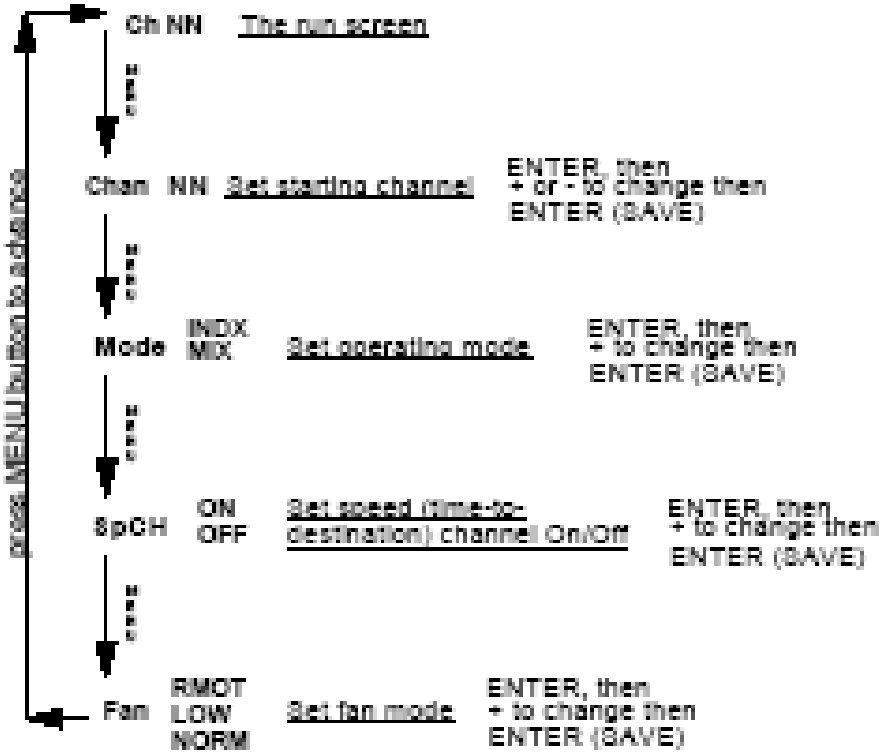
CXI Coloram, two scroll color changer mounted to Source Four Par

To quickly set up these color scrollers:

1. Select a starting address.
2. Then Set the CXI's to MIX mode (this allows independent control of the two gel strings).
3. Set the speed to OFF
4. Set the power supply to a starting address.
5. By changing the first board channel levels the position of gel string A will change position. The adjacent board channel will change the position of gel string B.

On the bottom of the CXI there is a LED display, four push buttons: MENU, -, +, Enter (Save). In addition there are also LED's that indicate mode, DMX and power. The MENU button advance your through the menu items. The ENTER button selects the menu item once you have paged through the menu items and terminates/ Saves the changes made.

The CXI menu tree is as follows:



One thing to keep in mind when setting the address is the formula to determine the address of the unit. The following formula is used to determine the address for each unit:

DMX= CXI Channel+ power supply starting channel –1

Or stated differently:

CXI channel = DMX channel- power supply starting channel +1

Example: DMX control channel 10 is desired.

CXI channel set to 4

Power supply starting channel 7+

11-1=10

1.Press the menu Button.
2.Press the enter Button.
3.Use the + or – buttons to find the address number.
4. Press enter again to save the address.

The CXI color changers have two different modes of operation; the first is indexing which positions both strings of gel, and the second channel of the CXI controls the speed at which the strings move. The other mode of operation is mixing mode, when this mode is used the first DMX channel of the CXI controls the first gel string. The Second DMX channel controls the other scroll. The third possible channel will control the speed of both gel strings; the speed needs to be enabled through the menu commands on the bottom of the CXI unit. When the CXI are in Mix Mode the Console channel sets the position by the board percentage, if it is set at a half percentage, the scroller will be set at a half frame.

There are some restrictions that are imposed upon the CXI's due to the Coloram power supplies. Using the 24 Way Power Supply gives you the address range of 1 to 48. The 12 way supply 1 to 24 and the 6 way 1 to 12. Each of the power supplies receives and retransmits gel string position in similar blocks of information as the address ranges. The 24 way receives data as a block of 48 which is also the maximum number of CXI addresses that are available.

Like the Colorams, the CXI's have a maximum cable length to observe or Head-Feet length. Head-Feet length is defined as all cable from the Power Supply to last CXI color changer.

Model 4560 4 inch CXI 750 head-feet max.
Model 7160 7.5 inch CXI 750 head-feet max.
Model 1011 10 inch CXI 500 head-feet max

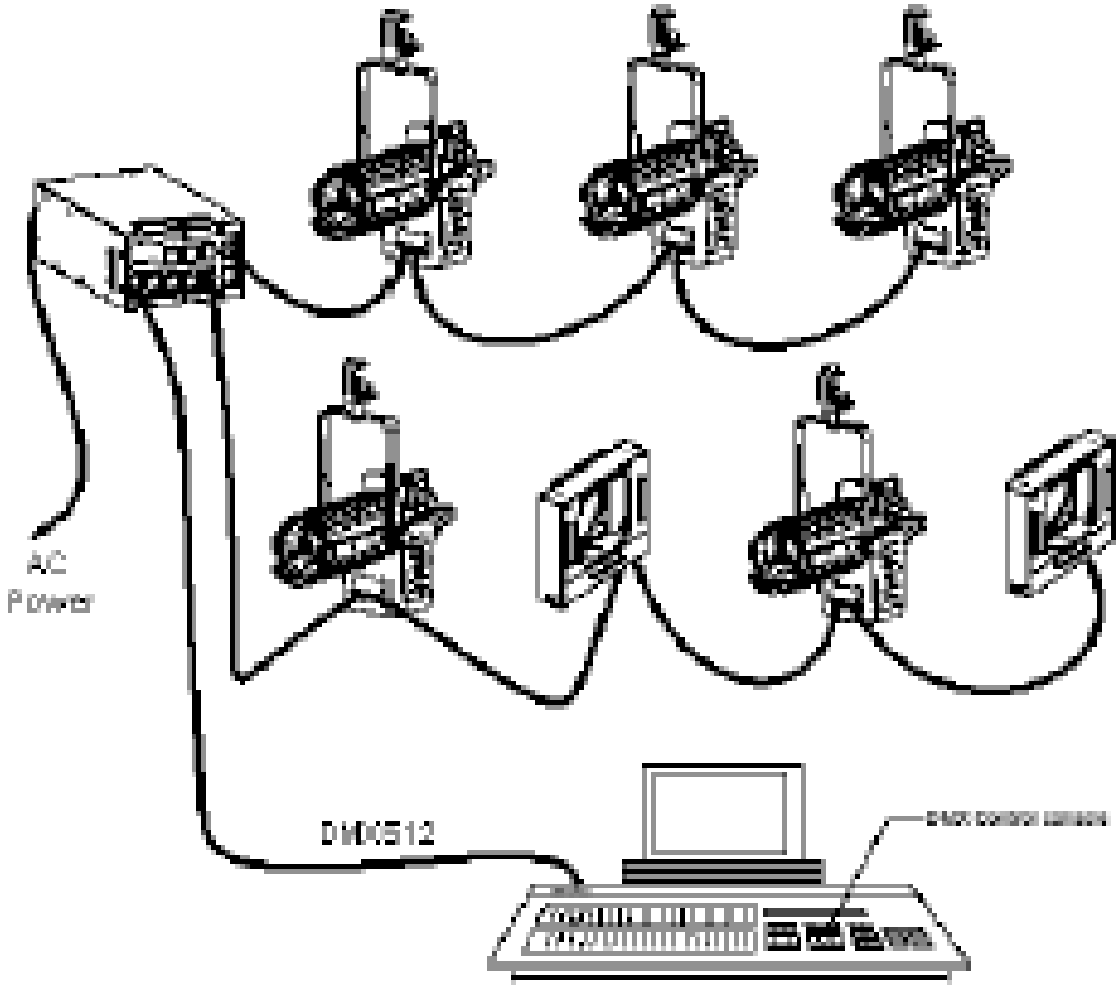
The maximum number of CXI color changers that may be cabled from a Coloram power supply is as follows:
24 Way Power Supply supplies 600 watts may power 12 CXI's
12 Way Power Supply supplies 300 watts may power 6 CXI's
6 Way Power Supply supplies 150 watts may power 3 CXI's

The general specifications of the CXI's:
Power requirement are 3 Amp Slow-Blo fuses
They are able to hold a gel string with 23 frames.
The LED indicates: Index mode Yellow LED
DMX signal Green LED
Power present Red LED

As previous seen the reloading of gel scrollers is a large part of maintenance on any type of color changer. The CXI's are no different and they have their own instructions for loading scrolls

Color Loading Instructions:

1. Put the color changer on table mounting plate down with the 4 pushbuttons toward you, remove the front cover
2. The lower gel string (B) is yellow-magenta
    a. tape the left end of gel string (long tag end) to lower left roller, roll it up
    b. holding the gel string, wind up the lower right roller 6 turns and tape gel string on (use 4 inches of gaff tape lengthwise on the roller)
    c. place the gel string in the tag sensor
3. The upper gel string (A) is magenta-cyan
    a. tape the left end of gel string (long tag end) to upper left roller, roll it up
    b. holding the gel string, wind up the upper right roller 6 turns and tape gel string on (use 4 inches of gaff tape lengthwise on the roller)
    c. place the gel string in the tag sensor
4. Replace the front cover


AC
Power
DMX512

Replacing the Fuse

The fuse is located on the same panel as the XLR connectors. Check the fuse if the unit does not operate and the red power indicator LED does not light when connected to a power supply. Use a 1.5A slow blow fuse only. Damage caused to the unit with the incorrect fuse installed is not covered under the warranty.

Head-Feet Restrictions

Head-Feet is defined as "the sum of cable lengths from each NEXERA™ color module to a single power supply output". The Head-Feet parameter is a method of accounting for the voltage drop in the power / signal cable caused by the current drawn by each color module.

To help understand this issue, think of it as water pressure (voltage) in a hose (cable) where you have multiple water sprinkler heads (NEXERA™ color modules). If the hose (cable) is too long or you have too many sprinkler heads (color modules), the water pressure (voltage) will be too low.

Use the following equation to determine total head feet:

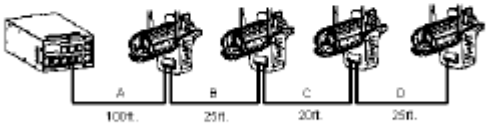
Head-Feet = [(A)+(A+B)+(A+B+C)+….]

where:
A = Cable length from power supply to first color module
B = Cable length between first and second color module
C = Cable length between second and third color module
and so on.

The maximum Head-Feet for each of the NEXERA™ fixtures is as follows

Model 2560	NEXERA™ Wash Luminaire	1500 Head-Feet max.
Model 2570	NEXERA™ Profile Spot	1500 Head-Feet max.

Head-Feet Example



In the figure above four NEXERA™ fixtures are daisy-chained off of the same power supply output. Using the equation given above, total head feet can be calculated as follows:

Head-Feet = [(A)+(A+B)+(A+B+C)+(A+B+C+D)]

= [(100) + (100 + 25) + (100 + 25 + 20) + (100 + 25 + 20 + 25)]

= [100 + 125 + 145 + 170]

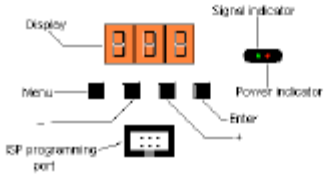
= 540 Head-Feet

Since total Head-Feet (540) is less than the maximum (1500) this is a valid configuration.

DMX Setup and Operation

Controls and Indicators

NEXERA™ has controls and indicators as follows:



- A three character seven-segment display
- 4 push buttons – **Menu**, (+), (-), and **Enter**
- Power (red) and signal (green) indicator LED's

The seven-segment display shows the channel number (c01 – c46) and the speed mode (hI S – lo S). It also displays any error messages, which will be covered in a later section.

The **Menu** button allows you to switch between channel and mode select. Pressing the Select button saves the current channel or mode setting before switching.

The (+) button allows you to increment NEXERA™'s Coloram channel when in channel mode, or toggle between high and low speed in speed mode. Changes are recorded in non-volatile memory immediately, and display flashes for 10 seconds to indicate that a change has been made.

The (-) button allows you to decrement NEXERA™'s Coloram channel when in channel mode, or toggle between high and low speed in speed mode. Changes are recorded in non-volatile memory immediately, and display flashes for 10 seconds to indicate that a change has been made.

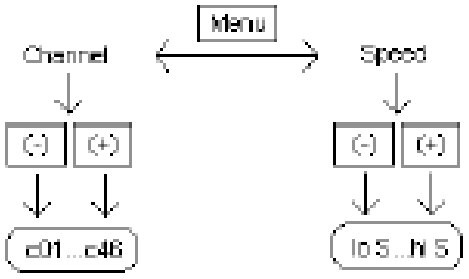
The **Enter** button stops the display from flashing after changing the channel or speed.

The red power indicator LED remains lit as long as there is power at the PC board.

The green LED flashes when a signal is present. It turns off 60 seconds after the last button press.

The ISP programming port allows the user to reprogram the unit as new software revisions become available without having to disassemble the unit. See 'Reprogramming via the ISP port' in the Service section of the manual for instructions on upgrading NEXERA™ software.

Menu Tree and Navigation



NEXERA™'s operating channel is set like other Coloram II family products.

DMX channel = NEXERA™ start channel + Power supply start channel – 1

Please see the Coloram II Power Supply user manual for instructions on setting the power supply start channel. A copy of the manual in .pdf format is available at www.wybron.com.

- To change NEXERA™'s start channel, press the **Select** button until the display shows **cxxx**, where **xxx** is a number between **01** and **46**.
- Use the (+) button to increment the channel. (Channel number loops from 46 to 1 when incremented.)
- Use the (-) button to decrement the channel. (Channel number loops from 1 to 46 when decremented.)
- Press **Select** to save setting, or allow NEXERA™ to automatically save the setting after 10 seconds.

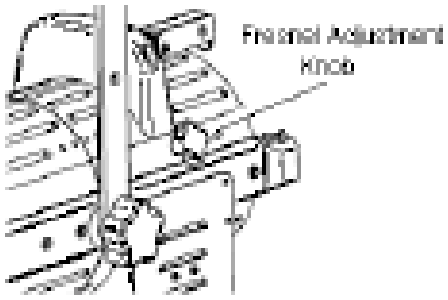
NEXERA™ offers high and low speed settings. High speed color changes are complete in two seconds or less. Low speed movements are inaudible and complete in four seconds or less.

- Press **Select** until the display shows **sxxx**, where **xxx** is either **hi** or **lo**.
- Use the (+) or (-) buttons to toggle between high and low speed.
- Press **Select** to save setting, or allow NEXERA™ to automatically save the setting after 10 seconds.

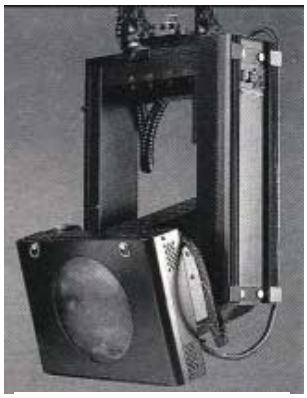
Adjusting field angle

Field angle can be adjusted on the NEXERA™ wash light.

- Loosen the Fresnel adjustment knob.
- Move the Fresnel back to increase field angle, or forward to reduce the field angle.
- Tighten the Fresnel adjustment knob to secure desired field angle.



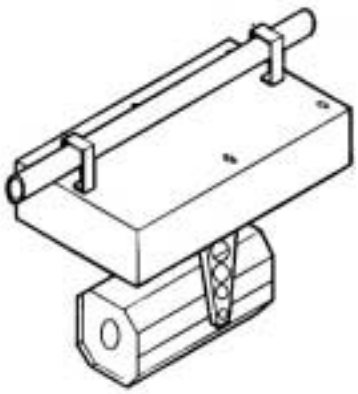
Moving Lights



Strand Par Scan II

Moving lights were first envisioned as early as the 1950's for use in automated television studios by George Izenour.

Early moving lights were one of two types, either a Par head built into a remote controlled yoke or an integrated unit. Moving Par heads typically had an incandescent lamp source that used a 1000 watt lamp and made use of the different beam spreads of ACL through Wide. These units also made use of color scrollers to facilitate remote control of their color and as an additional effect seeing the scroller moving while illuminated. The Par Scan made by Strand Lighting was introduced in circa 1986.



Vari*Lite VL1

While a moving par head was unique, the first mass produced moving light that embodied features seen in present day moving lights were made by Vari*Lite. Vari* Lite introduced the Model 1 during the 1986 Genesis Tour. These lamps made use of a compact arc lamp, the HTI Marc 350. Due to the Arc lamp source, they made use of an intensity Iris to control the intensity of each unit. Beam size was controlled using, a set of Gobo's with six different apertures to affect the beam size projected plus two for effects. In addition they made use of two dichroic color wheels one for color the other for saturation, these two wheels produced a total of 95 colors with 60 usable. As revolutionary as the VL1 was it lacked beam edge control and could only produce a hard edge beam pattern using a Plano-convex Lens. The Model 1 also had remotely controlled pan and tilt. These features were controlled using a proprietary moving light console that made use of their proprietary data signal to control 96 fixtures.

Highend Intellabeam

While there have been many refinements to the concept of moving heads with or without a upper enclosure, there is also one other notable difference in the family tree of moving lights. This is the concept of a moving mirror to facilitate the change in focus that a lamp may have. Moving mirror fixtures make use of the same features that a moving head contains, but substitutes the mirror in place of pan and tilt. These types of fixtures were the first to use the rotating gobo as an included effect.

Moving lights were revolutionary due to their use of remote control of Pan/Tilt, Color, Beam modification and intensity. These same features using this simple definition are essential in defining current stare of the art Moving lights by manufactures such as Vari*Lite, Highend and Martin, which are the three manufacture that we see on most job sites.

While moving lights added to the creative palette available to lighting designers they also drove the need for additional board channels/ DMX channels. While a proprietary console designed for moving lights had a finite number of control channels available. The lack of control channels was not apparent due to their specialized lighting control function. However when their control was merged into a conventional lighting console the lack of control channels became acute. In order to accommodate moving lights on conventional lighting consoles the need arose to develop the concept of DMX universes to satisfy the need of forever expanding control of features

Following is an overview of different lights and their features, along with technical aspects of each light:

Highend Moving Lights

Studio Color, note the Fresnel Lens

Studio Spot, not the PC lens

Electrical Specifications

Studio Color MSR or MSD 575-S Automatic voltage selection
Studio Spot MSR or MSD 575-2 Automatic voltage selection

Rated Voltage:	100-230 VAC
Rated Frequency:	50/60 Hz
Rated Current:	7.0 A @ 100 V/60 Hz
	3.0 A @ 230 V/50 Hz
Rated power	700 W max

Studio Color 575-M MSR or MSD
Lamp Magnetic Ballast

Rated Voltage:	208/230 VAC
Rated Frequency:	50/60 Hz
Rated Current:	3.2 A @ 208 V/60 Hz
	3.0 A @ 230 V/50 Hz
Rated power	700 W max

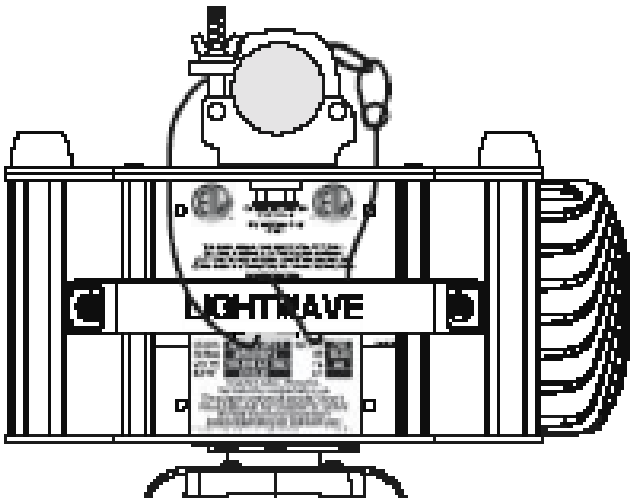
Studio Color 575-S 57 lbs
575-M 67.5 lbs (differing weight is due to different power supply type)
Studio Spot weight 59 lbs

Voltage	Fixtures per 20 Amp Breaker
100	2
110	3
200-208	5
220-240	6

*Note that it is possible to plug in the quantity to the left. Often each fixture will receive its own plug. This it to isolate a failure to one lamp and not to all that are plugged into a single circuit.

Selected Studio Color Features:
DMX 512 control protocol
Subtractive color mixing system plus six position fixed color wheel
Partial colors, color spins, synchronized color sequence, and random color sequences are available for effects
8-22 selectable beam angle that may be further shaped to variable horizontal or vertical positioning
Variable frost
Optional Par type lenses are available in VNSP, NSP, WFL and XWFL
Iris Dimming
Shutter for instant blackout, strobe effects and random strobe effects.
Lamp power reduction

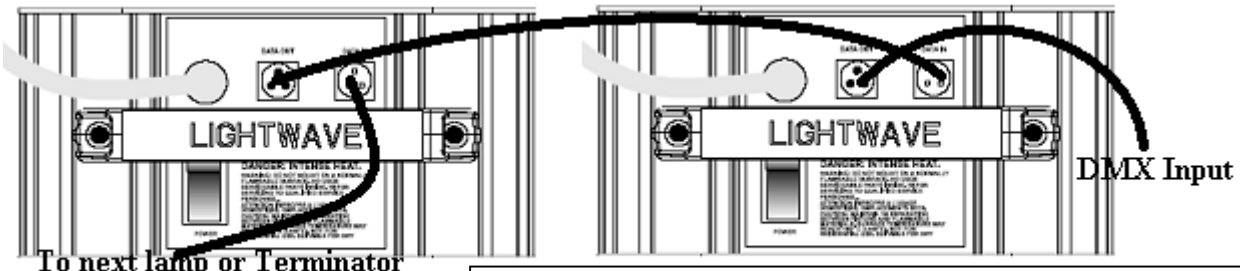
Selected Studio Spot Features:
DMX 512 control protocol
Two color wheels support five dichroic glass filters plus open. Other colors may be achieved through custom color filters being installed. Colors are interchangeable with Studio Color and Cyberlight.
35 Rotating Lithos and effect, plus tow open each with independent control. These are interchangeable with Technobeam, Technopro and Technoray fixtures.
Variable frost to define a hard edge or soft that may be used as an effect.
Dimming is achieved through a mechanical dimmer
Beam Iris to manipulate the beam diameter.
Lenses are interchangeable between an 18, 13 and 30 field that may be remotely controlled for either litho or effect wheel focus.
Power saving mode that decreases the wattage of the lamp and automatically goes to full from stand-by mode.



Drawing for locating truss mounting hardware and saftey

Fixture Mounting
Mounting of the fixtures may be achieved by using the four rubber feet for floor mounting. Or using clamps for truss or mounting on other pipe like structures. When mounting to a truss or other round structure the center holes are used to mount the clamps. The other holes are used for the attachment of two safeties, which are also looped through the handles on both sides of the fixture. See the illustration for clarification.

Data Connection of Fixtures
Connection of 21 fixtures is per DMX daisey chain is possible. When doing this the Data in and out ports will be used. At the end of the daisy chain a termination connector is necessary to prevent data being re-broadcast through the control lines.



DMX Daisy Chain, using input from first lamp and outputs until the last unit, which has a terminator installed

Lamp Installation Studio Color/ Spot

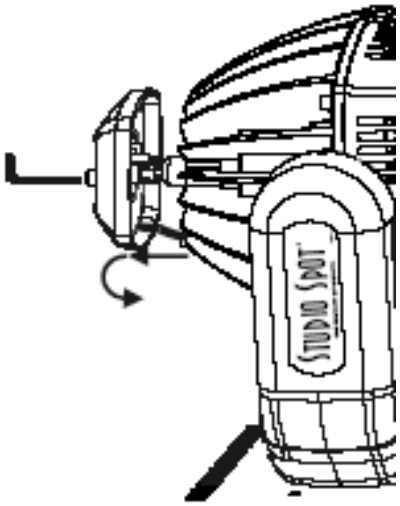
You will need the following items to install or replace the lamp:
¼" inch hex wrench
Phillips MSR 575/2 MSD 575 or factor apporved lamp or other factory approved GX 9.5 base 575 watt meatal-halide lamp. The 575/2 6200 Kand MSD 575 5600K burn at different color temperatures
Protective gloves.
Protective goggles.

To install or replace the lamp, use the following procedures:

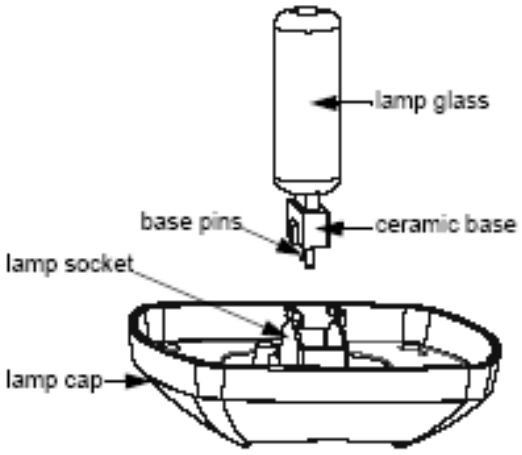
1. Remove power from fixture. If the fixture has been in operation, allow it to cool for at lest five minutes before continuing.
2. Using the ¼ inch hex wrench, loosen the hex screws located at the rear of the fixture and remove the lamp acces cover. Refer to the drawing below.
3. Remove old lamp from the socket by the lamp base and check the lamp socket for any arching.
4. Holding the lamp by its base align the lamp leads/ base to the socket and carefully push the lamp into the socket. Refer to the drawing below.

Warning: If the lamp is touched with bare fingers, clean with a soft cloth and isopropyl alchol or the cleaning tollett provided with the lamps.

5. Place the lamp assembly back into the housing and tighten the hex screws, being <u>carefull not to overtighten.</u>
6. Remember to reset the lamp hours clock on the fixture.



Lamp access cover removal.



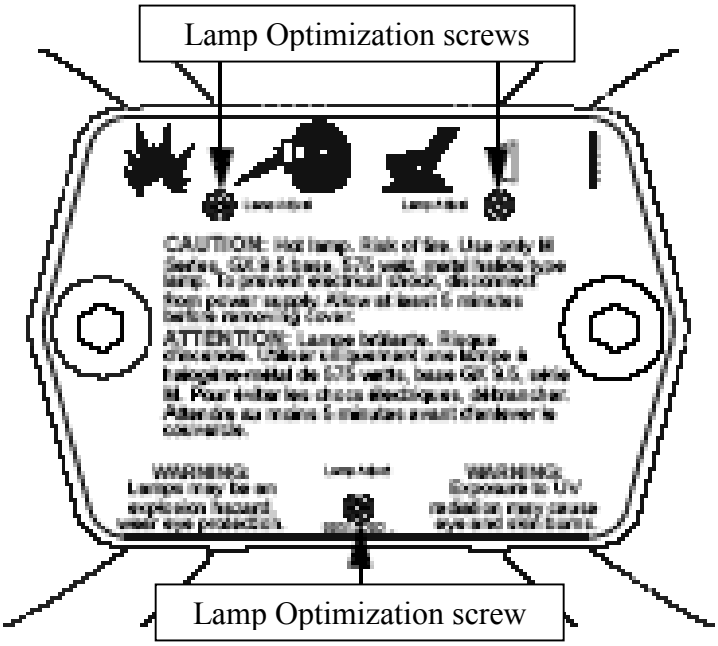
Replaceing the lamp in the socket

Once the lamp is installed, it will need to be optimized or bench focus to ensure a flat field across the entire beam diameter projected.

- Obviously a place to mount or set the fixture.
- A # 2 phillips screw driver
- Smooth white surface to project the beam onto.

Optimimzin the Lamp

Mount the fixture in an orientation so that it may be squarely projected onto a smooth white surface no less than 10 feet away.
Using a control or the menu system, focus an open white beam onto the surface and observe the beam.
Using a #2 phillips-head screw driver, rotate the trhee lamp adjust screws until you achieve a uniform flat field. Refer to the figure below to find the screws to turn. When this is completed the field will have an even disbursment of light over the entire beam diameter, Much like the leko examples previously.



Setting the Starting Channel by DMX Channel or by Fixture Number

1. Hold <MENU> until the display changes to **AddR**
2. Using the upa nd down buttons, scroll donw to the **SET** field and press <ENTER>
3. Using the up and down buttons, scroll down to the **CHNL** field and press <ENTER>.
4. Using the up and down buttons, select either **AddR** (fixture number) or **dmx** (DMX channel) and press <ENTER>.

Setting Fixtures Starting Channel

1. Hold <MENU> until the display changes to **AddR.** Press <ENTER> to edit the address field.
2. Using the up and down buttons, set a starting channel. The display will flash when the value is different fromt the stored value.
3. Press <ENTER> to store the appropriate channel. The display will stop flashing.

Fixture #	DMX Starting Channel	Fixture #	DMX Starting Channel	Fixture #	DMX Starting Channel
1	1	8	169	15	337
2	25	9	193	16	361
3	49	10	217	17	385
4	73	11	241	18	409
5	97	12	265	19	433
6	121	13	289	20	457
7	145	14	313	21	481

Note: if <ENTER> is not pressed the unit will not store the channel

Note: if an incorrect address is given, channels could overlap and produce erratic results.

Setting the Display output

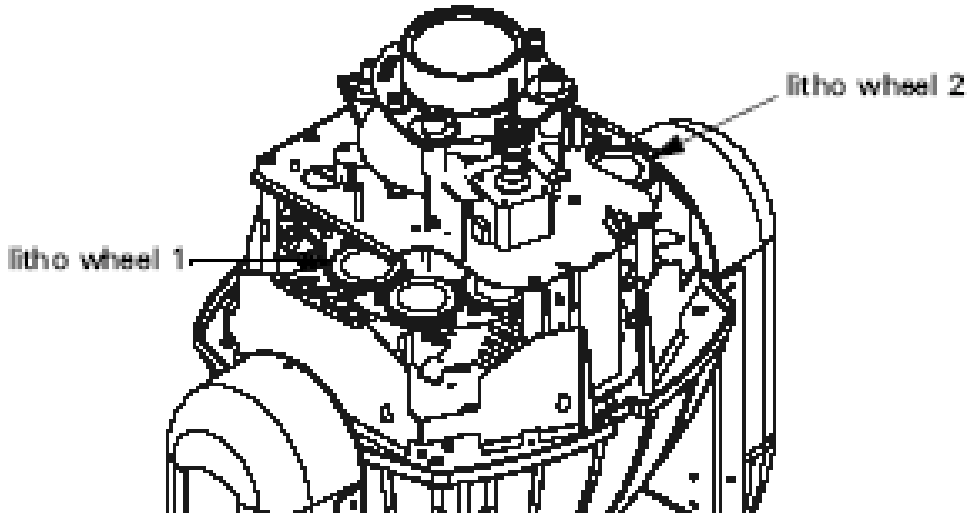
1. Hold <MENU> until the display changed to **AddR**.
2. Using the up and down buttons, scroll down to the **SET** field and press <ENTER>.
3. Using the up and down buttons, scroll down to the **dSPL** field and press<ENTER>.

Using the up and down button, select either **ON/ OFF** or **dIM** and press <ENTER>.

Studio Spot LithoPattern and Effect Installation

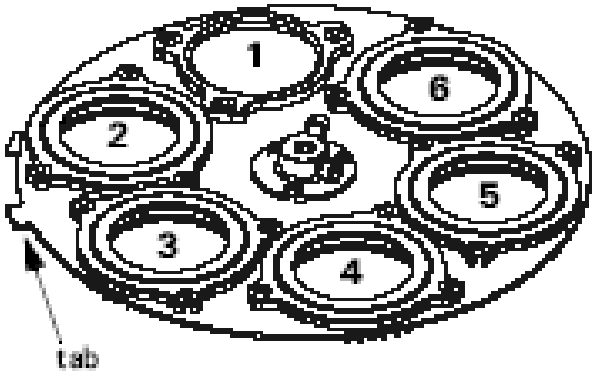
To install LithPatterns, gobos, or effects, complete the following procedure:

1. Remove power from the fixture and place it upright on a flat surface.
2. Remove the bezel (nose cover) by releasing the two latches located in the middle of the fixture head.
3. Remove the safety cable from its latch and set the bezel aside.
4. Locate the litho wheels. Refer to picture below:



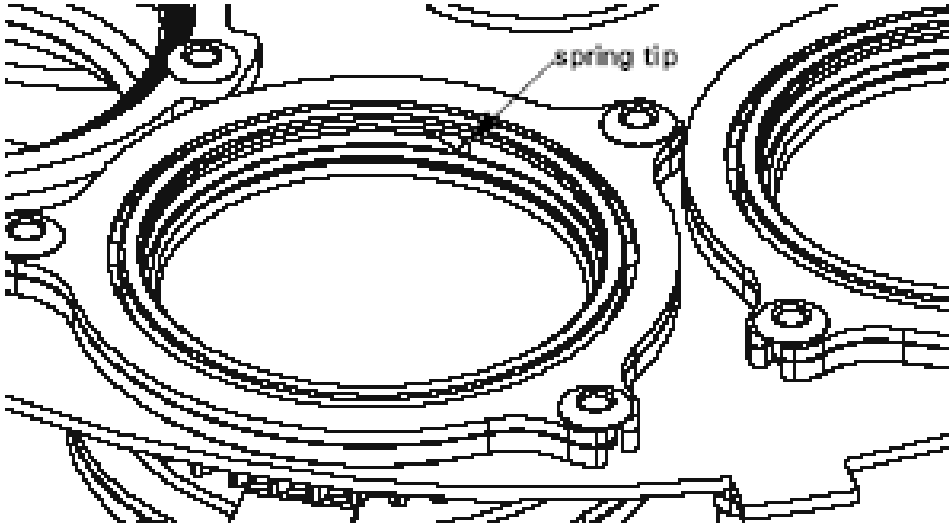
Locating the Litho/ Effect Wheel

5. Rotate the desired wheel to the litho or effect you want to replace. Take note of the position in relation to the tabs. Refer to picture below:



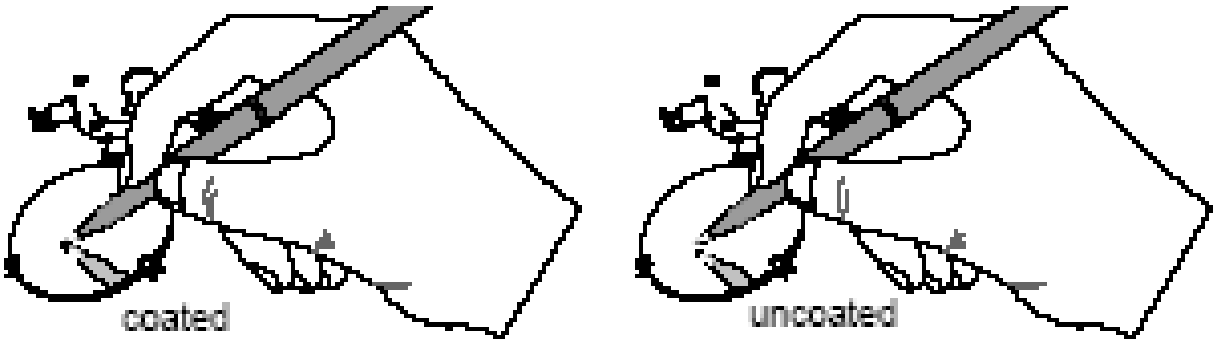
Factory Litho Wheel Positons

6. Locate the spring securing the litho or effect to the wheel. Pull the spring tip toward the center of the aperture. Refer to picture below. The spring will release from is groove inside the aperture.



Removing Securing Spring

7. Remove the spring and litho/effect fro the aperture.
8. Place the new lith, effect or gobo into the aperture and replace the spring. If you are installing a lith, insert it with **the coated side away from the lamp.** To determine the coated side refer to drawing. However, if you are installing an effect, insert it with the smooth side toward the wheel.



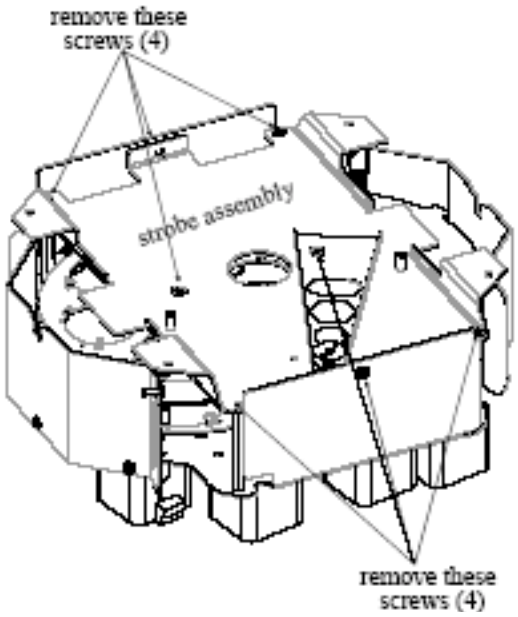
Place an object near the surface, the reflection will appear to touch the object on the coated side.

The need may arise to change the gobos/ effects as already outlined and assist in changing dichroic filters. Whose instructions are to follow. Prior to changing any dichroic filters make sure you look at how to tell the difference from front and back as seen above. Following is the procedure for the Studio Spot/ Color

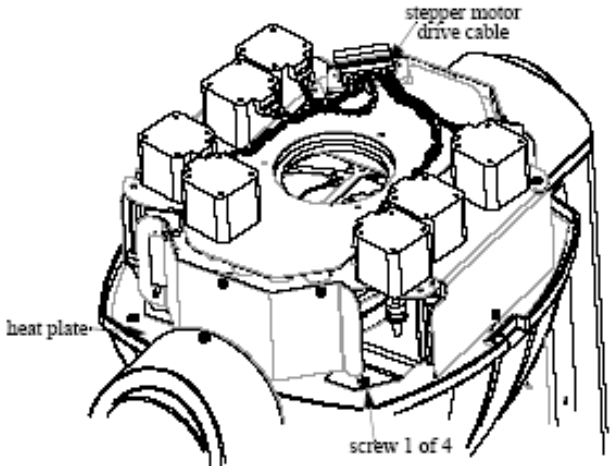
Changing dichroic filters

1. Remove power from fixture and place on flat surface
2. Remove the bezel by releasing the two latches and release the safety cable for the bezel.
3. Disconnect the stepper motor drive cable from its connector.

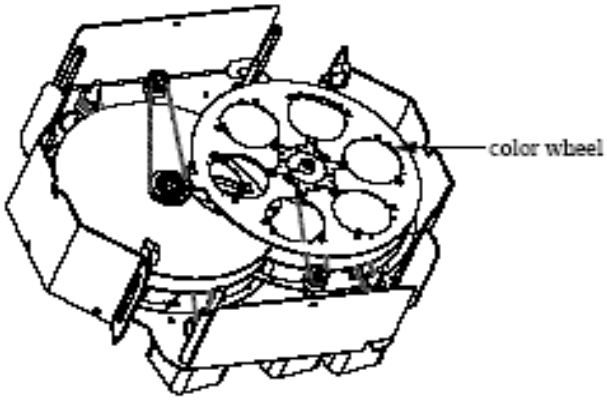
4. Using a Phillips-head screwdriver, remove the four screws holding the optical assembly to the heat plat and remove the assembly.
5. Turn the optical assembly over so that the stepper motors are resting on the table
6. Remove the six screws holding the strobe plate to its standoffs.



Strobe Plate Removal

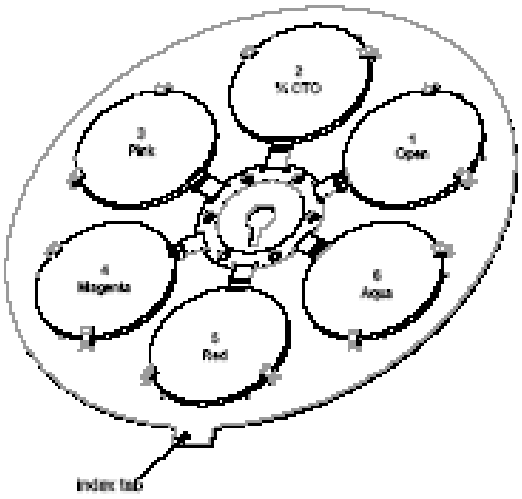


Stepper Drive Cable Removal and Heat Plate



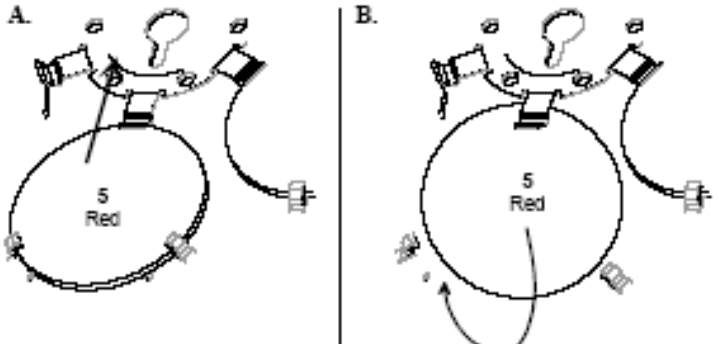
Color Wheel Location after Strobe Plate Removal

7. Remove the two screws securing the L-brackets to the sides of the optical assembly
8. Lift the strobe assembly straight up and away from the remaining optical assembly
9. Take special note of the index position on the color wheel.



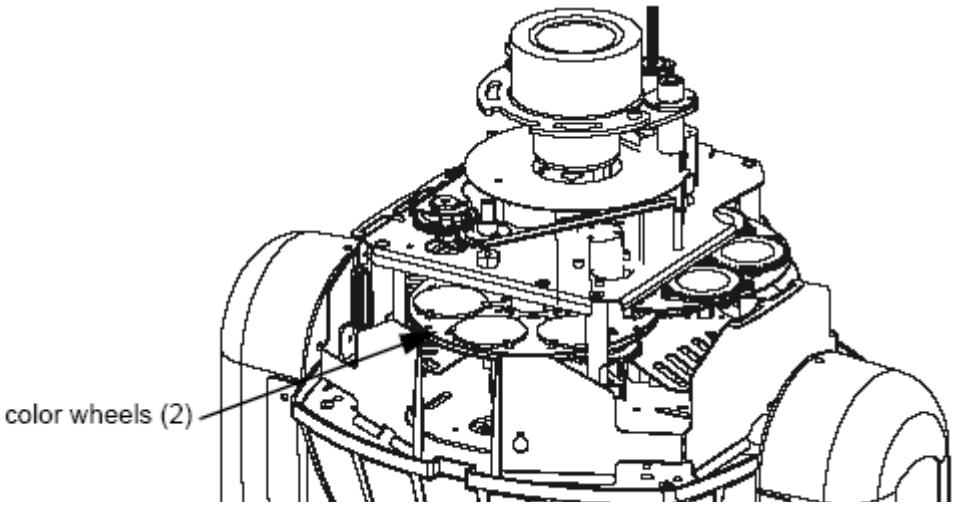
Color Wheel with Factory Index Tab

10. Gently push the glass toward the spindle in the center of the color wheel, (A) lift the edge away from the spindle (B) and remove the glass.



Removing the Dichroic Glass

11. Using the above steps reverse, install the new dichroic into the color wheel with the coated side down (towards the Lamp).
12. Assemble using the above steps in reverse order.

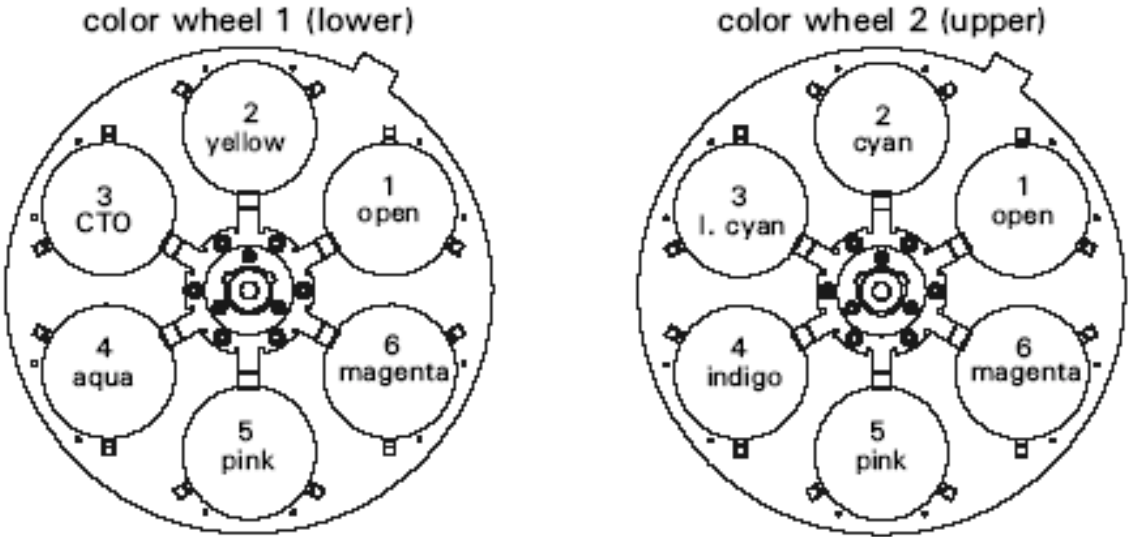


After following steps 1 and 2 the Studio Spot will look like this.

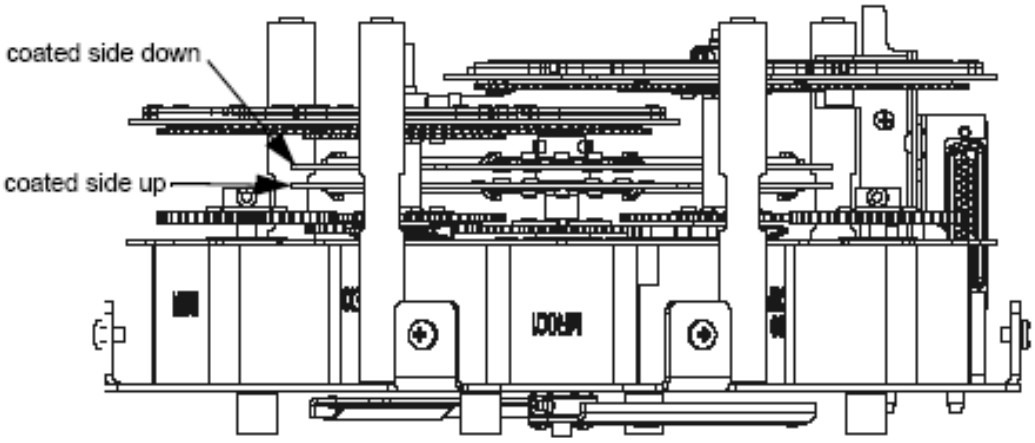
Studio Spot Dichroics
After following the first two steps the Studio Spot will resemble the lamp to the left.

9a. Rotate the desired color wheel so that the color you wish to replace is accessible from the edge and roatae the opposing color wheel so that its open poition is at the edge. Take special note of the index positons on the color wheel.

11a. Use those instructions to replace the dichroic filters.



Factroy installed dichroic filters and Index Positions on each wheel.



Note orintation of dichroic filters in bulkhead.

Often times moving lights will have self-Tests that may performed on themselves. Following are the steps necessary to access these on both the Studio Color/ Spot.

Self-Tests

For a comprehensive list of test refer to either manuel. The following are the button strokes to access these on either type of light. The Studio Spot has an additional two to access these, so complete all five when working on this light, Studio Color has one less, skip step 3. To begin the tests:

1. Hold <Menu> until the display changes to AddR.
2. Using the up and down buttons, scroll to the TEST field and press <ENTER>.
3. Using the up and down buttons, scroll to the SELF field and press <ENTER >.
4. Using the up and down buttons, scroll to the desired test and press < ENTER >. The fixture will perform the desired tests.

To exit the sets in progress, press to invert or swap the pan and tilt functions. This depends on the hanging position or if the fixture is located on the stage. As a floor light you may need to invert the Pan and Tilt. By doing this the Pan and Tilt encoders will only need to turned in one direction instead of remembering the fixtures orientation and its affect on the fixture. Or when they are mounted sideways the pan and tilt may be swapped. Following are the excerpts on how to do this.

Inverting Pan and Tilt

When fixtures are mounted on the floor (upside down), the pan and tilt can be inverted.

1. Hold < Menu > until the display changed to AddR.
2. Using the up and down buttons, scroll to the SET filed and press <ENTER >.
3. Using the up and down buttons, scroll to the "T" for tilts or "P" for pan field and press <ENTER >.
4. Using the up and down buttons, select either ON or OFF and press <ENTER >.

Swapping Pan and Tilt

When fixtures are mounted sideways, swap the pan and tilt functions.

1. Hold < Menu > until the display changed to AddR.
2. Using the up and down buttons, scroll to the SET filed and press <ENTER >.
3. Using the up and down buttons, scroll to the SWAP filed and press the <ENTER >.
4. Using the up and down buttons select either ON or OFF and press <ENTER >.

Excerpts from Studio Spot Menu system:
Studio Spot:

Table 3.1: Menu Map

Level 1	*Level 2*	*Level 3*	*Level 4*	*Level 5*	*Description*
AddR					address main menu
	F 01 - F 21 or C001 – C512				sets fixture address by fixture number or DMX start channel
INFO					information main menu
INFO	LAMP				lamp status
INFO	L/HR				lamp hours and minutes
INFO	L/ST				lamp strikes
INFO	VER				software version
INFO	L/RS				lamp reset menu
INFO	L/RS	REPR			resets lamp hours and strikes
INFO	F/HR				total hours and minutes the fixture has been on
INFO	F/RS				fixture reset menu
INFO	F/RS	REPR			resets fixture hours
INFO	TEMP				temperature menus (in degrees C)
INFO	TEMP	CURR			current internal temperature
INFO	TEMP	MINT			minimum internal temperature
INFO	TEMP	MAXT			maximum internal temperature
INFO	TEMP	RST			reset temperature
INFO	dMX				DMX value menu
INFO	dMX	FIXT			fixture menu
INFO	dMX	FIXT	ERRS		DMX errors
INFO	dMX	FIXT	CNTL		control channel value
INFO	dMX	FIXT	MACR		macro value
INFO	dMX	FIXT	MSPd		MSpeed value
INFO	dMX	FIXT	dIM		dim value

Table 3.1: Menu Map *(Continued)*

Level 1	*Level 2*	*Level 3*	*Level 4*	*Level 5*	*Description*
INFO	dMX	FIXT	SHUT		shutter value
INFO	dMX	FIXT	IRIS		iris value
INFO	dMX	FIXT	FCUS		focus value
INFO	dMX	FIXT	FRST		frost value
INFO	dMX	FIXT	LR2L		litho wheel 2 rotational value (low byte)
INFO	dMX	FIXT	LR2H		litho wheel 2 rotational value (high byte)
INFO	dMX	FIXT	LT2		litho wheel 2 aperture position value
INFO	dMX	FIXT	LTC2		litho wheel 2 control (function) channel value
INFO	dMX	FIXT	LR1L		litho wheel 1 rotational value (low byte)
INFO	dMX	FIXT	LR1H		litho wheel 1 rotational value (high byte)
INFO	dMX	FIXT	LT1		litho wheel 1 aperture position value
INFO	dMX	FIXT	LTC1		litho wheel 1 control (function) channel value
INFO	dMX	FIXT	CO2		color wheel 2 position value
INFO	dMX	FIXT	CO2C		color wheel 2 control (function) channel value
INFO	dMX	FIXT	CO1		color wheel 1 position value
INFO	dMX	FIXT	CO1C		color wheel 1 control (function) channel value
INFO	dMX	FIXT	TLTL		tilt value (low byte)
INFO	dMX	FIXT	TLTH		tilt value (high byte)
INFO	dMX	FIXT	PRNL		pan value (low byte)
INFO	dMX	FIXT	PRNH		pan value (high byte)
INFO	dMX	FIXT	STRT		start code
INFO	dMX	FIXT	OV		overrun errors
INFO	dMX	FIXT	FE		framing errors

Table 3.1: Menu Map *(Continued)*

Level 1	*Level 2*	*Level 3*	*Level 4*	*Level 5*	*Description*
INFO	dMX	FIXT	SRCE		indicates the data source values in the FIXT submenu
INFO	dMX	dATA			data menu
INFO	dMX	dATA	C001 - C512		views data on the selected DMX channel
INFO	SENS				sensor menu
INFO	SENS	PPOS			checks the pan position from the encoder
INFO	SENS	TPOS			checks the tilt position from the encoder
INFO	SENS	SENP			checks for pan homing tab on the sensor
INFO	SENS	SENT			checks for tilt homing tab on the sensor
INFO	SENS	COL			checks for color wheel homing tabs on the sensor (homed)
INFO	SENS	LT1			checks for litho wheel 1 homing tab on the sensor (homed)
INFO	SENS	LT2			checks for the litho wheel 2 homing tab on the sensor
INFO	SENS	SVCC			sensor power

General Troubleshooting

Use the following table to troubleshoot problems that are not identified by the menu system.

Table A.2: General Troubleshooting

Problem	*Probable Cause*	*Solution*
Unit will not turn on	• no power • breaker is turned off • power connectors • power line filter	• connect power • turn breaker on • refer to qualified technician • refer to qualified technician
Unit functions but lamp does not strike	• bad lamp • lamp is too hot from operation (unit turned off and on) • ignitor connection is loose	• replace lamp • leave the unit turned on, when the lamp's temperature drops, it will restrike • refer to qualified technician
Lamp is dimmer than other units	• bad lamp • dirty optics	• replace lamp • dirty optics
Unit will not home properly	• belt(s) is loose • bad sensor(s)	• tighten belt(s) • refer to qualified technician
Color system is not producing the correct color	• unit is not homed properly	• home the unit
Pan or tilt position is off	• unit is not homed properly • belt tension too loose	• home the unit • tighten belt(s)
Unit is not responding to controller	• wrong fixture DMX address • bad data cable(s) • link not terminated	• set the address as outlined in "Address Menu" on page 3-14 • check and replace data cables as needed • terminate link as outlined in "Data Cabling" on page 1-9
Unit is producing unexpected results	• incorrect DMX starting address on the controller • last fixture is not terminated	• refer to "Setting the Fixture Address" on page 1-10 • terminate fixture
Display is not functioning	• display is turned off • power connectors are loose • bad logic board	• refer to "Setting Display Intensity" on page 3-25 • refer to qualified technician • refer to qualified technician

Menu Map

The following information is a complete map of the menu system.

ADDR -fixture address

INFO

- L/HR - lamp hours†
- L/ST - lamp strikes†
- VER - software version
- L/RS - resets lamp hours and lamp strikes†
- F/HR - fixture hours
- F/RS - resets fixture hours
- TEMP
  - CURR - current internal temperature
  - MINT - minimum internal temperature
  - MAXT - maximum internal temperature
  - RST - reset temperature
- DMX
  - FIXT
    - ERRS - DMX errors
    - CSUM - checksum
    - CNTL - control value
    - MSPD - MSpeed value
    - DIM - dim value
    - SHUT - shutter value
    - FRST - frost wheel value
    - LENS - lens wheel value
    - CYAN - cyan wheel value
    - YELW - yellow wheel value
    - MAGN - magenta wheel value
    - CLR - color value
    - CLRF - color function value
    - TILT - tilt value
    - PAN - pan value

STRT - start code

CE - checksum errors

OV - overrun errors

FE - framing errors

#RTR

CH01 - CH12 - shows DMX data on the selected channel

CODE

SENP - pan sensor

TPOS - tilt position

PPOS - pan position

#UTY - encoder duty cycle

PCOR - pan or tilt corrections†

TIME - main loop time

5VCC - sensor power

SEN2 - sensor 2

SEN1 - sensor 1

SENT - tilt sensor

TEST

HOME - homes the fixture

S/UP - places the fixture in setup mode

SELF

ALL - runs through all self tests

#IN - test

SHUT - test

FRST - test

LENS - test

CYAN - test

YELW - test

MAGN - test

COLR - test

TILT - test

PAN - test

FUNC

F1 - reserved

F2 - reserved

F3 - reserved

BOOT - stores the new boot code into the Flash ROM

LAMP

STRT - lamp status†

LOFF - turns lamp off†

L ON - turns lamp on†

MODE

M1 - reserved

M2 - reserved

XLd - cross-loads fixture code

SET

FACT - sets factory defaults

CHNL

dMX - set the starting channel by DMX channel number

AddR - set the starting channel by fixture number

dSPL

ON - turns the display on

OFF - turns the display off

dIM - dims the display

P/IN - pan invert

T/IN - tilt invert

SWAP - swap pan and tilt

S/dN

5 MN - sets shutdown time for 5 minutes

10MN - sets shutdown time for 10 minutes

LAMP

575W - 575 watt setting

250W - 250 watt setting†

PCAL - pan calibration ±20 in .4° increments

TCAL - tilt calibration ±20 in .4° increments

†Note: *575-S model only.*

Studio Wash General Trouble Shooting:

Table A.2. General Troubleshooting

Problem	Probable Cause	Solution
Unit will not turn on	• no power • breaker is turned off • power connectors • power line filter	• connect power • turn breaker on • refer to qualified technician • refer to qualified technician
Unit functions but lamp does not strike	• bad lamp • incorrect voltage on the 575-M version • lamp is too hot from operation (unit turned off and on) • bad ballast • ignitor connection is loose	• replace lamp • provide correct power source or refer to qualified service technician to move power tap • leave the unit turned on, when the lamp's temperature drops, it will restrike • refer to qualified technician • refer to qualified technician
Lamp is dimmer than other units	• lamp is set for 250 watts • wrong voltage on 575-M version • bad lamp • different type of lamp	• set the lamp to 575 watts as outlined in "Setting the Lamp Power" on page 3-16 • provide correct power source or refer to qualified service technician to move power tap • replace lamp • replace lamp with identical type
Unit will not home properly	• belt(s) is loose • bad sensor(s)	• tighten belt(s) • refer to qualified technician
Color system is not producing the correct color	• unit is not homed properly	• home the unit
Pan or tilt position is off	• unit is not homed properly • belt tension too loose	• home the unit • tighten belt(s)

Table A.2. General Troubleshooting

Problem	Probable Cause	Solution
Unit is not responding to controller	• wrong fixture DMX address • bad data cable(s) • link not terminated	• set the address as outlined in "Address Menu" on page 3-5 • check and replace data cables as needed • terminate link as outlined in "Data Cabling" on page 1-11
Unit is producing unexpected results	• incorrect DMX starting address on the controller • last fixture is not terminated	• Refer to "DMX Starting Channel" on page 1-12 • terminate fixture
Display is not functioning	• display is turned off • power connectors are loose • bad logic board	• Refer to "Setting Display Output" on page 3-14 • refer to qualified technician • refer to qualified technician
Cracks have developed in the color mixing wheels- "stress relieving fissures"	• heat and natural expansion of the glass	• stress relieving fissures are normal and do not in any way degrade the functionality or the performance of the fixture

Studio Color and Spot DMX Channels:

DMX Control

Studio Color may be controlled by either by 8- or 16-bit DMX controllers. Use the following table to control Studio Color functions.

Table 1: DMX Control

Chan.	Function	Notes	DMX	Fader %
1	Pan MSB	*coarse positioning, 8 bit;8-bit controllers use only high byte*	0-255	0-100%
2	Pan LSB	*fine positioning*	0-255	0-100%
3	Tilt MSB	*coarse positioning, 8 bit;8-bit controllers use only high byte*	0-255	0-100%
4	Tilt LSB	*fine positioning*	0-255	0-100%
5	Color functions	*default- color wheel continuous* *F1- allows the color mixing wheels to make two complete rotations* *F2- locks all motors to MSpeed* *F3- forw. color spins/ color mix sequences* *F4- revs. color spins/ color mix random* *F5- color wheel color lock and quick path* default F3 F4 F5 F1 F1 and F3 F1 and F4 F1 and F5 F2 F2 and F3 F2 and F4 F2 and F5 F1 and F2 F1, F2, and F3 F1, F2, and F4 F1, F2, and F5	 0 16 32 48 64 80 96 112 128 144 160 176 192 208 224 240	 0% 8% 14% 20% 26% 33% 39% 45% 51% 58% 64% 70% 76% 83% 89% 95%

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Table 1: DMX Control

Chan.	Function	Notes	DMX	Fader %
6	Color wheel	*default- continuously variable* pos 0 - open pos 1 - CTO pos 2 - pink pos 3 - magenta pos 4 - red pos 5 - aqua *F3- variable forward spin/color sequences* spin stop spin forward slowest spin forward fastest color seq. slowest color seq. fastest *F4- variable reverse spin/color random* spin stop spin reverse slowest spin reverse fastest color random slowest color random fastest *F5- color lock and quickest path* pos 0 - open pos 1 - CTO pos 2 - pink pos 3 - magenta pos 4 - red pos 5 - aqua	 0 & 255 44 86 128 170 213 0-3 4 127 128 255 0-3 4 127 128 255 0-43 44-85 86-127 128-169 170-212 213-255	 0 & 100% 17% 34% 50% 66% 83% 0-1% 2% 48% 50% 100% 0-1% 2% 48% 50% 100% 0-17% 18-33% 34-50% 51-66% 67-83% 84-100%
7	Cyan mix	*red subtractive* cyan in cyan out	 0 255	 0% 100%
8	Magenta mix	*green subtractive* magenta in magenta out	 0 255	 0% 100%
9	Yellow mix	*blue subtractive* yellow in yellow out	 0 255	 0% 100%

Table 1: DMX Control

Chan.	Function	Notes	DMX	Fader %
10	Lens wheel	*Full rotation, continuously variable* open wide angle filter narrow horizontal shaping center axis wide vertical shaping center axis	 0 & 255 64 128 192	 0 & 100% 25% 50% 75%
11	Frost wheel	*full rotation, continuously variable* open frost narrow vertical shaping center axis wide horizontal shaping center axis	 0 & 255 64 128 192	 0 & 100% 25% 50% 75%
12	Shutter	closed strobe slow strobe fast random strobe-low saturation random strobe-high saturation open	0-7 8 127 128 247 248-255	0-2% 3% 49% 50% 96% 97-100%
13	Dim	closed open	0 255	0% 100%
14	MSpeed	*movement speed* controller cross-fade slowest fastest	 0-3 4 255	 0-1% 2% 100%
15	Control[2]	safe home shutdown[2]	0 64 128	0% 25% 50%
16	Check-sum	set to default value (00)	00	0%

[1]*Note: the shutter must be closed and the value sent for 0.5 seconds*
[2]*Note: available only on the 575-S.*

Studio Spot DMX Protocol

Chnl.	Function	Notes	DMX	Fader %
1	Pan MSB	Coarse	0-255	0-100
2	Pan LSB	Fine	0-255	0-100
3	Tilt MSB	Coarse	0-255	0-100
4	Tilt LSB	Fine	0-255	0-100
5	Color wheel 1 function	*Full speed*		
		Indexed	0-31	0-12
		Forward spin	32-47	13-18
		Reverse spin	48-63	16-24
		Continuous	64-79	25-30
		Fast scan	80-87	31-33
		Slow scan	88-95	34-37
		Random	96-111	37-43
		Blink-indexed	112-127	44-49
		MSpeed		
		Indexed	128-159	50-62
		Forward spin	160-175	63-68
		Reverse spin	176-191	69-74
		Continuous	192-207	75-80
		Fast scan	208-215	81-83
		Slow scan	216-223	84-87
		Random	224-239	88-93
		Blink-indexed	240-255	94-100
6	Color wheel 1 position	*Indexed*		
		Color 1	0-19	0-7
		Color 1 and 2	20-39	8-15
		Color 2	40-59	16-23
		Color 2 and 3	60-78	24-30
		Color 3	79-98	31-38
		Color 3 and 4	99-118	39-46
		Color 4	119-137	47-53
		Color 4 and 5	138-157	54-61
		Color 5	158-177	62-69
		Color 5 and 6	178-196	70-76
		Color 6	197-216	77-84
		Color 6 and 1	217-236	85-92
		Color 1	237-255	93-100
		Continuous		
		Color 1	0	0
		Color 2	43	16
		Color 3	85	33
		Color 4	128	50
		Color 5	170	66
		Color 6	213	83
		Color 1	255	100

Studio Spot DMX Protocol

Chnl.	Function	Notes	DMX	Fader %
6 cont.	Color wheel 1 position	*Forward spin*		
		Spin stop	0-3	0-1
		Spin slowest	4	2
		Spin fastest	255	100
		Reverse spin		
		Spin stop	0-3	0-1
		Spin slowest	4	2
		Spin fastest	255	100
		Random		
		Stop	0-3	0-1
		Slowest	4	2
		Fastest	255	100
		Combined		
		Color 1	0-6	0-2
		Color 2	7-13	3-5
		Color 3	14-20	6-7
		Color 4	21-27	8-10
		Color 5	28-34	11-13
		Color 6	35-41	14-16
		Color 7	42-47	17-18
		Color 8	48-54	19-21
		Color 9	55-61	22-23
		Color 10	62-68	24-26
		Color 11	69-75	27-29
		Color 12	76-82	30-32
		Color 13	83-89	33-34
		Color 14	90-96	35-37
		Color 15	97-103	38-40
		Color 16	104-110	41-42
		Color 17	111-117	43-45
		Color 18	118-124	46-48
		Color 19	125-130	49-50
		Color 20	131-137	51-53
		Color 21	138-144	54-56
		Color 22	145-151	57-58
		Color 23	152-158	59-61
		Color 24	159-165	61-64
		Color 25	166-172	65-67
		Color 26	173-179	68-69
		Color 27	180-186	70-72
		Color 28	187-193	73-75
		Color 29	194-200	76-78
		Color 30	201-207	79-80
		Color 31	208-213	81-83
		Color 32	214-220	84-85
		Color 33	221-227	86-88
		Color 34	228-234	89-91
		Color 35	235-241	92-94
		Color 36	242-248	95-96
		Color 1	249-255	97-100

Studio Spot DMX Protocol

Chnl.	Function	Notes	DMX	Fader %
6 cont.	Color 1 wheel position	*Combined continuous*		
		Color 1	0	0
		Color 2	8	3
		Color 3	15	5
		Color 4	22	8
		Color 5	29	11
		Color 6	36	14
		Color 7	43	16
		Color 8	50	19
		Color 9	57	22
		Color 10	64	25
		Color 11	72	28
		Color 12	79	30
		Color 13	86	33
		Color 14	93	36
		Color 15	100	39
		Color 16	107	41
		Color 17	114	44
		Color 18	121	47
		Color 19	128	50
		Color 20	136	53
		Color 21	143	55
		Color 22	150	58
		Color 23	157	61
		Color 24	164	64
		Color 25	171	66
		Color 26	178	69
		Color 27	185	72
		Color 28	193	75
		Color 29	200	78
		Color 30	207	80
		Color 31	214	83
		Color 32	221	86
		Color 33	228	89
		Color 34	235	91
		Color 35	242	94
		Color 36	249	97
7	Color wheel 2 function	*Full Speed*		
		Combined	0-15	0-5
		Indexed	16-31	6-12
		Forward spin	32-47	13-18
		Reverse spin	48-63	16-24
		Continuous	64-79	25-30
		Fast scan	80-87	31-33
		Slow scan	88-95	34-37
		Random	96-111	37-43
		Blink-indexed	112-127	44-49

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Studio Spot DMX Protocol

Chnl.	Function	Notes	DMX	Fader %
7 cont.	Color wheel 2 function	*MSpeed*		
		Indexed	128-159	50-62
		Forward spin	160-175	63-68
		Reverse spin	176-191	69-74
		Continuous	192-207	75-80
		Fast scan	208-215	81-83
		Slow scan	216-223	84-87
		Random	224-239	88-93
		Blink-indexed	240-255	94-100
8	Color wheel 2 position	*Indexed*		
		Color 1	0-19	0-7
		Color 1/2	20-39	8-15
		Color 2	40-59	16-23
		Color 2/3	60-78	24-30
		Color 3	79-98	31-38
		Color 3/4	99-118	39-46
		Color 4	119-137	47-53
		Color 4/5	138-157	54-61
		Color 5	158-177	62-69
		Color 5/6	178-196	70-76
		Color 6	197-216	77-84
		Color 6/1	217-236	85-92
		Color 1	237-255	93-100
		Continuous		
		Color 1	0	0
		Color 2	43	16
		Color 3	85	33
		Color 4	128	50
		Color 5	170	66
		Color 6	213	83
		Color 1	255	100
		Forward spin		
		Spin stop	0-3	0-1
		Spin slowest	4	2
		Spin fastest	255	100
		Reverse spin		
		Spin stop	0-3	0-1
		Spin slowest	4	2
		Spin fastest	255	100
		Random		
		Stop	0-3	0-1
		Slowest	4	2
		Fastest	255	100
9	Litho wheel 1 function	*Full speed*		
		Indexed	0-15	0-5
		Forward rotate	16-31	6-12
		Reverse rotate	32-47	13-18
		Wheel spin	48-63	19-24
		Scan	64-79	25-30
		Random	80-95	31-37
		Blink wheel	96-111	38-42
		Blink aperture	112-127	43-49

Studio Spot DMX Protocol

Chnl.	Function	Notes	DMX	Fader %
9 cont.	Litho wheel 1 function	*MSpeed*		
		Indexed	128-143	50-55
		Forward rotate	144-159	56-62
		Reverse rotate	160-175	63-68
		Wheel spin	176-191	69-74
		Scan	192-207	75-80
		Random	208-223	81-87
		Blink wheel	224-239	88-93
		Blink aperture	240-255	94-100
10	Litho wheel 1 position	Position 0	0-36	0-14
		Position 1	37-73	15-28
		Position 2	74-109	29-42
		Position 3	110-146	43-57
		Position 4	147-182	58-71
		Position 5	183-219	72-85
		Position 0	220-255	86-100
11	Litho wheel 1 rotation high	*Indexed mode*	0-255	0-100
		Forward rotate		
		Stop	0-3	0-1
		Slowest	4	2
		Fastest	225	100
		Reverse rotate		
		Stop	0-3	0-1
		Slowest	4	2
		Fastest	225	100
		Cont. spin		
		Fastest forward	0	0
		Slowest forward	127	49
		Slowest reverse	128	50
		Fastest reverse	255	100
		Scan mode		
		Slowest	0	0
		Fastest	255	100
		Random mode		
		Stop	0-3	0-1
		Slowest	4	2
		Fastest	255	100
12	Litho wheel 1 rot. low	*Indexed mode*	0-255	0-100
13	Litho wheel 2 function	*Full speed*		
		Indexed	0-15	0-5
		Forward rotate	16-31	6-12
		Reverse rotate	32-47	13-18
		Wheel spin	48-63	19-24
		Scan	64-79	25-30
		Random	80-95	31-37
		Blink wheel	96-111	38-42
		Blink aperture	112-127	43-49

Studio Spot DMX Protocol

Chnl.	Function	Notes	DMX	Fader %
13 cont.	Litho wheel 2 function	*MSpeed*		
		Indexed	128-143	50-55
		Forward rotate	144-159	56-62
		Reverse rotate	160-175	63-68
		Wheel spin	176-191	69-74
		Scan	192-207	75-80
		Random	208-223	81-87
		Blink wheel	224-239	88-93
		Blink aperture	240-255	94-100
14	Litho wheel 2 position	Position 0	0-36	0-14
		Position 1	37-73	15-28
		Position 2	74-109	29-42
		Position 3	110-146	43-57
		Position 4	147-182	58-71
		Position 5	183-219	72-85
		Position 0	220-255	86-100
15	Litho wheel 2 rotation high	*Indexed mode*	0-255	0-100
		Forward rotate		
		Stop	0-3	0-1
		Slowest	4	2
		Fastest	225	100
		Reverse rotate		
		Stop	0-3	0-1
		Slowest	4	2
		Fastest	225	100
		Cont. spin		
		Fastest forward	0	0
		Slowest forward	127	49
		Slowest reverse	128	50
		Fastest reverse	255	100
		Scan mode		
		Slowest	0	0
		Fastest	255	10
		Random mode		
		Stop	0-3	0-1
		Slowest	4	2
		Fastest	255	100
16	Litho wheel 2 rot. low	*Indexed mode*	0-255	0-100
17	Frost	No frost	0	0
		Variable frost	1-127	1-49
		Full frost	128-143	50-55
		Periodic strobes	144-159	56-62
		Random strobes	160-175	63-68
		Ramp/snap	176-191	69-74
		Snap/ramp	192-207	75-80
		Ran. ramp/snap	208-223	81-87
		Ran. snap/ramp	224-239	88-93
		Open	240-255	94-100
18	Focus	Focus closer	0	0
		Focus farther	255	100

Chnl.	Function	Notes	DMX	Fader %
19	Iris	Closed	0	0
		Variable	1-127	1-49
		Open	128-143	50-55
		Periodic strobes	144-159	56-62
		Random strobes	160-175	63-68
		Ramp/snap	176-191	69-74
		Snap/ramp	192-207	75-80
		Ran. ramp/snap	208-223	81-87
		Ran. snap/ramp	224-239	88-93
		Open	240-255	94-100
20	Shutter	Closed	0-31	0-12
		Periodic strobes	32-63	13-24
		Random strobes	64-95	25-37
		Ramp/snap	96-127	38-49
		Snap/ramp	128-159	50-62
		Ran. ramp/snap	160-191	63-74
		Ran. snap/ramp	192-223	75-87
		Open	224-255	88-100
21	Dim	Closed	0	0
		Open	255	100
22	MSpeed	Controller xfade	0-3	0-1
		longest (252.7)	4	2
		shortest (0.15)	255	100

Chnl.	Function	Notes	DMX	Fader %
23	Macros	No macro	0-7	0-2
		Macro 1	8-15	3-5
		Macro 2	16-23	6-9
		Macro 3	24-31	10-12
		Macro 4	32-39	13-15
		Macro 5	40-47	16-18
		Macro 6	48-55	19-21
		Macro 7	56-63	22-24
		Macro 8	64-71	25-27
		Macro 9	72-79	28-30
		Macro 10	80-87	31-34
		Macro 11	88-95	35-37
		Macro 12	96-103	38-40
		Macro 13	104-111	41-43
		Macro 14	112-119	44-46
		Macro 15	120-127	47-49
		Macro 16	128-135	50-52
		Macro 17	136-143	53-55
		Macro 18	144-151	56-59
		Macro 19	152-159	60-62
		Macro 20	160-167	63-65
		Macro 21	168-175	66-68
		Macro 22	176-183	69-71
		Macro 23	184-191	72-74
		Macro 24	192-199	75-77
		Macro 25	200-207	78-80
		Macro 26	208-215	81-84
		Variable random	216-247	85-96
		No macro	248-255	97-100

Chnl.	Function	Notes	DMX	Fader %
24	Control'	Safe	0-9	0-3
		Pan/tilt MSpd. off	10-19	4-7
		Display off	20-28	8-11
		Display dim	30-38	12-14
		Display bright	40-48	15-18
		Home	60-68	23-26
		Lamp on	80-88	31-34
		Lamp off	90-98	35-38
		Shutdown	120-130	46-50
		Reserved	131-255	51-100

Mac 2k Profile/ Spot

Fuses

The MAC 2000 profile II comes with two: 20 AT time delay main fuses for use with AC supplies of 15 Amp main fuses for use with Ac supplies of 200-250 volts.

SPECIFICATIONS

PHYSICAL

Length:	408 mm (16.0 in)
Width:	490 mm (19.3 in)
Height:	743 mm (29.3 in)
Weight, w/ electronic ballast:	40 kg (89 lbs)
Weight, w/ magnetic ballast:	47 kg (103 lbs)

SOURCE

Lamp:	1200 W short arc discharge
Base:	Double-ended SFc 10-4 with key
Approved models:	Osram HMI 1200 W/S Short-Arc
Control:	automatic and remote, hot re-strike w/ electronic ballast

THERMAL

Maximum ambient temperature (Ta):	40° C (104° F)

CONTROL AND PROGRAMMING

Protocol:	USITT DMX-512 (1990)
Receiver:	Opto-isolated RS-485
Control channels:	20 or 24
Data I/O:	locking 3-pin & 5-pin XLR, pin 1 shield, pin 2 cold (-), pin 3 hot (+)

ELECTRICAL

AC input:	3 m trailing cable w/o cord cap
Wiring options, magnetic ballast:	208, 230, 245 V / 50 Hz, 208, 230 V / 60 Hz
Wiring options, electronic ballast:	100, 120, 210, 230, 250 V / 50-60 Hz
Maximum power and current:	1500 W, 8.3 A @ 230 V / 50 Hz
Main fuses (2).	T 20 A, 250 V
Fuse F901	T 4 A, 250 V
Fuse F902	T 6.3 A, 250 V

Mac 2K Wash

SPECIFICATIONS

Physical

Length	408 mm (16.0 in)
Width	490 mm (19.3 in)
Height	750 mm (29.5 in)
Weight	34 kg (74.8 lbs)

Installation

Minimum distance to combustible materials	1 m (39 in)
Minimum distance to illuminated surfaces	3 m (10 ft)
Minimum distance around fans and vents	0.1 m (4 in)
Orientation	any

Source

Lamp	1200 W short arc discharge
Base	Double-ended SFc 10-4 with key
Approved models	Osram HMI 1200 W/S, Philips MSI 1200
Control	automatic and remote, hot re-strike
Ballast	electronic

Electrical

AC input	3 m trailing cable w/o cord cap
Operating ranges	100-130 V/200-250 V (switchable), 50/60 Hz
Main fuses (x 2 - when local AC supply is 200 - 250 V)	15 A
Main fuses (x 2 - when local AC supply is 100 - 120 V)	T 20 A
Fuse F101	T 6.3 A
Fuse F102	T 10 A
Fuse F103	T 3.15 A
Fuse F104	T 3.15 A
Ballast	electronic

Maximum power and current

100 V @ 50 Hz	1530 W, 20.9 A
100 V @ 60 Hz	1570 W, 20.9 A
120 V @ 50 Hz	1520 W, 18 A
120 V @ 60 Hz	1520 W, 17.7 A
208 V @ 50 Hz	1450 W, 10.4 A
208 V @ 60 Hz	1450 W, 10.2 A
230 V @ 50 Hz	1450 W, 9.5 A
230 V @ 60 Hz	1460 W, 9.4 A
250 V @ 50 Hz	1450 W, 8.8 A
250 V @ 60 Hz	1460 W, 8.6 A

Mounting/ Hanging Lamps

When you are working with Mac's you need to take note of the transport locks that are on each light. These are usually unlocked/ locked on the truss or hanging structure. There are two of them: one located on the Yoke, the other at the base of the pan axis. The fixture must be unlocked prior to usage. See the drawing to the right.

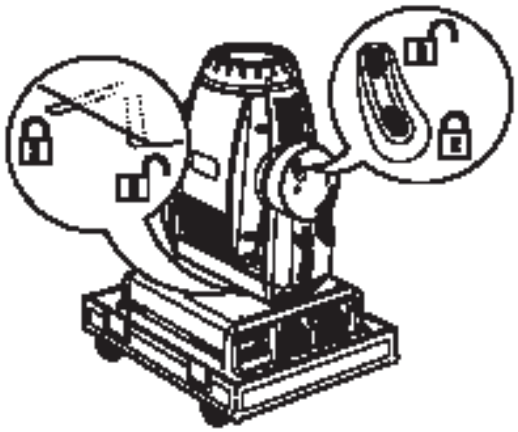


Figure 1: Pan and tilt locks

Mac's use a quarter turn fitting to attach the hook to the upper enclosure. There are four different mounting configurations: two on the flat sides and two on the diagonals. Each pair of mounting holes across form the other must be used as a set.

Once the mounting clamps are installed and the lamp hung on the truss, the safety cable needs to be attached. Marting has provided an attachment point in the center of the upper enclosure for this. Typically the safety cable is looped through this and the " caribiner" type snap hook is then clipped back to itself to form a closed loop. Martin suggests looping the cable around the structure the lamp hanging off and clipping to the attachment point on the lamp. Martin does **not** approve of using the handles for a secondary attachment!

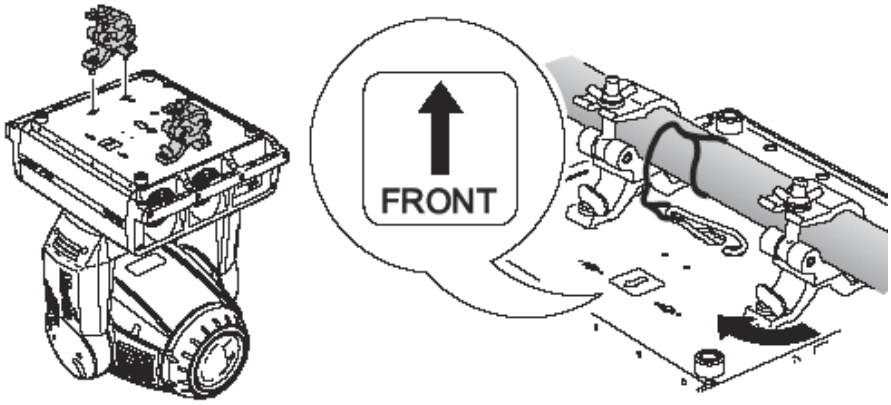


Figure 7: Rigging hardware installation

Data Connections

Like the Highend Studio Colors and Spots data connections are necessary. The Martin equipment is plugged Daisy chained as well. However, the Martin Mac Wash and Profile lights have both 3-pin and 5-pin XLR connectors for DMX input and output. The pin-out on all sockets is pin 1 to shield, pin 2 to – or cold, and pin 3 to + or hot. There are no connections to pins 4 and 5.

Both the 3-pin and 5-pin connections are wired in parallel, both inputs and outputs. Only one set of connectors should be used either the 3-pin or 5-pin should be used at a time. However occasion may arise where you may need to mix connector types, such as damage to the 5-pin input or output. May necessitate mixing connections to facilitate data transmission in the daisy chain.

Like the Highend Studio Color and Spots the Martin Mac 2k's have a limit to the number of fixtures that may be daisy chained together their limit is 32 fixtures. The Mac's also require a terminator at each end of the DMX daisy chain between sets of lights. Lamp changes are one of the first things that one will need to do. They typically have a average life of 750 hours. To reduce the risk of explosion replace the lamp before usage exceeds 125% of the average life (940 hours). To read lamp hours from the control panel refer to readouts on page 14 of the manual. For the best lamp life, avoid striking and dousing lamps prior to them fully warming up!

Lamp Replacement

Important **Do not touch** the quartz bulb bare fingers.

The lamp can be replaced with the following:
OSRAM HIS 1200 W/S or
Philips MSI 1200 W/S

The clear quartz bulb must be clean and free of any oils from your fingers. Clean the lamp with an alcohol wipe and polish it with a dry cloth particularly if you accidentally touch the bulb.

Replacing the lamp

1. Disconnect the fixture from power and allow it to cool. Lock the head horizontally with the top up.
2. Release the 4 quarter-turn fasteners marked with arrows on the rear plate. Pull the lamp assembly staright back as far as it goes and let it reest in place.

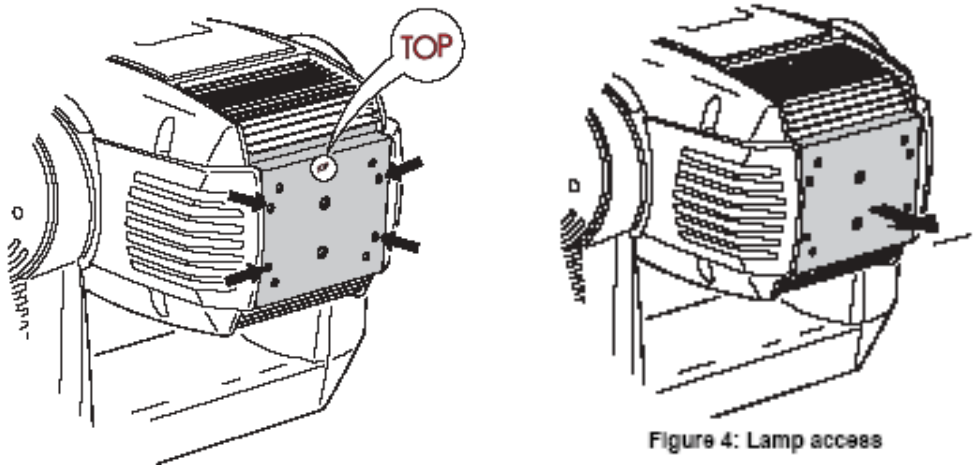


Figure 4: Lamp access

3. Pull the retention spring on the left end up and then swing the end of the lamp out. Pull the other end out of the socket.
4. With the nipple on the bulb facing the back, insert the right end of the new lamp in the socket. Pull up on the left spring and snap the other end into place.
5. Lift the lamp assembly so that the lamp is level with the center of the reflector. Push the assembly staight in unitl it seats, making sure the lamp passes through the reflector opening. Lock the 4 quarter-turn fasteners.
6. When installing a new lamp, reset the lamp hour and lamp strike counters as describe on page 15 of the manual.

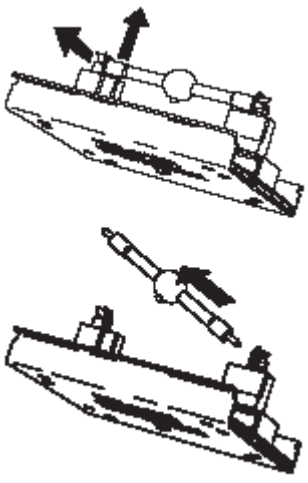


Figure 5: Lamp removal

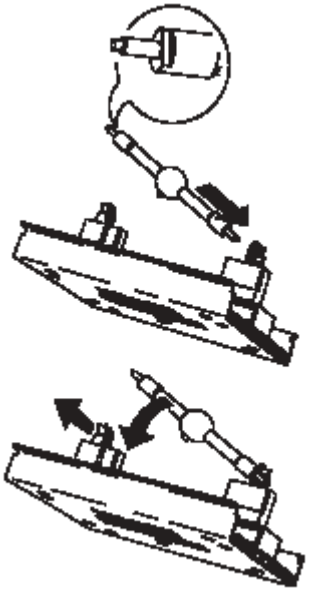


Figure 6: Lamp Insertion

Lamp Optimization/ Bench Focus

1.Turn on the lamp and project an open white beam on a flat surface.
2.Center hot spot vertically using the top Allen-head adjustment screw in the center of the rear plate.
3.If there is significant hot spot, turn the bottom adjustment screw counterclockwise until thelight is evenly distributed.
If the light is brigher around the edge than it is in the cener, or if light output is low, turn the bottom adjustment screw clockwise until the light is bright and evenly distributed. (See leko bench focus pictures).
4.Repeat step 2 and 3 as necessary.

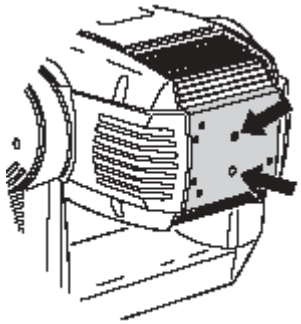


Figure 7: Lamp adjustment

Menu

In order to navigate the Mac menu screens pressing the [Menu] key. Once this is done, using the [up] or [down] key will navigate one through the menus. To select a function r or submenu press [Enter]. Escaping a function or menu press [Menu].

Setting the DMX address and protocol

The DMX address also known as the start address is the first channel used to receive instructions from the controller. For independent control, each fixture must be assigned its won control channels. Two Macs may share the same address, if identical behavior is desired. Address haring can be useful for diagnostic purposes and symmetrical control, particularly when combined with the inverse pan and tilt options.

When contemplating DMX protocols there is an 8-bit and 16-bit control resolutions. The 8-bit mode used 20 control channels for full basic control. The 16-bit offers finer resolution for the gobo and pan and tilt parameters.

Setting the DMX address and protocol

1. Press [Menu] to enter the main menu.
1. Press [Menu] until AddR is displayed. Press [Enter] to snap to channel 1, press [Enter] and [up]. Scroll to the desired channel and press [Enter].
3. Select PSET from the main menu and press[Enter]. Select 8 bit or 16 bit and press [Enter].

Display Adjustments

The display (dINT) setting controls display brightness. The display on/off setting (dISP) determines whether the display remains on or extinguishes two minutes after the last key-press. To flip the display, press [Up} and [Down] simultaneously.

Lamp Striking Settings

There are two setting that modify lamp control. Automatic Lamp On (ALON) and DMX Lamp Off (DloF). When ALON is off, the lmap remains off until a “lamp on” command is received from the controller. When ALON is on, the lamp strikes automatically after the fixture is powerd on. When ALON is set to DMX, the lamps strikes automatically when the fixture receives DMX data, and it extinguishes 15 minutes after DMX is lost.

When ALON is set to either ON or DMX, the automatic lamp strike timing is staggered to prevent all lmaps from striking at once. The delay is determined by fixture address.

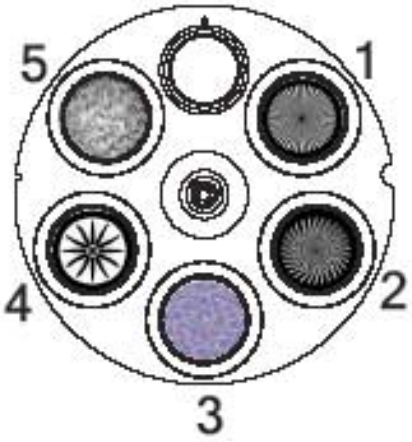
If striking lamps from the controller, noted that striking many lamps at once may cause a voltage drop large enough to prevent lamps from striking or trip the main circuit breaker. Avoid this by programming a “lamp on” sequence that strikes lamps one at a time at 5 second intervals.

Power to the lamp can be turned off from the controller if DMX lamp Off (dLOF) is on. If dLOF is off, A DMX lamp off command is executed on if position 7 is selected on the color wheel and gobo 5 is selected on both gobo wheels.

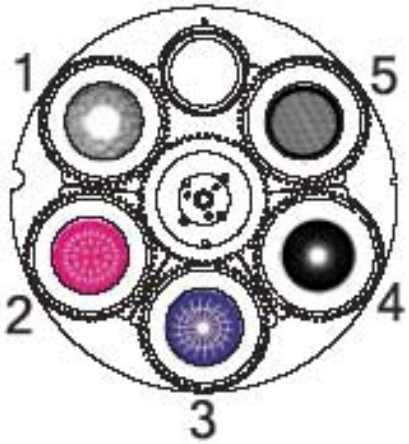
Rotating Gobo Wheels

Due to the lack of spares at times, on a show or the short turn around time in lighting shops it may facilitate the need to change gobos. Like any lighting fixture the Macs have their own methodology to accomplish this task as set out. In addition it will also be necessary to know th correct order to load the gobos into the proper wheels.

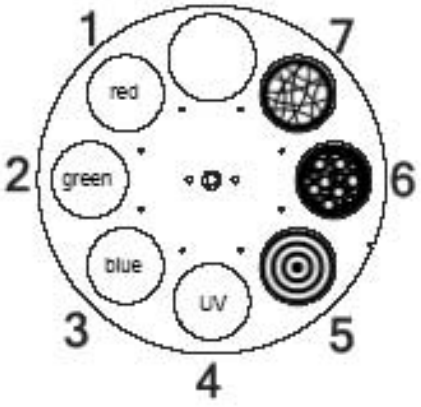
Gobos may be of the glass variety when loaded into a moving light or made from Stainless Steel. When they are of the glass type it will be neccessary to discern between the coated and non-coated sides. Coated gobos are inserted with the coating against the rim of the holder (away from the spring). Textured gobos are inserted with the smooth side against the spring. This orientation provides the best results when combining rotating gobos.



Gobo wheel 1



Gobo wheel 2

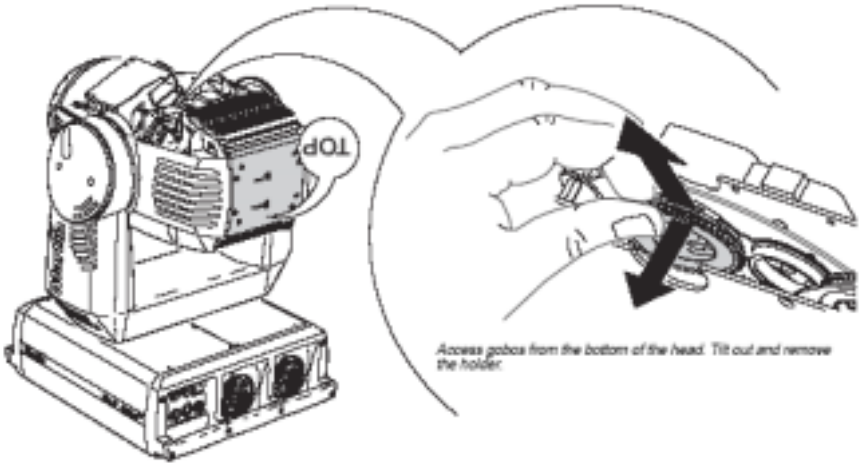


Color/gobo wheel

Changing Gobos and Color in Spot/ Profile Mac

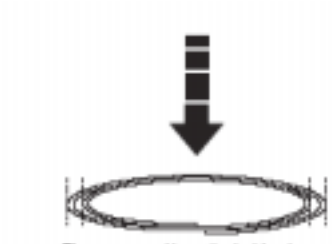
Rotating Gobos:

1. Disconnect the fixture from power and allow it to cool.
2. Lock the head in the upside down position and remove the bottom cover. Turn the gobo wheels as required to access the desired position. Pull the gobo holder away from the wheel slightly to release. Remove the gobo holder.

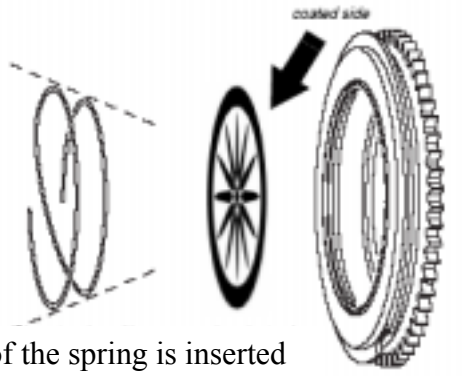


Access gobos from the bottom of the head. Tilt out and remove the holder.

3. Remove the gobo retention spring from the gobo holder and drop the gobo out of the holder. Insert the new gobo in the holder. Insert the spring with the narrow end against the gobo. To identify the narrow end, press the spring flat: the narrow end is on the inside. Push the end of the spring in under the lip of the holder.



The narrow end is on the inside when the spring is compressed.



The narrow side of the spring is inserted against the gobo.

4. Work the rim of the gobo holder under both clips and snap the gobo holder back in to position. If necessary, a small screwdriver or similar tool may be used to pry the clips away from the wheel.
5. Replace the bottom cover and release the pan and or tilt locks before operating.

Rotating Effects

1. Disconnect the fixture from power and allow it to cool.
2. Lock the head in the upside down position and remove the bottom cover. Turn the effect wheel so that the locking plate is under the sensor bracket
3. Remove, hold the reim of the effect holder and pull back on the locking plate, remove effect from the wheel.
4. Re-install by pulling back on the locking plate. If both effects are removed, pull straight back on both tabs. Position the groove in the effect holder over the fixed plate. Release the locking plate d an verify that the effect is properly seated.
5. Replace the bottom cover and unlock the head.

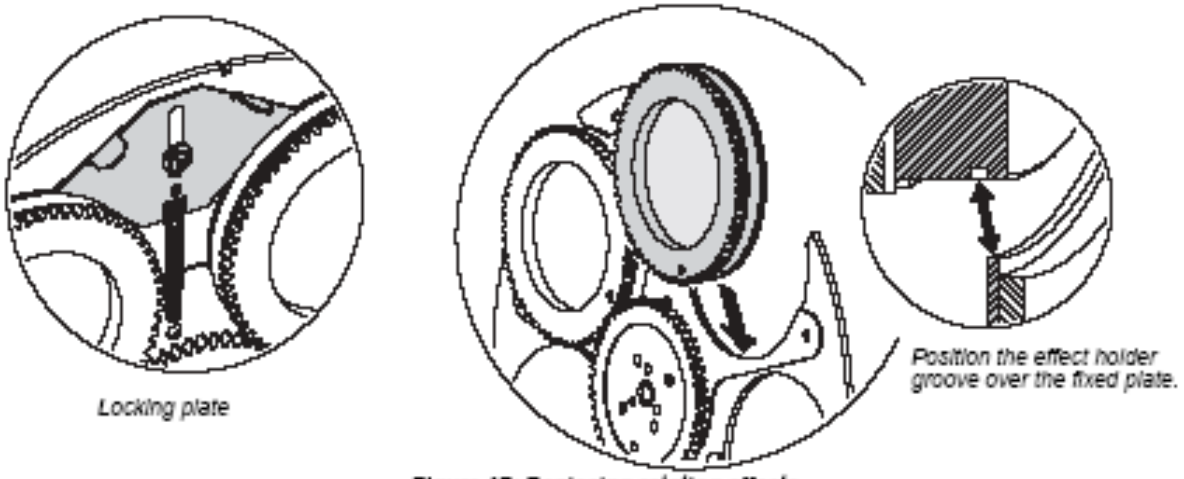
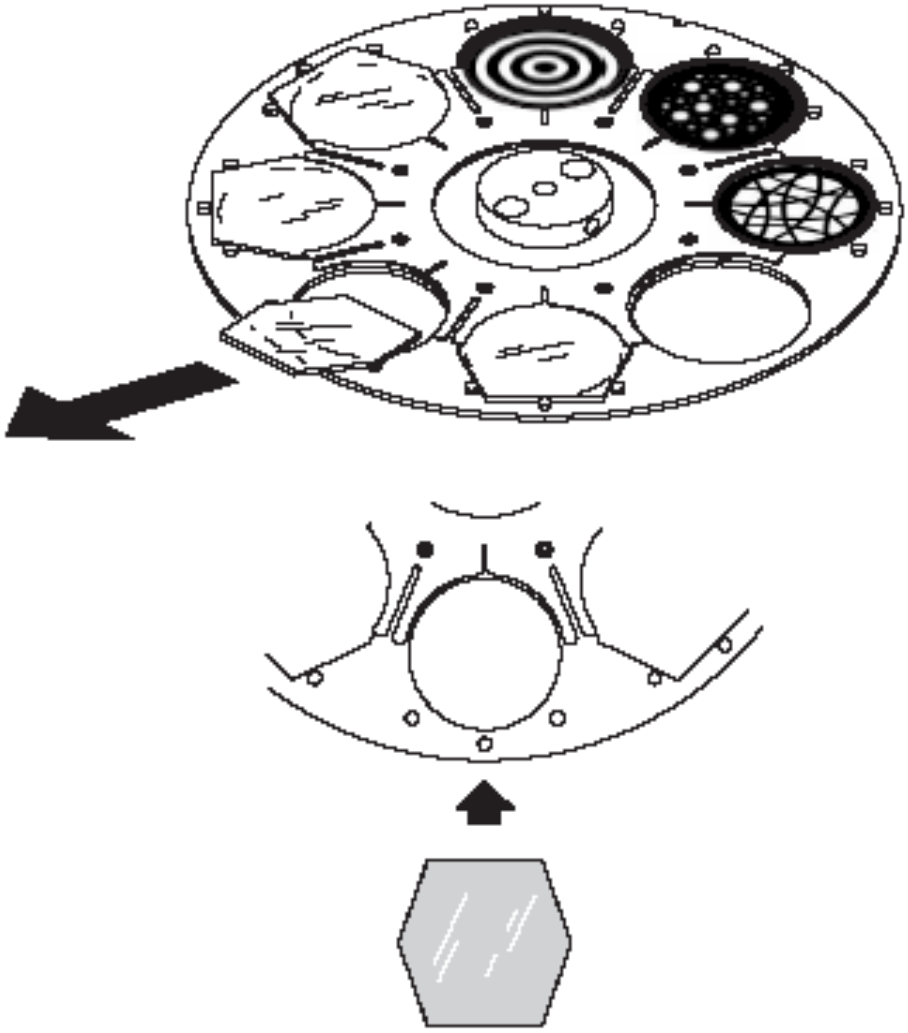


Figure 17: Replacing rotating effects

Fixed Gobos and Color Wheel

The color/gobo wheel housed foru dichroic glass color filters and three static gobos, when changing they install with the coated side away from the wheel. Their replacement is as follows:

1. Disconnect the fixture from power and allow it to cool.
2. Lock the head in the upside down position and remove the bottom cover. Turn the color/ gobo wheel as required to access the desired position.
3. Remove by pressing the filster or gobo from thelamp side to relaes it and remove from wheel.
4. To inset work the filter or gobo under the retention spring and position it between the pins. The long edge of the six-sided color filters must be precisely aligned with the inside of the hub in order to fit.
5. Replace the bottom cover and unlock the head.



Color Wheels in the Mac 2k Wash

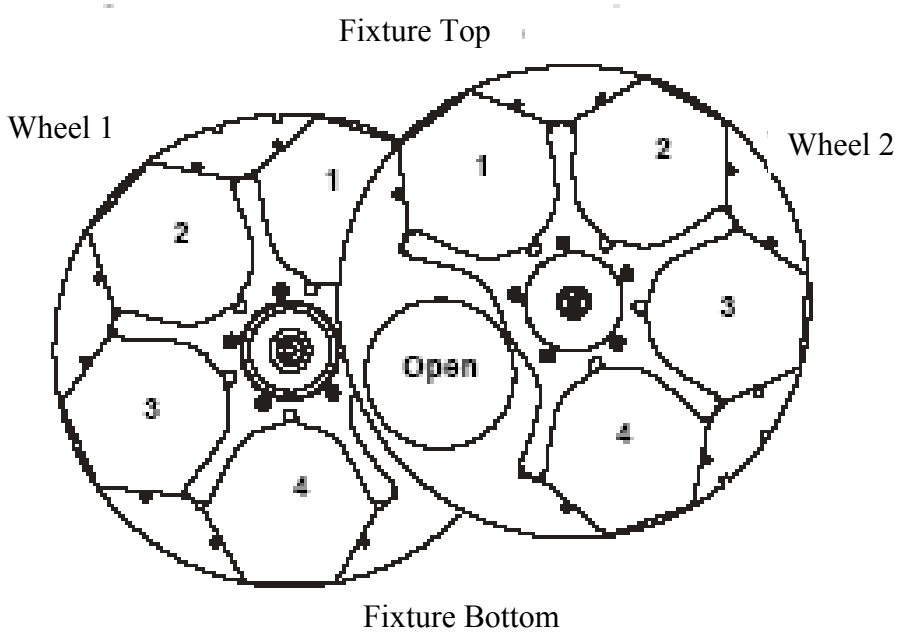
Color Wheel 1

Position 1 Green
Position 2 Blue
Position 3 UV
Position 4 Half Minus Green
Position 5 Open

Color Wheel 2

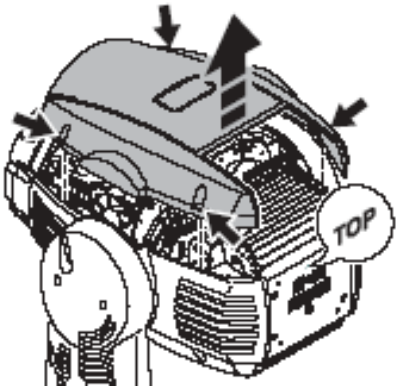
Position 1 Red
Position 2 Orange
Position 3 Green
Position 4 Blue
Position 5 Open

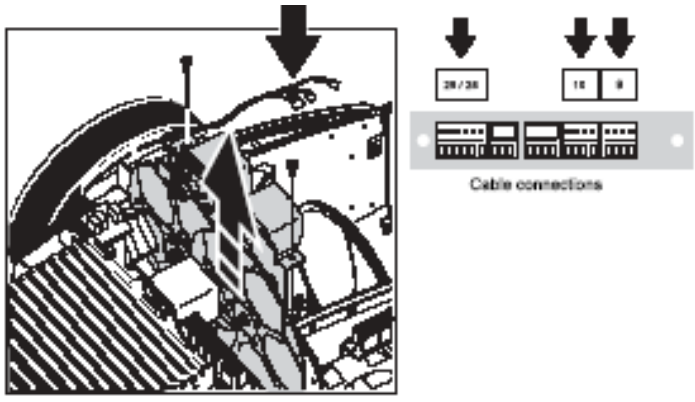
Color Wheels as seen from the lamp end.

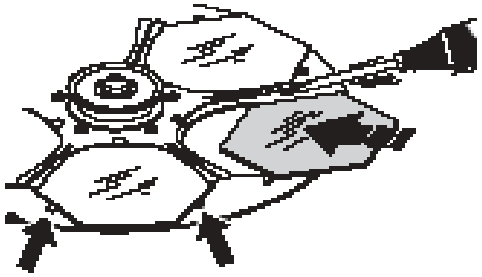


Another facet of working with moving lights is the need to replace or switch color selections on their color wheels the following is the procedure to this with the Martin Mac 2K wash luminaries:

1. Disconnect the fixture from power and allow it to cool.
2. Lock the head in the top up position.
3. Remove the top cover of the fixture using a flathead screwdriver to unlock the four quarter-turn screws.
4. Remove the two screws holding the color wheel bulkhead in place using a Phillips screwdriver. Disconnect the cable and lift the whole bulkhead out of the fixture.
5. Remove the filters using your fingers and a soft cloth to protect the lens.
6. To install a filter, use a small flathead screwdriver to lift the filter support leaves on the color wheel
7. Reinsert the color wheel bulkhead, screw it into place and connect the cables and check for correct operation.
8. Replace the fixture cover and apply power.

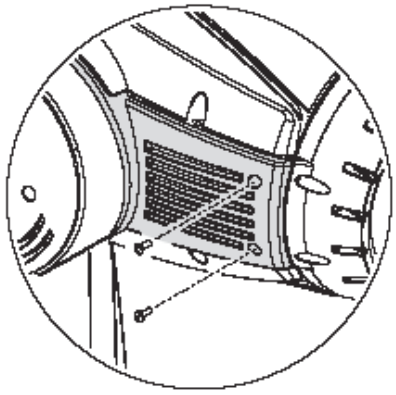


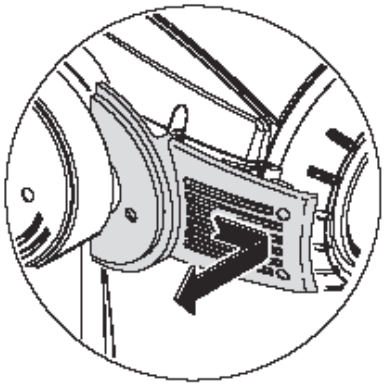


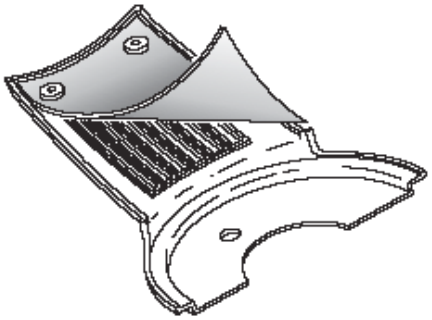


Cleaning or replacing air filters on Mac 2k Profile mk II and Wash:

1. Disconnect fixture from power and lock the head in a convenient position. On each side of the head, remove the 2 screws that hold the side cover using a Torx-20 screwdriver. Slide the cover forward to remove. Lift the filter off of the cover.
2. Vacuum or blow away loose dust, if the filter is saturated with smoke fluid or other things soak in warm soapy water and blot dry. Replacement may be necessary if they are tow dirty.
3. Place the filters on the covers and replace the covers.

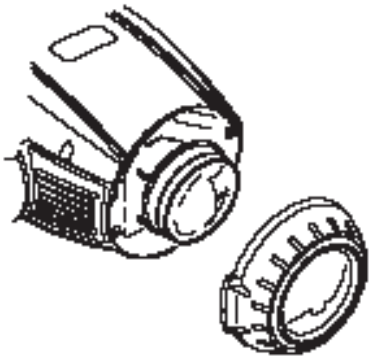


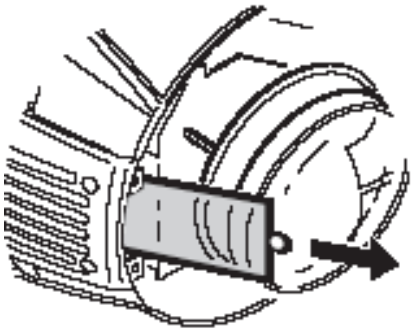




Filter replacement on Mac 2K

1. Disconnect fixture from power and lock the head in a convenient position. Remove the ring around the front lens.
2. Using needle nose pliers grasp the air filter by the tab and slide it forward through the slot.
3. Vacuum or blow away loose dust, if the filter is saturated with smoke fluid or other things soak in warm soapy water and blot dry.
4. To insert a filter, slide it through the slot with washer facing out. Place the washer over the locking magnet.
5. Replace the ring around the front lens.





Menu	Item	Options	Notes (Default settings in bold print)
AddR	-	1-512	DMX address
PSET	-	8bit	Full control with coarse pan, tilt, and gobo indexing
		16bt	Full control with fine pan, tilt, and gobo indexing
PATI	SWAP	ON	Map DMX pan control to tilt channel and vice versa.
		OFF	Normal pan and tilt control
	PINV	ON	Reverse DMX pan control, right → left
		OFF	Normal pan control, left → right
	TINV	ON	Reverse DMX tilt control, down → up
		OFF	Normal tilt control, up → down
PTSP	-	**NORM**	Medium pan/tilt speed
		FAST	Optimize movement for speed
		SLOW	Optimize movement for smoothness
Stud	-	**OFF**	Optimize effects for speed
		ON	Optimize effects for silence
PERS	dISP	**ON**	Display remains on
		OFF	Display extinguishes 2 minutes after last key press
	dINT	10-100	Adjust display intensity
	dLOF	ON	Enable DMX lamp off command
		OFF	Disable DMX lamp off command
	dRES	**ON**	Enable DMX reset command
		OFF	Disable DMX reset command
	ALON	ON	Lamp strikes automatically within 90 seconds of power on
		OFF	No automatic lamp strike
		dMX	Lamp strikes if DMX is present, douses 15 mins. after it's missing
	SCUT	**ON**	Color, gobo, and effect wheels turn shortest distance
		OFF	Color, gobo, and effect wheel paths oscillate
	TRAC/MOdE	**MOd1**	Absolute delta value algorithm (for most controllers)
		MOd2	Real delta value algorithm
	TRAC/CAL	1-10	Tracking samples. Increase if pan/tilt is not smooth. (Default = 6)
dFSE	FACT	LOAD	Return all personality settings (not calibrations) to factory defaults
	CUS1, CUS2, CUS3	LOAd	Load custom configuration
		SAVE	Save current configuration

Table 5: Control menu

TROUBLESHOOTING

Problem	Probable cause(s)	Remedy
One or more of the fixtures is completely dead.	No power to fixture.	Check that power is switched on and cables are plugged in.
	Primary fuse blown (located near mains inlet).	Disconnect fixture and replace fuse.
	Secondary fuse(s) blown (located on PCB inside base).	Disconnect fixture. Check fuses on PCB and replace.
Fixtures reset correctly but respond erratically or not at all to the controller.	Bad data link.	Inspect connections and cables. Correct poor connections. Repair or replace damaged cables.
	Data link not terminated.	Insert termination plug in output jack of the last fixture on the link.
	Incorrect addressing of the fixtures.	Check fixture address and protocol settings.
	One of the fixtures is defective and disturbs data transmission on the link.	Bypass one fixture at a time until normal operation is regained: unplug the XLR in and out connectors and connect them directly together. Have the fixture serviced by a qualified technician.
	XLR pin-out on fixtures does not match (pins 2 and 3 reversed).	Install a phase-reversing cable between the fixtures or swap pins 2 and 3 in the fixture that behaves erratically.
Magnetically indexed effect resets correctly but wanders after fixture reaches operating temperature.	Effect wheel requires mechanical adjustment.	Disable effects feedback (page 15). Contact Martin technician for service.
Mechanical effect loses position.	The transformer setting does not match local voltage.	Disconnect fixture. Check transformer setting and correct if necessary.
	Mechanical train requires cleaning, adjustment, or lubrication.	Contact Martin technician for service.
No light and "LERR" error message displayed.	The ballast and transformer settings do not match local AC voltage and frequency.	Disconnect fixture. Check ballast and transformer settings and correct if necessary.
	Lamp blown	Disconnect fixture and replace lamp.
	Lamp not installed	Disconnect fixture and install lamp.
	Lamp access safety switch open	Verify that lamp access plate is fully seated and locked in place.
	Lamp too hot to strike	Send a lamp off command. Allow the lamp to cool for 5 - 10 minutes and try again.
Lamp cuts out intermittently.	Fixture is too hot.	Allow fixture to cool. Clean air filters. Reduce ambient room temperature.
	The ballast and transformer settings do not match local AC voltage and frequency.	Disconnect fixture. Check ballast and transformer settings and correct if necessary.

Table 8: Troubleshooting

DMX PROTOCOL

DMX channel				Start code = 0
8-bit	16-bit	Value	Percent	Function
1				**Shutter, Strobe, Reset, Lamp On/Off**
		0 - 19	0 - 7	Shutter closed
		20 - 49	8 - 19	Shutter open
		50 - 72	20 - 28	Strobe, fast→slow
		73 - 79	29 - 31	Shutter open, lamp power reduced (MAC 2000 E only)
		80 - 99	31 - 39	Opening pulse, fast →slow
		100 - 119	39 - 47	Closing pulse, fast →slow
		120 - 127	47 - 50	Shutter open
		128 - 147	50 - 58	Random strobe, fast
		148 - 167	58 - 65	Random strobe, medium
		168 - 187	66 - 73	Random strobe, slow
		188 - 190	74 - 75	Shutter open
		191 - 193	75 - 76	Random opening pulse, fast
		194 - 196	76 - 77	Random opening pulse, slow
		197 - 199	77 - 78	Random closing pulse, fast
		200 - 202	78 - 79	Random closing pulse, slow
		203 - 207	80 - 81	Shutter open
		208 - 217	82 - 85	Reset fixture[1]
		218 - 227	85 - 89	Shutter open
		228 - 237	89 - 93	Lamp power on
		238 - 247	93 - 97	Shutter open
		248 - 255	97 - 100	Lamp power off (hold 5 seconds)[2]
2				**Intensity**
		0 - 255	0 - 100	0 → 100%
3				**Cyan**
		0 - 255	0 - 100	White → Cyan
				Cyan limit for random CMY color
		0 - 127	0 - 50	At least 0 → 100%
		128 - 255	50 -100	At most 0 → 100%
4				**Magenta**
		0 - 255	0 - 100	White → Magenta
				Magenta limit for random CMY color
		0 - 127	0 - 50	At least 0 → 100%
		128 - 255	50 -100	At most 0 → 100%
5				**Yellow**
		0 - 255	0 - 100	White → Yellow
				Yellow limit for random CMY color
		0 - 127	0 - 50	At least 0 → 100%
		128 - 255	50 -100	At most 0 → 100%
6				**CTC**
		0 - 255	0 - 100	Cold → Warm (0-178 mireds)

[1] If reset is disabled, i.e., dRES=OFF, the command executes only when position 7 is selected on the color wheel and gobo 5 is selected on both gobo wheels.

[2] If lamp off is disabled, i.e., dLOF=OFF, the command executes only when position 7 is selected on the color wheel and gobo 5 is selected on both gobo wheels.

DMX channel				Start code = 0
8-bit	16-bit	Value	Percent	Function
				Color/Gobo Wheel
				Continuous scroll
		0 - 20	0 - 7	White → Position 1
		20 - 40	7 - 16	Position 1 → Position 2
		40 - 60	16 - 23	Position 2 → Position 3
		60 - 80	23 - 31	Position 3 → Position 4
		80 - 100	31 - 39	Position 4 → Position 5
		100 - 120	39 - 47	Position 5 → Position 6
		120 - 140	47 - 55	Position 6 → Position 7
		140 - 160	55 - 63	Position 7 → Open
				Stepped scroll
		160 - 163	63 - 64	Position 7 (Dots)
		164 - 167	64 - 65	Position 6 (Highways)
	7	168 - 171	66 - 67	Position 5 (Triple Cone)
		172 - 175	67 - 68	Position 4 (UV)
		176 - 179	69 - 70	Position 3 (Blue 111)
		180 - 183	70 - 72	Position 2 (Green 201)
		184 - 187	72 - 73	Position 1 (Red 308)
		188 - 191	74 - 75	Open
				Continuous rotation
		192 - 217	75 - 85	CW, fast → slow
		218- 243	85 - 95	CCW, slow → fast
				Random CMY color (set limits on ch. 3 - 5)
		244 - 247	96 - 97	Random color, fast
		248 - 251	97 - 98	Random color, medium
		252 - 255	99 - 100	Random color, slow
				Gobo Wheel 1, Gobo & Function
		0 - 9	0 - 3	Open
				Indexed gobo rotation
		10 - 14	3 - 5	Gobo 1 (Jet Fan)
		15 - 19	5 - 7	Gobo 2 (Pipe Dreams)
		20 - 24	7 - 9	Gobo 3 (Double Worms)
		25 - 29	9 - 11	Gobo 4 (Inverted King Star)
		30 - 34	11 - 13	Gobo 5 (Limbo)
				Continuous gobo rotation
		35 - 39	13 - 15	Gobo 1
		40 - 44	15 - 17	Gobo 2
		45 - 49	17 - 19	Gobo 3
		50 - 54	19 - 21	Gobo 4
		55 - 59	21 - 23	Gobo 5
	8			Indexed gobo shake
		60 - 74	23 - 29	Gobo 1, shake slow → fast
		75 - 89	29 - 35	Gobo 2, shake slow → fast
		90 - 104	35 - 40	Gobo 3, shake slow → fast
		105 - 119	41 - 46	Gobo 4, shake slow → fast
		120 - 134	47 - 52	Gobo 5, shake slow → fast
				Rotating gobo shake
		135 - 149	53 - 58	Gobo 1, shake slow → fast
		150 - 164	59 - 64	Gobo 2, shake slow → fast
		165 - 179	65 - 70	Gobo 3, shake slow → fast
		180 - 194	70 - 76	Gobo 4, shake slow → fast
		195 - 209	76 - 82	Gobo 5, shake slow → fast
				Gobo wheel rotation
		210 - 232	82 - 91	CW, slow → fast
		233 - 255	91 - 100	CCW, fast → slow

Set position / velocity on next channel. Fine position on ch. 10 (16-bit).

DMX channel				Start code = 0
8-bit	16-bit	Value	Percent	Function
				Gobo Wheel 1, Position/Velocity
		0 - 255	0 - 100	Coarse Position (MSB), Min → Max
9	9			Rotation velocity
		0 - 2	0 - 1	No rotation
		3 - 127	1 - 50	CCW, slow → fast
		128 - 252	50 - 98	CW, fast → slow
		253 - 255	99 - 100	No rotation
				Gobo Wheel 1, Fine Position
-	10	0 - 255	0 - 100	Fine Position (LSB), Min → Max
				Gobo Wheel 2, Gobo & Function
		0 - 9	0 - 3	Open
				Indexed gobo rotation
		10 - 14	3 - 5	Gobo 1 (Limbo Donut)
		15 - 19	5 - 7	Gobo 2 (Triangle Cones)
		20 - 24	7 - 9	Gobo 3 (Congo Star)
		25 - 29	9 - 11	Gobo 4 (Space Sun)
		30 - 34	11 - 13	Gobo 5 (Waves)
				Continuous gobo rotation
		35 - 39	13 - 15	Gobo 1
		40 - 44	15 - 17	Gobo 2
		45 - 49	17 - 19	Gobo 3
		50 - 54	19 - 21	Gobo 4
		55 - 59	21 - 23	Gobo 5
10	11			Indexed gobo shake
		60 - 74	23 - 29	Gobo 1, shake slow → fast
		75 - 89	29 - 35	Gobo 2, shake slow → fast
		90 - 104	35 - 40	Gobo 3, shake slow → fast
		105 - 119	41 - 46	Gobo 4, shake slow → fast
		120 - 134	47 - 52	Gobo 5, shake slow → fast
				Rotating gobo shake
		135 - 149	53 - 58	Gobo 1, shake slow → fast
		150 - 164	59 - 64	Gobo 2, shake slow → fast
		165 - 179	65 - 70	Gobo 3, shake slow → fast
		180 - 194	70 - 76	Gobo 4, shake slow → fast
		195 - 209	76 - 82	Gobo 5, shake slow → fast
				Gobo wheel rotation
		210 - 232	82 - 91	CW, slow → fast
		233 - 255	91 - 100	CCW, fast → slow
				Gobo Wheel 2, Position/Velocity
		0 - 255	0 - 100	Coarse Position (MSB), Min → Max
11	12			Rotation velocity
		0 - 2	0 - 1	No rotation
		3 - 127	1 - 50	CCW, slow → fast
		128 - 252	50 - 98	CW, fast → slow
		253 - 255	99 - 100	No rotation
				Gobo Wheel 2, Fine Position
-	13	0 - 255	0 - 100	Fine Position (LSB), Min → Max

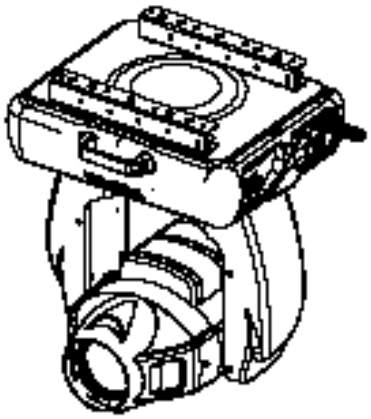
Set position / velocity on next channel. Fine position on ch. 13 (16-bit).

Table 3: DMX protocol

DMX channel				Start code = 0
8-bit	16-bit	Value	Percent	Function
				Effect Wheel Selection and Macros
				Effect selection
		0	0	Open
		1 - 175	1 - 68	Variable frost, 0 → 100%
		176 - 183	69 - 72	Effect 1, indexed rotation
		184 - 191	72 - 75	Effect 2, indexed rotation
		192 - 199	75 - 78	Effect 1, continuous rotation
		200 - 207	78 - 81	Effect 2, continuous rotation
		208 - 215	81 - 84	Open
12	14			
				Macro selection
		216 - 220	85 - 86	1
		221 - 225	87 - 88	2
		226 - 230	89 - 90	3
		231 - 235	91 - 92	4
		236 - 240	92 - 94	5
		241 - 245	94 - 96	6
		246 - 250	96 - 98	7
		251 - 255	98 - 100	8
				Effect Wheel, Position / Velocity
		0 - 255	0 - 100	Position, Min → Max
				Rotation velocity
13	15	0 - 2	0 - 1	No rotation
		3 - 127	1 - 50	CCW, slow → fast
		128 - 252	50 - 98	CW, fast → slow
		253 - 255	99 - 100	No rotation
				Iris
		0 - 199	0 - 78	Open → closed
		200 - 215	78 - 84	Closed
		216 - 229	85 - 90	Pulse opening, fast →slow
14	16	230 - 243	90 - 95	Pulse closing, fast →slow
		244 - 246	96 - 96	Random pulse opening, fast
		247 - 249	97 - 98	Random pulse opening, slow
		250 - 252	98 - 99	Random pulse closing, fast
		253 - 255	99 - 100	Random pulse closing, slow
15	17			**Focus**
		0 - 255	0 - 100	Infinity → near
16	18			**Zoom**
		0 - 255	0 - 100	Flood → spot
17	19			**Pan Coarse** (MSB)
		0 - 255	0 - 100	Left → right (128 = neutral)
-	20			**Pan Fine** (LSB)
		0 - 255	0 - 100	Left → right
18	21			**Tilt Coarse** (MSB)
		0 - 255	0 - 100	Up → down (128 = neutral)
-	22			**Tilt Fine** (LSB)
		0 - 255	0 - 100	Up → down
				Pan/Tilt Speed
		0 - 2	0	Tracking
		3 - 242	1 - 95	Fast → slow
19	23	243 - 245	95 - 96	Tracking, PTSP = SLOW (slow pan/tilt speed)
		246 - 248	96 - 97	Tracking, PTSP = NORM (normal pan/tilt speed)
		249 - 251	98	Tracking, PTSP = FAST (fast pan/tilt speed)
		252 - 255	99 - 100	Blackout
				Effect Speed (Dimmer, Color, Gobos, Effects, Indexed Rotation, Iris, Focus, and Zoom)
		0 - 2	0 - 1	Tracking
		3 - 239	1 - 94	Fast → slow
20	24	240 - 242	94 - 95	Tracking, STUd = OFF (studio mode off)
		243 - 245	95 - 96	Tracking, STUd = ON (studio mode on)
		246 - 248	96 - 97	Tracking, SCUT = OFF (shortcuts off)
		249 - 251	98 - 98	Tracking, SCUT = ON (shortcuts on)
		252 - 255	99 - 100	Fast. *Blackout "speed" for color wheel*

Set position / velocity on next channel.

Overview



The VL2000 spot luminaire contains the following standard features:

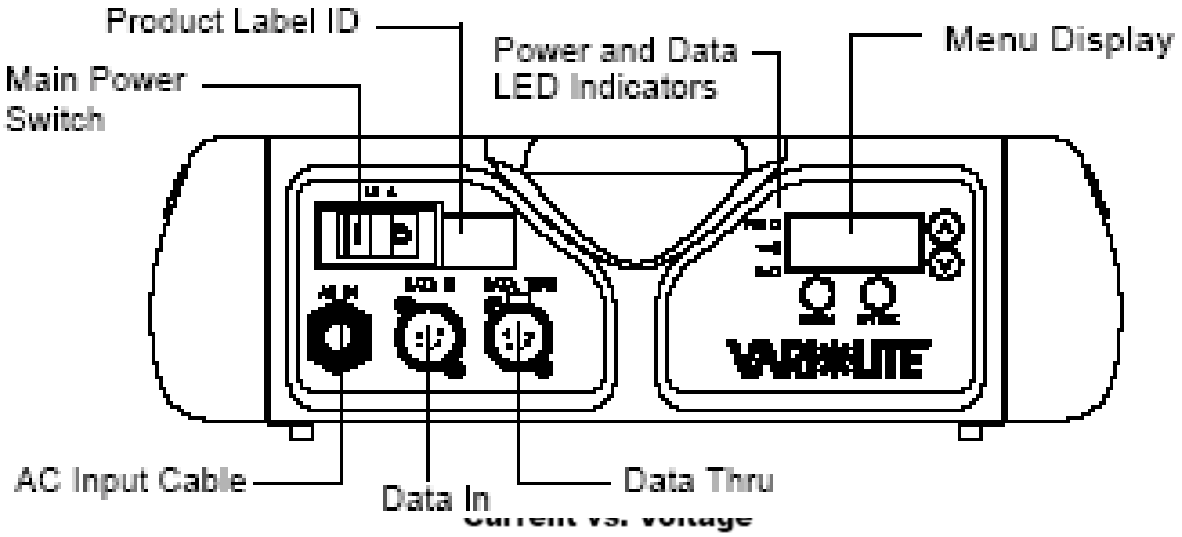
- Variable beam focus to soften the edges of gobos or spots and enable gobo morphing.
- Full field dimmer to allow smooth timed fades and fast blackouts.
- A mechanical iris which provides continuous beam size control for both rapid beam size changes and smooth timed beam angle changes.
- Rotatable gobo wheel which contains five individually rotatable, indexable gobos.
- Two, 12-position wheels, each providing 11 easily loaded positions (and 1 open) for interchangeable dichroic color and gobo selections.
- Zoom optics system with a zoom angle of 2.8 to 1.
- Power factor corrected arc power supply for a Philips arc lamp.
- 700 watt arc source.
- Faceted reflector designed for an optimal flat field.
- Control by DMX512 protocol.
- Two truss hook brackets for versatile hanging configurations.

VL2201 Spot Luminaire

- 400 watt arc source.
- Zoom optics system which provides an adjustable field angle from 13° to 35°.
- Smooth reflector which produces a peaked or flat field.

VL2202 Spot Luminaire

- 700 watt arc source.
- Zoom optics system which provides an adjustable field angle from 19° to 43°.
- Faceted reflector designed for an optimal flat field.



Current vs. Voltage

The following table provides the luminaire's current draw at specific voltages. Current is calculate with the lamp on and all motors sequencing.

For single-phase power at 100 to 240 volts RMS:

Connection	Pin
AC Neutral	X
AC Line	Y
Ground (Earth)	G

For three-phase power at 208 volts RMS:

Connection	Pin
Phase 1	X
Phase 2	Y
Ground (Earth)	G

Table 2-1: Current vs. Voltage

Voltage @ 60Hz	Current
90.0	11.8
100.0	10.6
110.0	9.5
120.0	8.5
130.0	7.9
140.0	7.2
180.0	5.5
190.0	5.2
200.0	4.9
210.0	4.7
220.0	4.5
230.0	4.3
240.0	4.1
250.0	3.9

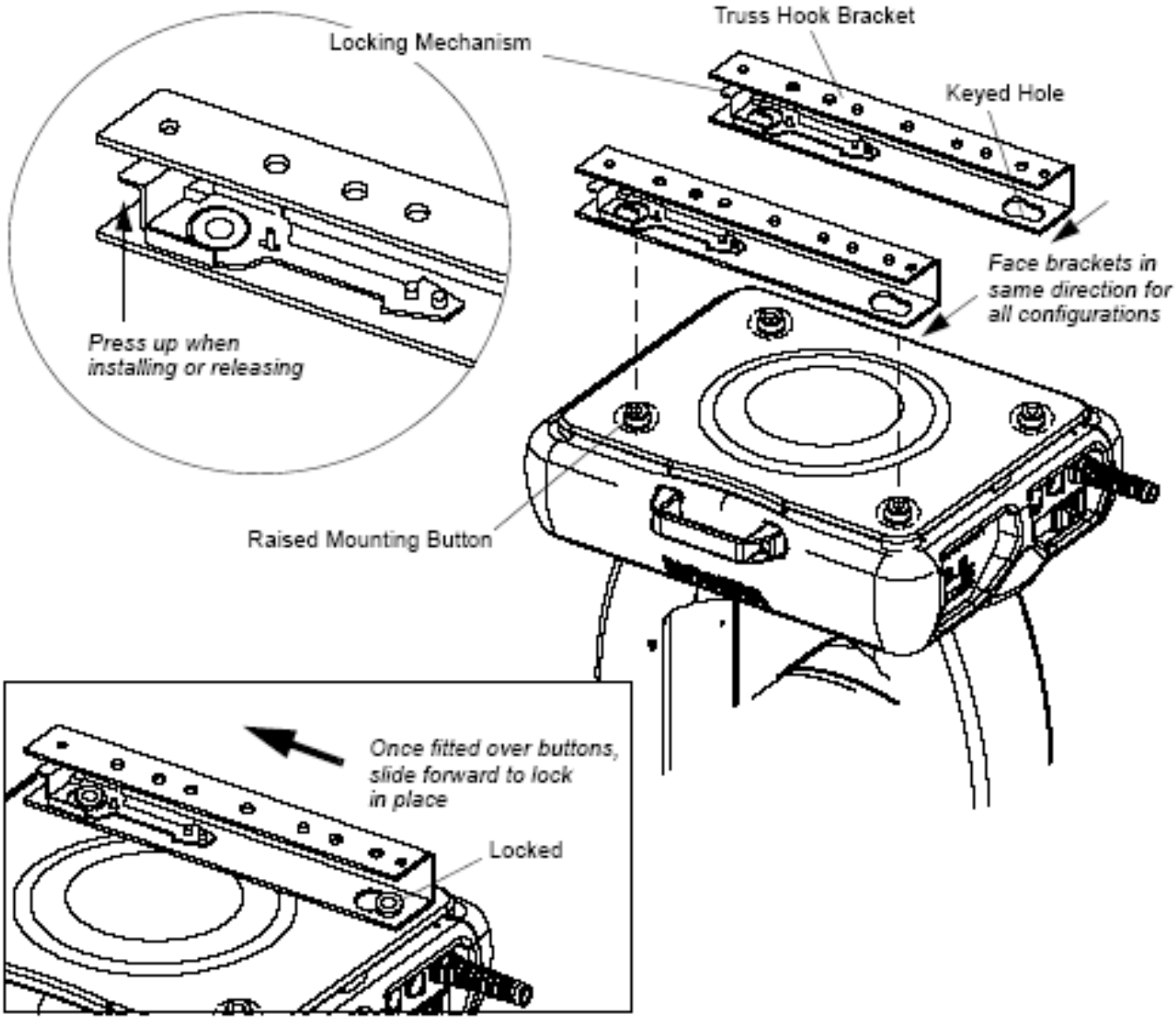


Figure 2-4: Installing Brackets on Luminaire Enclosure

To install lamp:

Step 1. Ensure power is removed from luminaire.

Step 2. Remove lamp from shipping box.

Step 3. At backcap, using slotted screwdriver (or fingers) turn captive knob until loose.

Step 4. Slide backcap away from head assembly (it will remain attached by tether and lamp wires.).

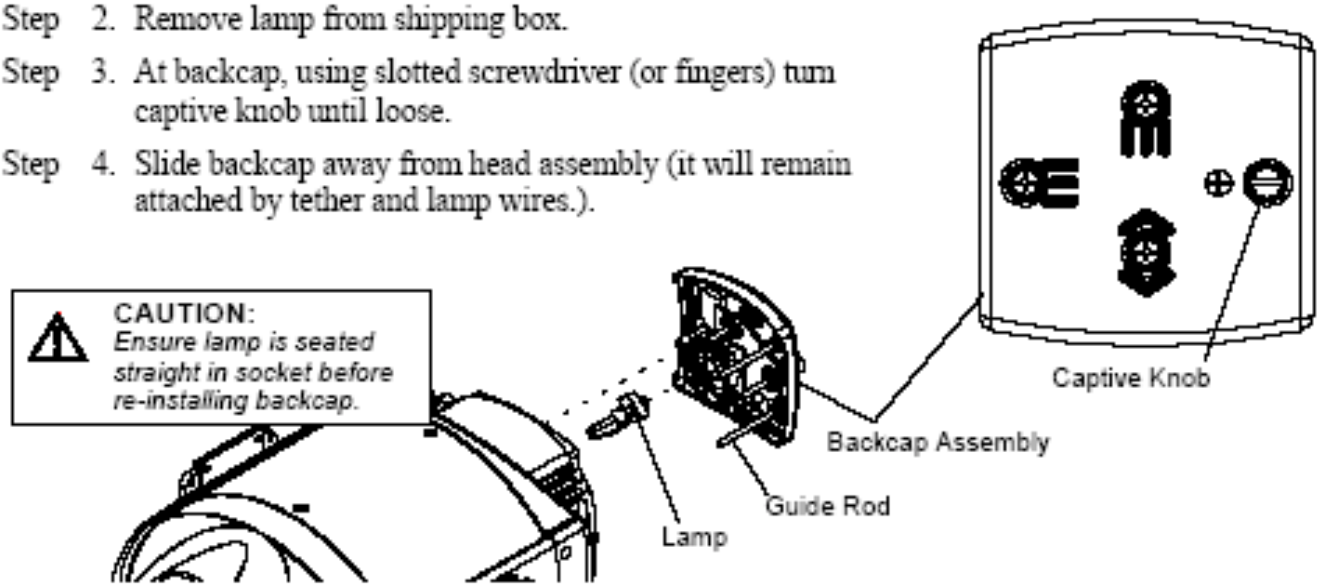


Figure 2-1: Installing Lamp

Step 5. Install lamp by pressing into socket. Ensure lamp is fully seated in socket and parallel to guide rods. (Lamp can be damaged when inserted through reflector if not parallel to guide rods.)

Step 6. Align guide rods in guide holes and slide backcap into head assembly. Re-tighten captive knob.

Step 7. If required, reset lamp hour and strike counters as follows. (Refer to "Menu System" chapter on page 47 for more information.)

a. Power up luminaire.

b. At Menu Display, press [Menu].

c. Press [Up] / [Down] arrows until CFG (Configuration) appears. Press [Enter].

d. Press [Up] / [Down] arrows until LAMP appears. Press [Enter].

e. Press [Up] / [Down] arrows to access RHrs. Press [Enter] to reset lamp hour and strike counters.

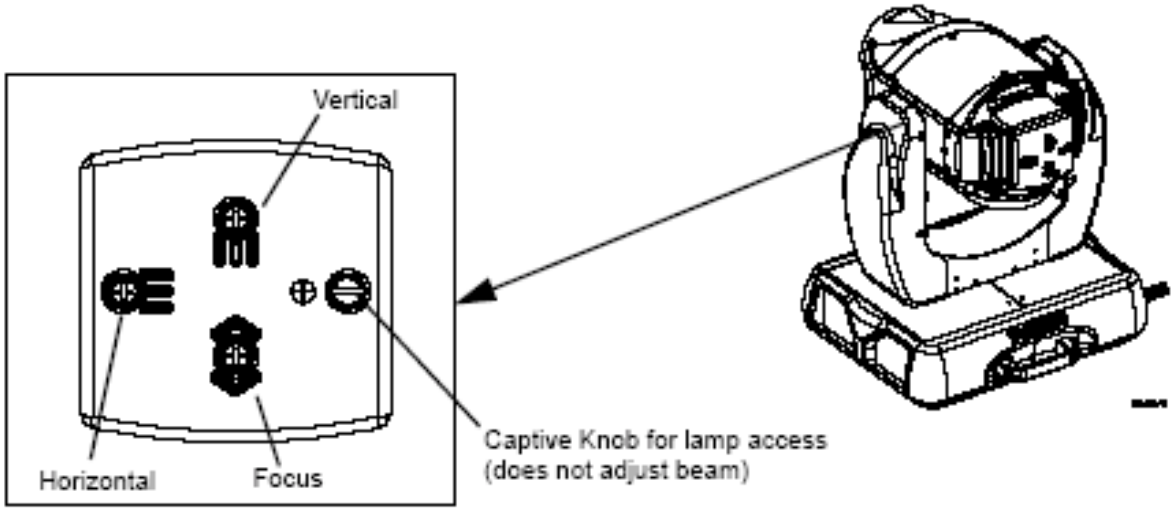
To align lamp:

Step 1. Using internal menus select Lamp test to set beam. See "Menu System Functions" on page 53 for more information. (If using console, set intensity to 100%, open beam size iris and focus for hard edge.)

Step 2. Position beam on a white wall at a distance of 10' to 20'.

Step 3. At backcap, using Vertical and Horizontal knobs, adjust hot spot to center of beam.

Step 4. Using Focus knob, adjust beam for best spot.



Program Starting Address

The address setting for DMX console or Virtuoso console controlled systems is entered using the Menu Display. (Refer to "Menu System" chapter on page 47 for detailed instructions.)

The luminaire retains the DMX and Virtuoso addresses that are stored even if power is removed.

Note: Refer to your console operating instructions for specific information regarding its addressing requirements.

Program a DMX or Virtuoso starting address:

Step 1. Press [Menu].

Step 2. Press [Up] / [Down] arrows until ADDR (Address) appears. Press [Enter].

Step 3. Press [Up] / [Down] arrows to access DMX (DMX console control) or VIRT (Virtuoso console control). Press [Enter].

Step 4. Press [Up] / [Down] arrows to enter starting address.

Step 5. Press [Enter] to set.

Program Starting Address Without Calibrating the Luminaire

It is possible to bypass the calibration sequence and go directly to the Menu Display programming in order to pre-program an address setting.

Program starting address without calibrating luminaire:

- While powering up luminaire, press and hold [Menu]. Program address as in Program Starting Address above.

Shortcuts

A few button combinations are provided as shortcuts for frequently used menu functions. These shortcuts are as follows:

- Pressing [Enter] and [Up] at the same time = Lamp On
- Pressing [Enter] and [Down] at the same time = Lamp Off
- Pressing [Menu] and [Up] at the same time = Recalibrate
- Pressing [Menu] at Power up interrupts calibration. See "Program Starting Address Without Calibrating the Luminaire" on page 23 for more information.

Keep in mind that [Up] and [Down] arrows are dependent on the Display Orientation. Refer to "Display Orientation" on page 49.

Standard Gobos - Wheel 2 (Fixed Gobo Wheel)

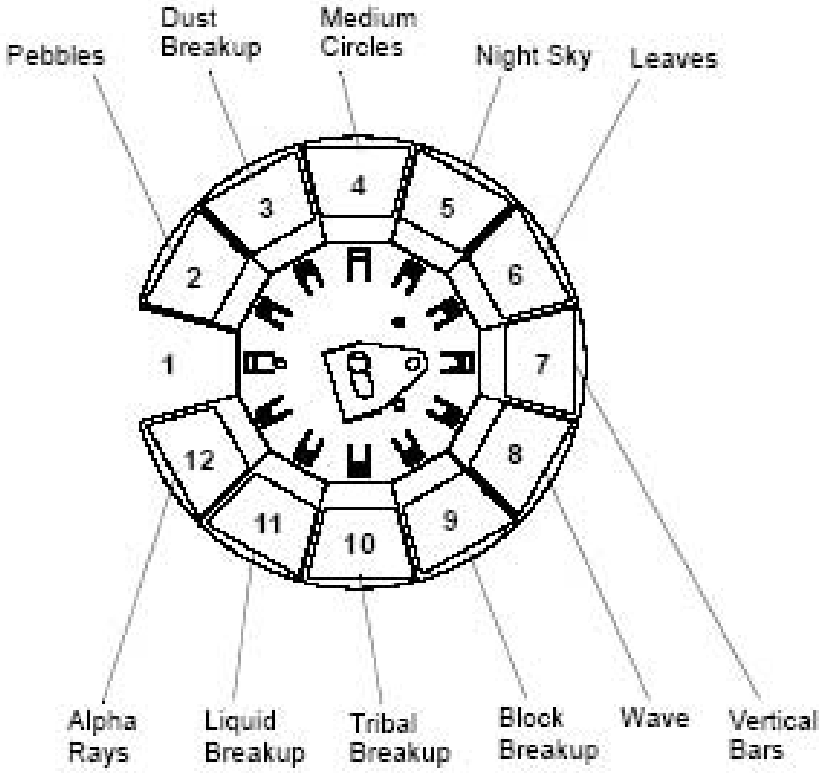


Figure 3-3: Standard Gobos - Wheel 2 (Fixed Gobo Wheel)

Standard Rotating Gobos

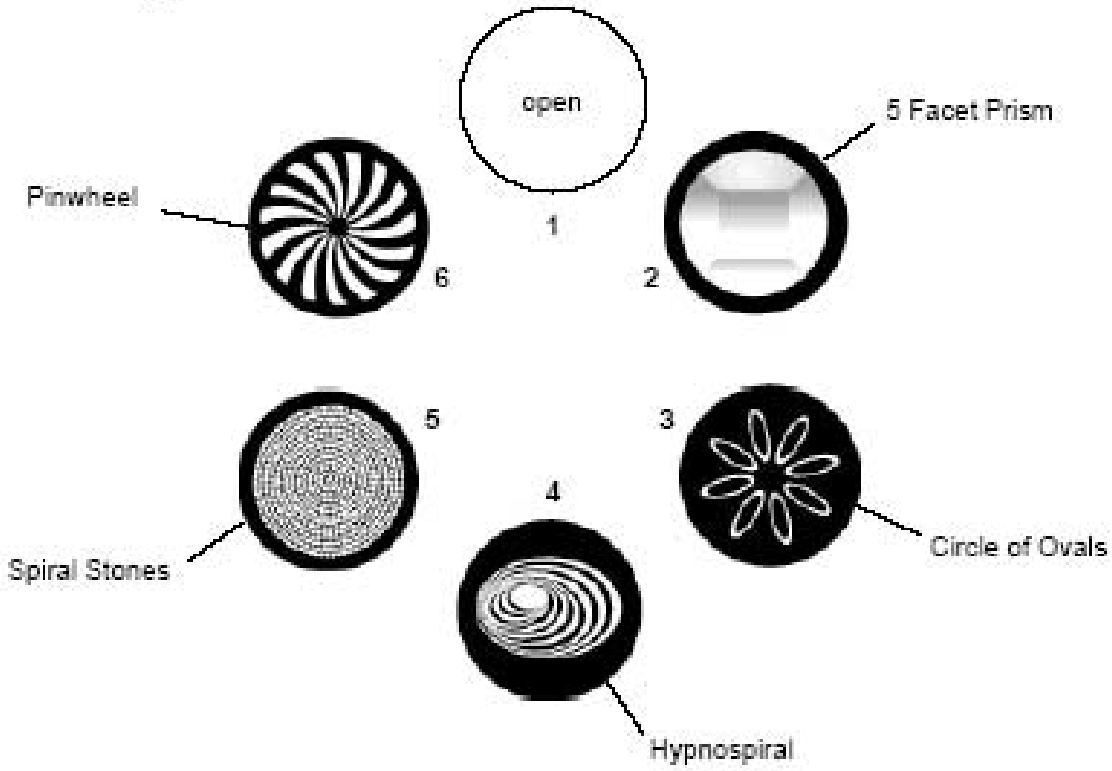
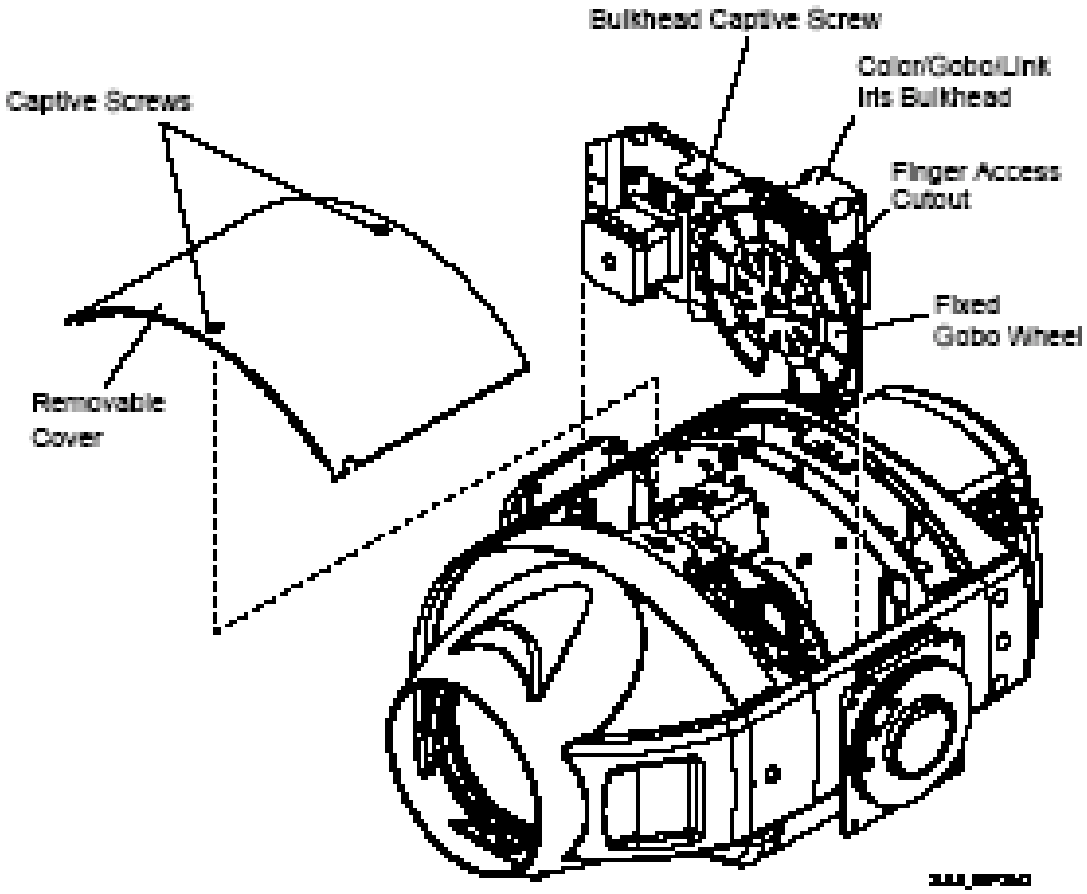


Figure 3-4: Standard Rotating Gobos

To remove and replace a fixed wheel gobo:

Step 1. Remove power from luminaire.

Step 2. At removable cover, using #2 Phillips screwdriver, turn two captive screws one-quarter turn and remove cover. (It will remain attached by tether and lamp wires.)



CAUTION: Do not touch gobos with bare fingers. Wear cotton gloves or other covering while replacing. Clean with glass cleaner and soft cloth if required.

Note: In some cases it is easier to slide bulkhead partially out of head assembly to access gobos. To do this, use #2 Phillips screwdriver to turn captive screw one-quarter turn and slide bulkhead upward. Disconnect motor connections as necessary.

Step 3. Rotate wheel until required gobo is accessible at finger access cutout.

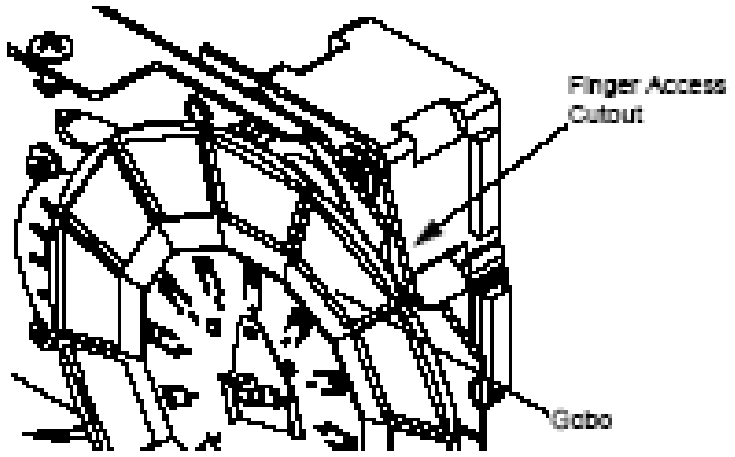


Figure A-6: Gobo Access

CAUTION: Do not touch gobos with bare fingers. Wear cotton gloves or other covering while replacing. Clean with glass cleaner and soft cloth if required.

Step 4. Using fingers, pull gobo out of wheel.

Step 5. Noting proper orientation of carrier slot and orienting "black" side of gobo toward front lens, insert new gobo into position and push fully into place.

Step 6. Re-install bulkhead (if applicable) and re-install removable cover.

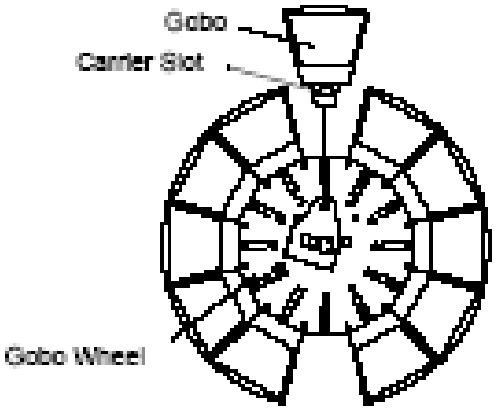


Figure A-7: Fixed Gobo Removal

To remove and replace a rotating gobo:

Step 1. Remove power from luminaire.

Step 2. At removable cover, using #2 Phillips screwdriver, turn two captive screws one-quarter turn and remove cover. (It will remain attached by tether and lamp wires.)

Step 3. At rotating gobo wheel, rotate until required gobo/filter is accessible.

Step 4. Locate end of coiled spring which is fitted under carrier tab. Using hook and pick tool or small slotted screwdriver, push end of spring from under tab until it is free. Once free, remove entire coiled spring.

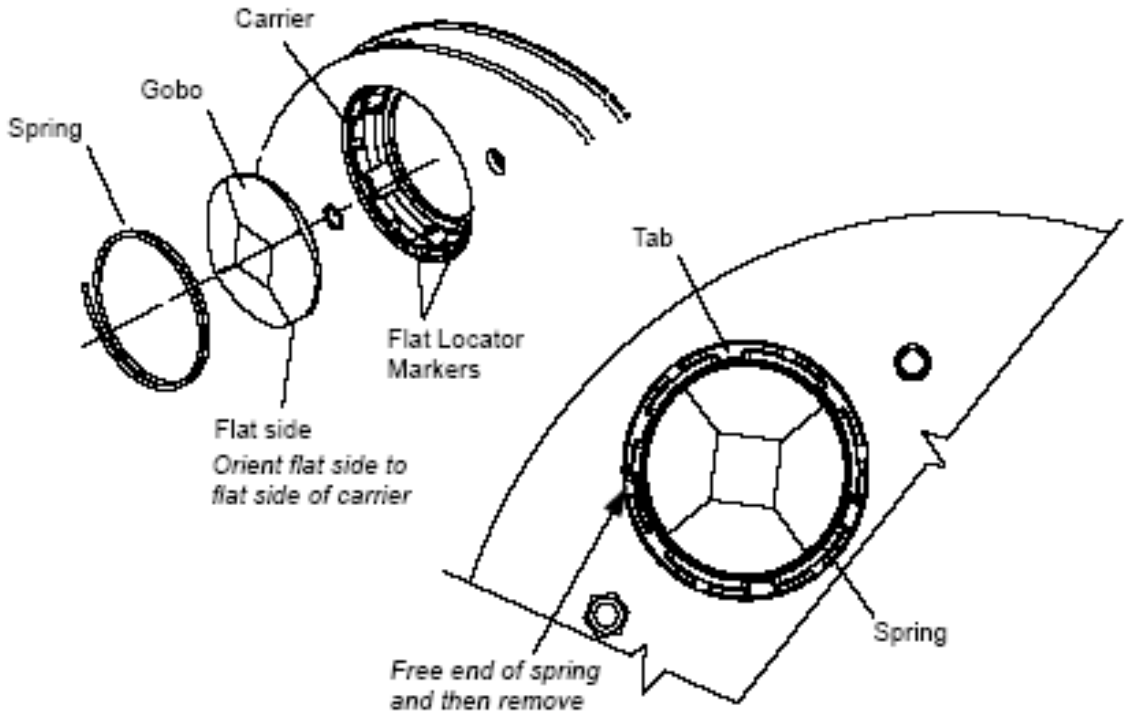


Figure A-9: Rotating Gobo Removal

CAUTION: Do not touch gobos with bare fingers. Wear cotton gloves or other covering while replacing. Clean with glass cleaner and soft cloth if required.

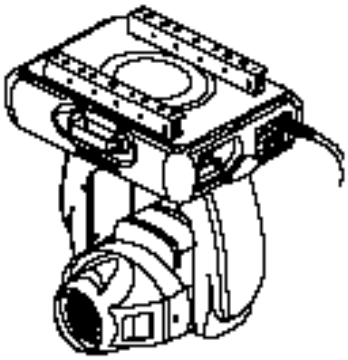
Step 5. Remove gobo.

Step 6. Aligning flat side correctly and orienting "black" side of gobo toward front lens, install new gobo.

Step 7. Re-install spring, ensuring it is fully secured under carrier tabs.

Step 8. Re-install removable cover.

The VL2000 wash luminaire features zoomable beam spreader optics, color mixing, a separate fixed color wheel and a high performance dimmer/strobe mechanism.



The luminaire contains the following standard features:

- Zoomable beam spreader.
- Crossfading color mixer mechanism. The mechanism allows independent blue, amber and magenta color control.
- Fixed Color wheel has 12 positions (1 open) for dichroic color.
- An internal mechanical douser which provides intensity control and strobing.
- An upper enclosure that houses the control electronics as well as a power factor corrected arc power supply.
- Control by DMX512 protocol.
- Two truss hook brackets for versatile hanging configurations.
- 700W arc source.

Color Mixing

The color mixing mechanism is made up of three graduated color disks: blue, amber and magenta. These disks provide full-spectrum color crossfades from pastel to saturated color.

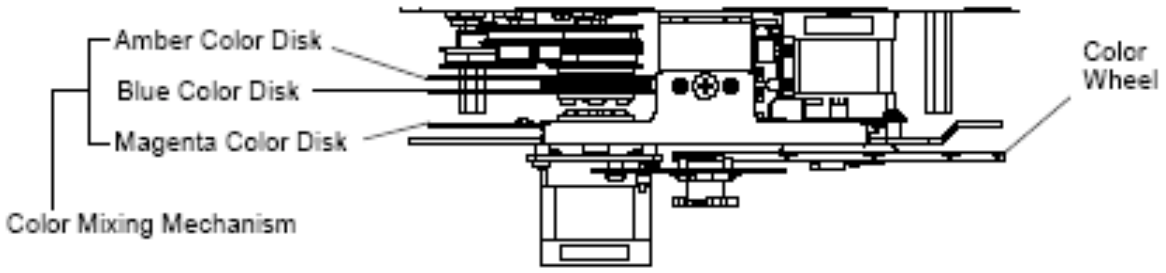


Figure 3-1: Color Mixing Mechanism

Color Wheel

The color wheel is capable of rapid and timed changes, as well as half and full frame positions.

The color wheel has 12 positions, one being open.It offers partial frame control and various spin rates in either direction.

The following illustration shows the standard color configuration:

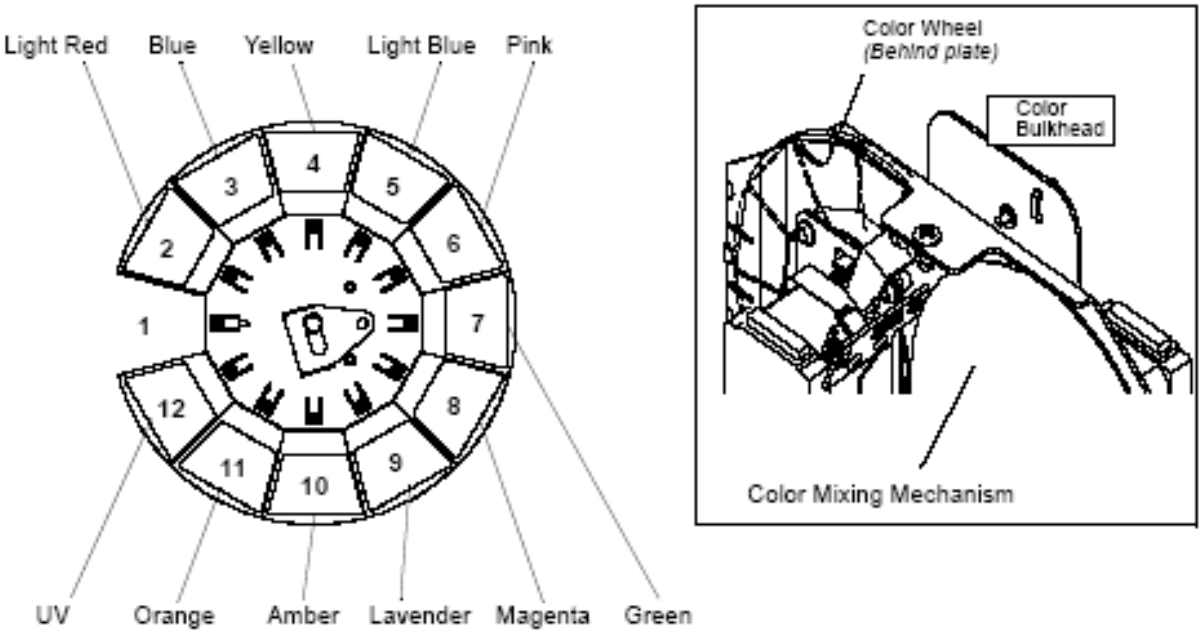
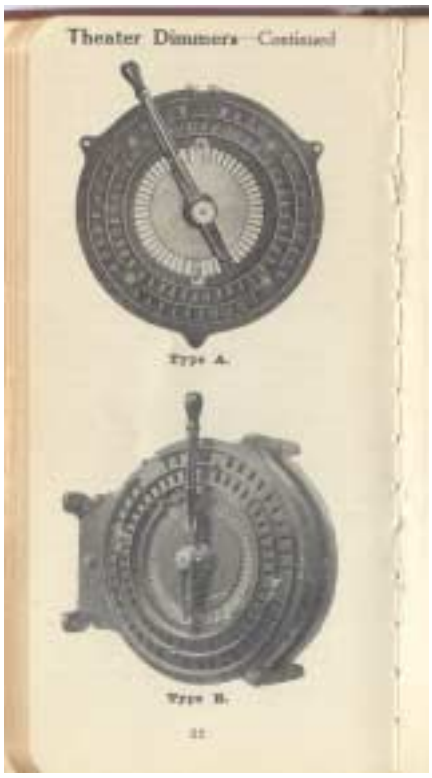


Figure 3-2: Standard Color Configuration

Dimmers



Typical resistance dimmer plates from the 1916-17 era.

Previous to the modern dimmer racks in use today. That are configured as full road racks or the small shoebox variety used in hotels there were two prevalent types in use. These were, resistance dimmers and autotransformers. Resistance Dimmers have a couple of characteristics that should be noted: in general they had a specific load rating that needed to be filled, in order for the dimmer to properly maintain a linear fade up and down. If the maximum load rating/ capacity was not reached, then a ghost load was included in the dimmer hook-up. These were located were they would not affect the performance. Another characteristic of the resistance dimmer was the amount of heat that they generated (the byproduct of excess current flow is heat). The resistance dimmer plates were typically packaged in a large Piano board road box. This case arrangement ensured the operators a dead front, which ensured the safety of the multiple operators that were needed to operate these types of lighting boards. The applicability of this technology to today's theatrical technicians is its use of a ghost load. A ghost load today is used for different reasons: a ghost load today is applied when a dimmable fluorescent lighting fixture is used. A 1K (1000 watt) or 2K (2000 watt) load is used to help smooth out the fade ups and downs. It may also be utilized when mini-strips are used with 12-volt lamps and a full length is not required. The balance of the load is placed off stage to make up the remainder of resistance necessary to operate in a 110-volt system. A ghost load can also be used with ACL lamps, when a number other than four are required. Typically four ACL's are used because they are wired in series. In a series circuit, the voltage in this case is added together to equal 100 volts, and enables the lamps to be used in a 110-volt system.

Modern "Ghost Load" used with Dimmable Fluorescents

Piano Box Resistance Dimmer touring system with stage plugs.

The next technological leap came, with the introduction of Auto Transformer dimmers. Unlike the resistance dimmer plates, an autotransformer dimmer could be used with any load as long as the maximum

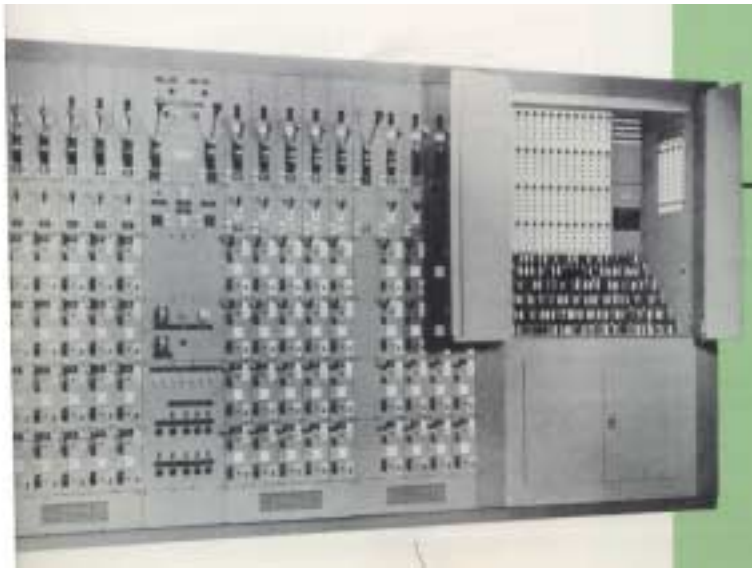
Shubert Theatre's House Light Autotransformer Board

load capacity of the dimmer was not exceeded. Autotransformers could also generate a-lot heat like the resistance dimmer plates. Both the resistance and autotransformer style dimmers had load protection so as to not exceed the capacity of the dimmer. These dimmers were configured as either a permanent set of dimmers, permanently mounted in the theatre or as a portable dimmer packs often referred to as a "coffin".

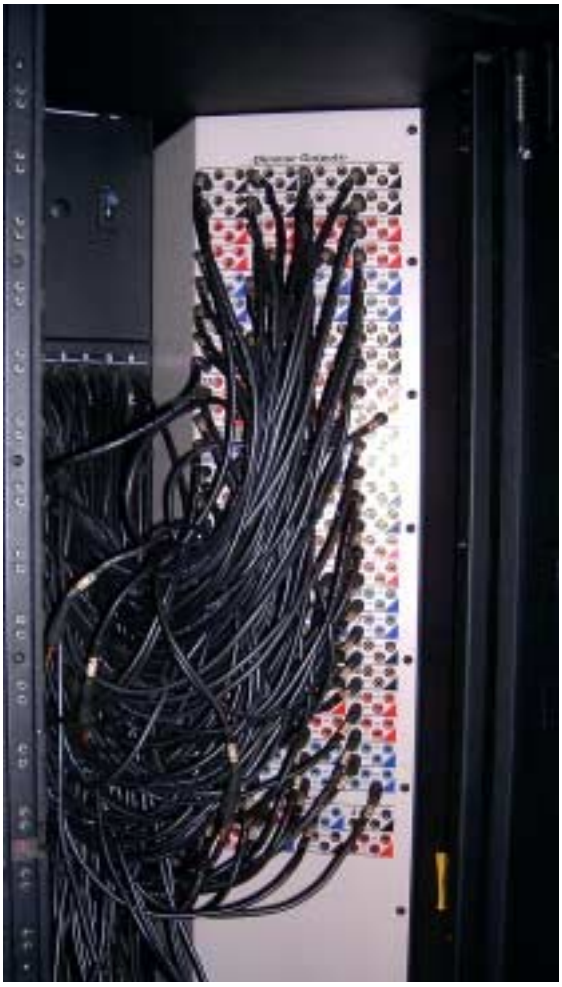
Ward Leonard "6 Pack Coffin" with stage pin load patch

When installed in a theatre they typically had their loads hard wired to each dimmer or a phone cord style load patch was used. These systems had a limited amount of circuits available for a touring shows lighting system. The spare load circuits were often floor or wall pockets that one simply plugged additional lighting into. When more than a few lights were needed, additional lighting control and circuits were brought into the theatre as portable dimmers that had a simply system of load patching at the dimmer racks.

When the house had a large autotransformer board installed, often there was an integrated telephone or pin patch built-in, sometimes called a "cross-connect panel". The male pin patches were labeled with the circuit number on them that corresponded to a location within the theatre. The male pins were attached to a counterweighted cable that would automatically retract when the patch was changed or wiped clean. Once the cable/ pin were pulled out to patch a circuit they were simply plugged into a dimmer, which was a female receptacle. That had its other end terminated at one of the autotransformer dimmers. By "patching it" the load was connected to a dimmer and was ready to use. The idea of load patching is still in use today on road racks. Were each positive conductor from the "Soco" outputs is terminated to a banana jack that is patched to a particular dimmer.



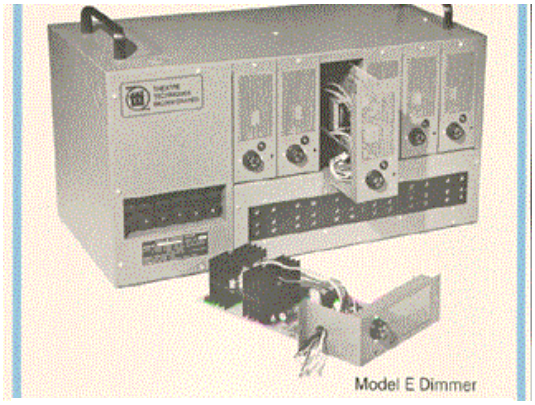
Grand Stage Lighting Autotransformer board with a cross-connect panel.



Load patch center in a ETC 96 dimmer banana jack.

As you have seen by the previous illustrations, for the first 50 years of electrical lighting in theatres. The dimmers and control were one in the same. Each of the early dimmer types, resistance dimmer plates or the autotransformer had a lever attached to the "dimmer" which was simply a large capacity variable load resistor that had a wiper brushing across the windings. A variation of the same theme were motor driven autotransformers that could be remotely placed and driven with a control voltage, these were often used in house light control. The remotely controlled house light dimmers were a precursor to the next quantum leap in theatrical lighting control.

The next leap in dimmer control was the use of a remote dimmer rack with a control signal sent to a dimmer. The control signal controlled the intensity of the lighting fixtures that were patched into the respective dimmers. The dimmers became a SCR dimmer (Silicon Rectifier) or a high capacity transistor and they tended to be enclosed in a drawer for ease of servicing, take note of this with the dimmer on its side in the TTI portable dimmer picture and the Major Controls dimmer rack with the missing dimmer drawer. The SCR or Transistor controlled dimmers had either an on state or off state. They acted as a switch of sorts with the duration of "on" was in proportion to the amount of voltage applied to the control circuitry. The control signal voltage utilized an analog signal that varied by manufacture from 10 to 24 volts D.C. So at first, the lack of a standard control protocol; precluded the interchange of consoles between dimmer manufactures. This was true of the new smaller portable dimmer racks, such as those made by TTI or by Major Controls for house installations well into the late 70's. However, this was remedied in the early 80's with the introduction of smaller dimmers and the introduction of portable dimmer systems for Rock and Roll tours by console manufactures such as Avab, Avolites and Celco. These manufactures settled on a standard of 0-10vdc.



TTI portable dimmer rack with Pin Connector load patch.

Major Controls installed dimmer Rack

As the quantity of dimmers increased for use in controlling loads, there was also the need to increase the number of console control channels to set intensity for each dimmer. Due to the analog control the dimmers; there was an increase in the number of wires to control each dimmer. In other words each dimmer required a wire to deliver the 0-10vdc, so dimming system with 100 dimmers required a minimum of 101 wires. This total consisted of at least a control positive for each dimmer and a common return or neutral, however the neutral had redundancy to aid in the stability of the control signal.

The best attribute of an analog controlled dimming system was the ease in troubled shooting. It was easy because once the load was verified as good through cross plugging or metering the lamp. There were two other sources of problems either the dimmer was bad or it was receiving a control signal.
The control signal could be verified by metering the incoming signal for 10vdc, if there was no DC voltage then it was either not patched or not up at a level on the lighting console.

NSI high-density dimmers.

As the dimmer count rose in installations and for road use, space requirements became an increasing issue. Some of the first manufactures to address this problem were Strand, CAE, and NSI. CAE with the introduction of their Lepricon dimmer packs that contained six dimmers per "pack", and Strand with their CD 80 dimmer packs that contained twelve dimmers, with the choice of analog or AMX 192.

Contemporary high-density Lepricon dimmers.

Strand CD 80 dimmer pack with thumb wheel addressing and full on buttons.

The previous discussion of historical dimming types builds two ideas, first of which is load patching at a dimmer and the application of ghost loads used with dimmable fluorescents. With the introduction of electronic dimmers and the application of a control signal helped stimulate the reduction in physical size and increase the dimmer counts used in installations and in portable applications. With the higher dimmer count it became necessary to create a control scheme that relied upon a digital protocol to ease the wiring burden in large systems. The DMX 512 digital protocol was created to full fill this need and is still in use today for intensity control.

ETC 48 dimmer rack with pin patch.

The road racks that we use today contain a higher density of dimmers and use the DMX 512 standard. These racks are made in 96, 72, 48 or 24 dimmer rack configurations. The dimmer racks are populated by using a 19" rack mount dimmer pack like the Lepricon or NSI racks. Or using a dimmer module that may contain a single 5K (5000 watt) dimmer, a pair of dimmers, relay module or a fluorescent dimmer module.

ETC "AF" (Advance Features) dimmer module

The dimmers racks that we receive on site to work with are usually made by ETC. However other manufactures such as Lepricon, NSI and Colortran make similar products.

Contained in the dimmer racks are various features. The larger dimmer racks will use an electronics module to manage features of the racks. Some of these are the type of dimmer modules', their order and location within the rack. DMX reception and whether it is being received by the A or B inputs, starting DMX address for the rack. These types of features are contained with in a module call a "CEM" on all ETC racks. In addition to the electronic modules, there are hardware elements that will vary slightly. Modern dimmer racks are built with Soco Pac screw type connectors, Edison convenience outlets, hot pockets and optional pin connectors that are parallel dimmer outputs. These connectors are often mounted on the back of the racks along

Colortran dimmer rack Soco input and Cam Lock view

with the power input connectors that are exclusively Cam-Lock style locking connectors. Along with the assortment of connectors, dimmer racks will also have a breaker on the rack to energize, protect the dimmer rack and personnel from catastrophic failures. There are variations depending on the size of the racks and options that are ordered by the equipment suppliers.

Depending on the quantity of incandescent lamps and layout of the dimmers, a show may have any combination dimmer rack sizes. This is especially true of the industrial shows that done in hotels. These types of shows may have a couple of large capacity dimmer racks such as the 96 racks. Or on the smaller shows, more typically the 24K dimmer racks without a CEM. When the shows use less the 12 lamps than a shoebox dimmer is sent from the rental shop. When any of the dimmer racks are used there will be a method to set its' DMX starting address, either through a thumb wheel of some sort or through a menu driven key pad.

CAE Shoe Box Dimmers with DMX

ETC 24 Dimmer rack with an A/B DMX input. Note the absence of a CEM

As you have seen the essential job or a dimmer rack is: to take a line source of power and distribute it to multiple dimming devices, through a one to one patch or through a load patch interconnect system. Control the amount of current delivered to each lamp. Give each lamp a circuit breaker to protect the personnel working with the equipment and protection to the equipment. Provide over current protection to the dimmer rack.

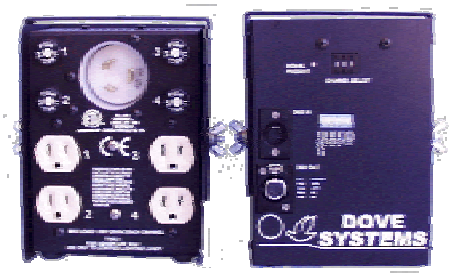
Below are some further types of dimmer racks that you may see.

Strand CD80 House Rack

Dove Systems 12 dimmer pack 19" rack mount

Digital NSI / Colortran 6 dimmer Pack 19" rack mount

ETC Dimmer rack



Dove Systems Shoe Box Dimmer with DMX

Spotlights

No. 1701 ARC SPOTLIGHT

140 Ampere—10-Inch Lens

BEAM SPREAD—4 FT. SPOT TO 100 FT. SPREAD AT 150 FEET DISTANCE

Especially Designed for Light Projection From Motion Picture Booths in Large Theaters

Used for spotlighting and floodlighting performers, stage setting, organist, and musicians in the orchestra pit; also for the projection of special stage-lighting effects from the motion picture booth, in exceptionally large theaters, or from back stage.

THE SPOTLIGHT THAT HAS EVERYTHING!

200 foot throw
Floodlights the widest stage
Six color boomerang
Louver-type air vents
Controls in rear
Marked scales and dial pointers
Exceptionally large heat-resisting lens
Rheostat separate for installation out of the way
Extra slide grooves for special effects
Means for quickly and easily tilting
Projects an intensely brilliant spot or an evenly diffused flood of light
Provides in a single compact unit everything required for white or color-lighting, with framing and fading shutters
Iris shutter
Curtain shutter
Motor-driven arc feed
Safety glass peep-holes
Metal shield eliminates "ghosts"
Center balanced

No. 1701 Arc Spotlight has an arc lamp liberally designed to allow continuous operation at full capacity without overheating, and provided with controls that permit smooth and speedy adjustments of the arc and carbons in every way possibly required. Motor-driven mechanism provides for the automatic regulation of the arc when lamp is in operation, with means for hand regulation when desired.

The arc lamp is mounted on a movable carriage, and travels along the optical axis, thus provides for focusing the light from a spot to a flood. A hand wheel controls the movement of the carriage.

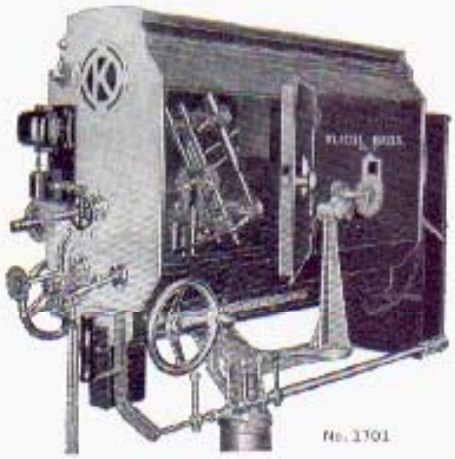
A metal shield, positioned in advance of the arc, eliminates the projection of ghosts or light rings caused by rays from the arc flame entering the optical system, off center.

Both upper and lower carbon holders are fitted with clamps which hold any size carbon from 7/16" to 1 1/8" in diameter—with a firm, positive grip, and good electrical contact. Carbons: trim size recommended for D.C.: top—1 1/8" x 12" cored projector; bottom—1/2" x 6" cored Orotip.

The lens of special heat-resisting glass is removably mounted in a support designed to allow unrestricted expansion, with provisions for adequate movement of air to keep the temperature about the lens at a minimum.

KLIEGL
Arc Spotlight
No. 1701

An Exceptionally Powerful Long-range Arc Spotlight with Color changing and Beam Controls.



No. 1701

As you can see there has been very little change in the last 70 years of follow spots being manufactured and used. The largest change to occur is the elimination of the Carbon Rods that were once burned in a follow spot to produce illumination. The lamp sources in modern follow spots are either a Xenon lamp source or an HMI lamp. Each type of lamp is enclosed within a quartz envelope that uses a plasma arc to produce light. However, there are two spots that use an incandescent lamp source, these are usually used for a very short throw and are often seen today in smaller venues.

When one is called to operate a follow spot, you will be required to use a headset to listen to ques being called by either a Lighting Director as done on most Arena shows. Or a Lead follow spot operator/Roadie under contact on theatrical show.

Typically you will see one of three manufactures lamps as front lights: Strong, Lycian and Robert Juliat. Lycian uses a variant of their front light as a Side and truss light. All the previous spot lights will have the following controls in common: Color boomerang mounted towards the front of the light, intensity dowser or iris, beam size iris, a chopper and a slot on the top of the unit for color or effects. The Juliat's will also have three additional controls: frost that may be dissolved in or out, 3400° Kelvin color correction and blue correction for video usage. They also have a bump button on some models used in conjunction with the intensity iris. There will also be a "trombone" on most all spots that will be able to set the maximum beam diameter on stage.

When a stage call is accepted to run a follow spot you will work in under a Lighting Director in concert venues or Industrial Shows or. In theatrical shows, a Lead Follow Spot operator. Either person will typically have a set list of ques. These ques are called to a follow spot by assigning a number to the position you work at. You will also receive color information by the number it occupies in the boomerang. The spot boomerangs are numbered from Frame one, which is the closest to Frame six; the farthest away from the operator.

The intensity value is given as a percentage except out, being no light emitted from the front of the lamp. Otherwise all other intensities are given as a percentage to 100% or full. Intensity changes will be asked for as a bump which is a 0 count or in time. A timed fade may be a two to fifteen count fade up or out. When a bump out command is given, means a 0 count to go to 0 intensity. In addition to the calls on intensity values, you can be called upon to ride the intensity iris in order to correct for the distance you are from your spot position. The reason for this is the person you are following is perceived to be illuminated at the same relative level.

The chopper may also be used in conjunction with the intensity dowser on the Strong and Lycian brand follow spots. This is useful, when the beam iris is open to cover more than two people. The chopper is used to make a shutter cut from the top and bottom of the beam on stage like a Leko.

Another, necessary control to use is the beam Iris, which adjust the size beam on light on stage. The person calling the follow spot ques will tell you the size. The size is stated as follows and is the literal meaning. Full body, half body, knee and head shot. You will be asked to do these in time, the same as intensity changes. In addition to the simple beam sizes assigned to you, riding the beam size to keep the same size, as the actor moves will also be required of you.

The person calling spot ques will either work off a Set List as done for Rock Shows or a more sophisticated means for Theatrical Shows. A spot caller on a theatrical show will often use a list with all the information need to call the Show. The following are a couple of examples of this. However, when the que list is given to an operator, it may resemble the one the caller uses or broken down to each follow spot by lamp number.

On smaller shows, the spot caller will simply call the show to you, with expectations that each show will improve.

The following pages show master call sheets that is used for theatrical shows. There is a que number given as a reference, a brief description, and the action required by each light. Typically the person calling the show will give you a set-up in advance of the next ques, followed by a "standby" when one able and always a "Go".

	LION KING CHEETAH TOUR	SPOT CALLING SCRIPT
CUE	**Description**	
	Sc.1 Circle of Life	SPOTS **5**,1,2 **FR.3** SPOTS 3,4 FR. 2-4
102.5	Rafiki after 1st line	**5 25% RAFIKI H DSL**
105.5	W/Q 105.5 (sun rises)	**5 WIDEN to 3/4 BUILD TO 75%**
109	Cheetah enters SR	
110	5 cts after Cue 110	**5 TIGHTEN to AVOID PROCESSION**
	After Cheetah face wash	
111.3	end Rafiki solo	**5 F/O 3ct (5 chng FR.2-DF)** 1 100% SOLOIST SL W 2 100% SOLOIST SR W
111.4	Mufasa/Sarabi up rock	
	2nd lap w/rock	
112.6	w/ Q112.6 -(vari*lite up)	
112.7	Soloists turn US for group bow towards Rock	**1,2 F/O (1,2 chng FR.2-DF)**

Page from "*Lion King*" Spot Book, with all lamps and actions for each lamp.

"ALL SHOOK UP"
Master Spot List
12/30/04

Chicago - Palace

Lighting by

FRONT: L162+R3318

Frame 1: Single Baggie
Frame 2: 1/2 CTO R3408
Frame 3: True Pink R337
Frame 4: Pale Gold L152
Frame 5: Full CT Blue L201
Frame 6: Lavender CalColor R4915

F/B: Full Body
1/2 BDY: 1/2 Body
H/S: Head & Shoulders
P/U: Pick up
c: time count

AF: Auto Follow
B/U: Bump up
AF: Autofollow
Default 3 c

Cue #	Action	Spot 1	Color	Body Int'y	Spot 2	Color	Body Int'y	Spot 3	Color	Body Int'y	Cue #
Act 1 sc 1 - Outside Gas Station - Love Me Tender											
11	with LQ (Scrim Bleed Thru)				**P/U Natalie** (SR at Pump)	Fr: 1+4	Tight 1/2 Bdy GLOW				**11**
in **11**	Bouquet Thrown				**Fade Up** to just over 1/2 Inty 1c						
in **15.5**	Dennis Enters from SL DS SCRIM	**P/U Dennis** 1c	Fr: 1+4	Tight 1/2 Bdy Just Over 1/2 Inty							
16	Dennis Sings				**Fade Out** 1c						**16**
17	Solo Over				**Bump Restore to 1/2 Inty**						**17**
18	Dennis Exits	**F/O with Exit** not pass pump									**18**
19	with LQ end of scene				**F/O in Place**						**19**
		Color Change to Fr: 1+2			*Color Change to Fr: 1+2*			*Color Change to Fr: 1+2*			
Act 1 sc 2 - Sylvia's Honky Tonk - Heartbreak Hotel											
19.5	ASAP when scrim clears				**P/U Sylvia** C	Fr: 1+2	1/2 Bdy Full Inty	**P/U Lorraine**	Fr: 1+2	1/2 Bdy Full Inty	**19.5**
in **19.5**	Dennis Enters	**P/U Dennis** SR	Fr: 1+2	1/2 Bdy Full Inty				**F/O** 5c (hold a bit longer after dennis enters)			
20	with LQ Top of Song				**Fade Out Sylvia**			**B/U BarFly** SR	Fr: 1+2	3/4 Bdy Full Inty	**20**
22	with LQ	**Fade Out**									
22	3 BEATS after LQ							**Fade Out**			**22**
23	Female Soloist (SR)							**P/U 2nd Barfly soloist**	Fr: 1+2	1/2 Bdy Full Inty	**23**
in **23**	2nd Barfly Finish Vocal							**Fade Out**			
23.5	Sylvia Sings				**P/U Sylvia** 2c up						

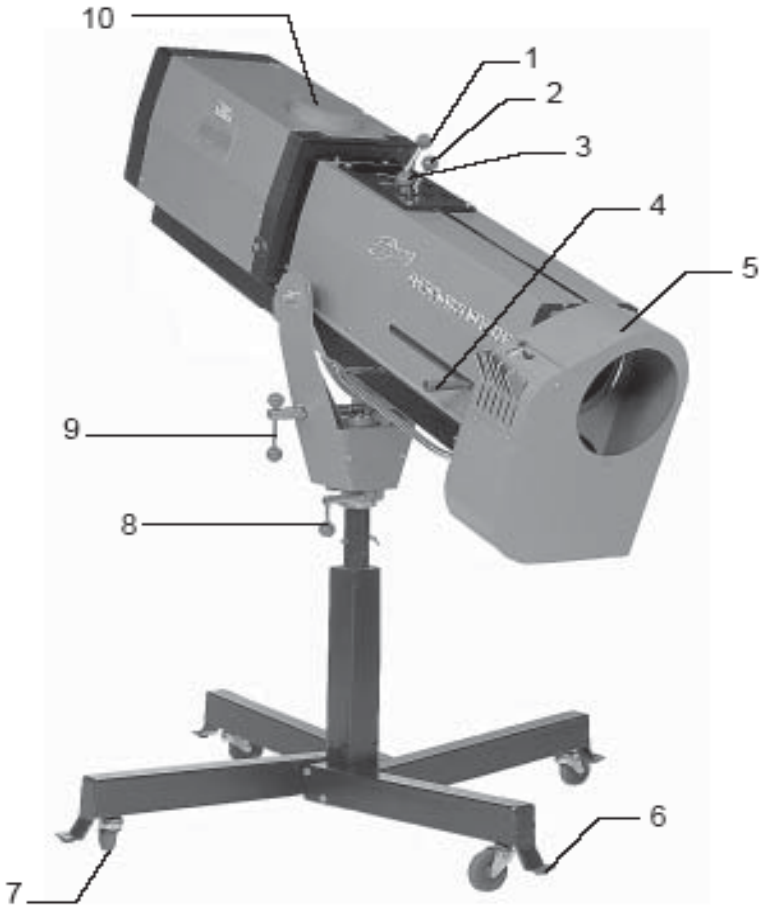
Comparing the two Master call sheets you will see notice one is easier to read. The "*All Shook UP*" spot sheet was also the spot que list that each operator was given. I believe you will find it hard to read, and there fore, much more difficult to extract information out of quickly during a show. Much of the confusion can be attributed to the size of the text, which was chosen to get more information on each page. Because, if you get lost during a show, or wish to look ahead at your next ques, a-lot of time will be spent finding your place. You will also notice the hand written notes that were made for changes. Often times there are errors or changes that do not make it onto the sheets, which the operator uses. However the master sheets are the final arbitrator to any questions.

Sweet Charity
Followspot Cue Sheet - MASTER

Lighting By: Brian MacDevitt
Assistant Lighting Design:
Jennifer Schriever

Q Ref.	Placement	Spot 1	Spot 2	Spot 3
Scene: POND				
9.5	*With her entrance UR*	**SB** Something better than this in overture		
Notes		OFF F2 - SOFT	Pick Up CHARITY ENTERS UR 3/4 BODY FULL 1 CT F2 - SOFT	OFF F2 - SOFT
IN 10	*With his entrance SR*	**SB**		
Notes		Pick Up "Charlie" ENTERS SR HALF BODY FULL 1 CT F2 - SOFT	CHARITY F2 - SOFT	OFF F2 - SOFT
IN 11	*When he pushes her in*	**SB**		
Notes	**SHE IS PUSHED IN SPOT 1 WITH HIS EXIT**	Fade Out "Charlie" & CHG COLOR 3 CT F4 - SOFT	Bump Out CHARITY 1 CT F2 - SOFT	OFF F2 - SOFT
IN 11.5	*WITH his entrance SL, anticipate speaking*	**SB** ASAP		
Notes		OFF F4 - SOFT	OFF F2 - SOFT	Pick Up COP ENTERS SL HALF BODY FULL 1 CT F2 - SOFT

The different controls and locations are shown in the following pictures:

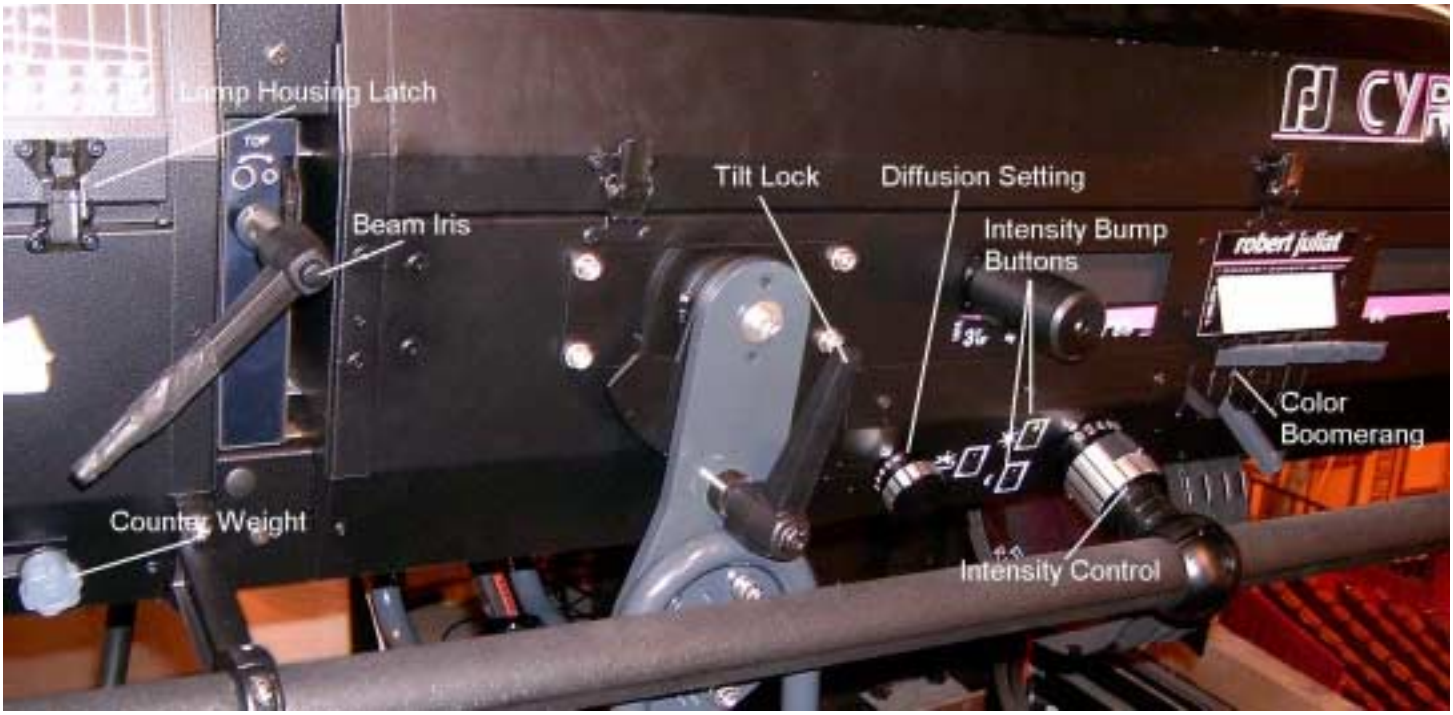


1. Fade-Out Mechanism Control Lever
2. Masking Shutter (Chopper) Control Lever
3. Iris Control Lever
4. Spot Size Control Handle
5. Color Boomerang
6. Leveling Foot Bracket (1 of 4)
7. Caster (1 of 4)
8. Horizontal Swing Control Lever
9. Vertical Tilt Control Lever

Strong International Xenon Super Trouper

Lycian 2k and 3K lamps, not shown is the ballast.

Lycian Stark Light, shown with out ballast.



The picture is of Robert Juliat Cyrano Follow Spot controls. The Aramis lacks the bump buttons; diffusion setting knob, and the intensity knob is substituted. While the Intensity control is deleted.

Changing Lamps in Follow Spots

Changing HMI or Xenon lamps in a spotlight can be a dangerous job to do. In all cases one should wear a full-face safety shield and at the minimum a long sleeve shirt. However, it is strongly suggested that a leather-welding shirt be worn for protection in case the lamp envelope breaks and the lamp explodes.

When spot lamps need to be changed they will exhibit some tell tale conditions. These may be the arc dancing around in the field; this can be seen on stage. The lamp noticeably getting dimmer while struck up and dimming down as you look at it. Or there may be a catastrophic failure of the lamp simply exploding while the lamp is struck up. All lamp manufactures will also specify the maximum number of hours a lamp should be use. Knowing the lamp hours is the simplest and safest way to determine when the lamp should be changed.

The lamp housings generally have security screws of some sort when they are released from the factory to prevent untrained personnel from changing lamps. However, some lamps encountered will have standard fasteners instead to facilitate faster lamp changes. You may also need a crescent wrench, Allen keys, wire cutters and a nut driver. Consulting the maintained books that are included will tell you the tools necessary and any factory specified safety equipment that is needed to change the lamps. Once you have all the tools necessary, it may also be necessary to remove any ventilation equipment attached to the chimney's and locking the tilts down on the lamps is necessary to do.

3K Xenon Lamp from a Lycian 1293 that burned out. Note the black envelope surrounding the anode and cathode. You can also see the Lamp seal or PST, upper right of lamp

Following are the safety procedures as outlined by *Strong International in their Xenon Super Trouper, Short Throw Manuel Type 83061 and 83081 Rev. January 2004*. You should read these over and be familiar with their content.

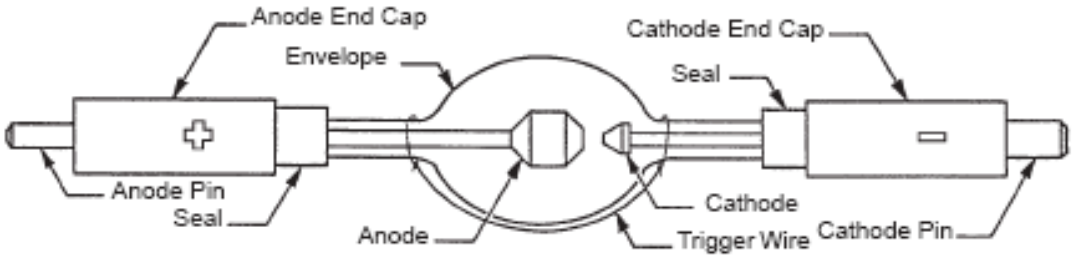
In addition to the safety content there is also a very good lamp illustration above, that explains the different parts of a Xenon lamp which is necessary to properly install this type of lamp in a follow spot

SAFETY PROCEDURES

THE XENON BULB is highly pressurized. When ignited, the normal operating temperature of the bulb increases the pressure to a level at which the bulb may explode if not handled in strict accordance to the manufacturer's operating instructions. The bulb is stable at room temperature, but may still explode if dropped or otherwise mishandled.

REFER bulb replacement and service to QUALIFIED PERSONNEL with adequate protective clothing (face shield, clean cotton gloves, welder's jacket). For routine lamphouse service, observe the following rules:

1. Allow the bulb to cool to room temperature before opening the lamphouse. Put on protective clothing described above.
2. De-energize the xenon power supply at the AC source before opening the lamphouse compartment.
3. When possible, encase the bulb in its protective cover when cleaning or servicing the lamphouse interior. The bulb, when outside the lamphouse, must be encased in the cover.
4. Clean the bulb after it has cooled to room temperature. Do not touch the quartz envelope of the bulb; fingerprints will burn in and create hot spots which may shorten bulb life. If fingermarks are made, they should be carefully removed with methyl alcohol and cotton prior to bulb operation.
5. Never view an ignited bulb directly. BLINDNESS OR PERMANENT EYE DAMAGE MAY BE INCURRED.
6. Use only xenon bulbs designated as OZONE FREE. When possible, vent the lamphouse exhaust to outside atmosphere.
7. Maintain the lamphouse blower in good operating condition. Keep the blower inlet clean for unrestricted air flow.
8. To insure maximum bulb life, operate the lamphouse blower and the exhaust system for *at least* ten minutes after extinguishing the bulb.
9. If returning a bulb for warranty adjustment, pack it in its original shipping container. Complete and return all required warranty information.
10. Dispose of expired bulbs that are beyond warranty in the following manner: Wrap the bulb tightly in several layers of canvas or heavy cloth. Place it on a hard surface and shatter the envelope with a sharp hammer blow. DO NOT place an unshattered bulb in an ordinary refuse container.
11. DO NOT PERMIT UNAUTHORIZED PERSONNEL TO PERFORM OR ATTEMPT ANY PHASE OF XENON BULB HANDLING OR SERVICE.

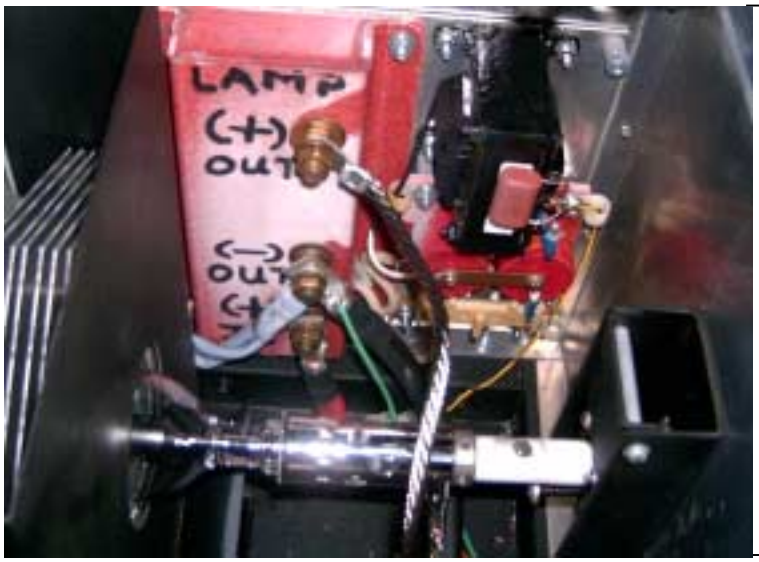


On the Xenon Super Troupers you will need to remove the four security screws that are on the top of the unit in the four corners. The fifth screw is a standard one and it is left alone. Once the screws are loosened and removed the top of the lamp housing pulls up. The foam gasket may provide some resistance, simply pull with steady force and it should come up.
This when your specified safety equipment should already be on! If it is not put it on! A cavalier attitude will not bring back your eye site.

Once the lamp housing is removed take note of the anode (+ Positive end) and Cathode (-Negative end) are located this is important.
On some models of Strong products lamp adapters are necessary for proper installation of the lamps, consult their instructions it there is any question.
Loosen the Allen screw that tightens the collets around the cathode and then the anode. Take note of the location of the trigger wire (really thin copper wire wrapped around the lamp or attached to the ends) if either or both ends are attached to the end

Remove the collet from the anode end will provide more room to slide the lamp out through the hole in the reflector. Remove any leads prior to removal or install prior to attachment to the anode or cathode. Once the lamp is ready to install insert the anode end first in the shock mount and then the cathode end of the lamp. Tighten Allen screws snuggly to prevent stress on the Quart lamp.

If the trigger wire is touching the reflector on strike up it may short circuit the current and cause bulb failure. Compare the old and new bulbs. The trigger wire should look like the old bulb



Lycian long through spotlights, have four screws that hold the top of the lamp housing onto the fixture. These screws may or may not be security screws. In the photo you can see the silver thread holes for their location.

The rear lamp base end uses the braided lamp lead. A threaded stud is used as its termination on the control board. Remove the nut that holds the anode bases braided lamp wire from the control board. The rear of the lamp is held in place by a collet and an Allen screw set screw. The front and rear set screws are loosened to facilitate removal of the lamp.

To the right is a photo of the front shock mount and Allen set screws. Once the Allen screws are loosened the lamp is installed and removed from the front side of the reflector. .

Prior to installation of the new lamp, remove the thumbnuts on the anode and Cathode. Check the bad bulb for the trigger wire, it's removed duplicate on new lamp. Once these are removed the lamp may be reinserted into the lamp base and the setscrews tightened, and the braided lamp lead reattached to the control board. If the lamp was touched clean with alcohol to remove the fingerprints.

Assuming the lamp struck up, the next step is to optimize the lamp. Like a Leko, you will want a bright lamp that has a flat or peak field; depending on the show. The upper knob moves the bulb in a circular motion in the reflector and the lower one, in/out. This is done simply by trial and error and there may some resistance to bulb movement. Simply use care when doing this!

Following are excerpts from Lycian's 1293 Spot Light Manuel for Lamp replacement. Note the removal of the trigger wire in the second to last paragraph.

LAMP SPECIFICATIONS

The correct lamp for this fixture is a 3kW short-arc discharge lamp with a xenon gas filled envelope.
The lamp voltage is 30V DC and requires a current of 100A maximum which is provided by the electronic ballast for the fixture.
The anode (+) terminal is 9.5mm diameter with a cable attached for connection to the ignitor. The cathode (-) terminal is 8.0mm diameter.
The overall length of the lamp is 342mm, with a globe diameter of 60mm.
The lamp has a suggested life expectancy of 1200 hours. The lamp light output diminishes with age as the inside of the globe blackens and therefore the lamp maybe replaced earlier to maintain high output levels.
The lamp should be rotated through 180 degrees along its length after 600 hours so that the top blackened area is at the bottom, avoiding blackening in one spot.

The recommended manufacturers of suitable lamps are:

Osram XBO 3000 W/HS OFR

Yumex YXL 30SC

Ushio CXL30SC

Optical Radiation Corp (ORC) XH3000HS

LAMPING.

Remove all electrical power from the fixture by turning off the 30A circuit breaker on the power tray or by turning off the wall disconnect switch.

Remove the lamphouse top cover by undoing the six security screws using the special torx wrench provided with each followspot.

On removal of the xenon lamp from its protective container, using a pair of small wire cutters, clip off the very thin assist wire that goes across the lamp globe and attaches to the +ve terminal. Discard this wire.
If this wire is not removed, it is probable that the ignition voltage (50KVAC) will jump between this wire and the reflector rather than striking across the lamp electrodes inside the globe.

Tilt the front lamp support forwards.

Standing on the right hand side of the lamphouse, and holding the xenon lamp (+ve) terminal in the left hand, insert the (-ve) terminal through the hole in the rear of the reflector. Bring the front lampholder up to meet the lamp and insert the terminal into the front lampholder block. Do not tighten the two screws at this time. Insert the (+ve) terminal into the rear lampholder insulator/collar. Tighten the rear collar screw when the terminal is fully seated in the (+ve) rear lampholder.

Attach the (+ve) electrode wire to the **top** 3/8 dia stud on the red ignitor. Secure with the 3/8 nut and lockwasher. Tighten the nut with a wrench ensuring that the lug remains away from any grounded metal.

Rotate the lamp counterclockwise (as seen from the front of the fixture) with the lamp (+ve) wire loosely wrapped around metal part of the lamp end.
IMPORTANT. LAMP LEAD MUST NOT COME CLOSER THAN ONE INCH FROM ANY METAL PART (other than lamp end) OR ARC-OVER WILL OCCUR.

Assure lamp (-ve) terminal is fully seated in the front lampholder and tighten the two socket cap screws evenly. As a final check make sure all lamp fittings and connections are tight and that the cable is correctly routed away from chassis metalwork. Also make sure that any tools or other loose items are not in the lamphouse and that nothing has fallen into the blower.

Replace the lamphouse top cover with the top exhaust vent towards the rear of the fixture. (The holes will not align if reversed.) Fasten using ONLY the security screws and special torx wrench provided.

Open rear door. Loosen the top of the two lamp adjustment knobs enough that the knob can be moved and center it within its range of travel. Retighten the knob. Close the rear door.

DE-LAMPING

When the lamp needs to be removed or rotated longitudinally, use the following procedure.

Remove all electrical power from the fixture by turning off the 30A circuit breaker on the power tray or by turning off the wall disconnect switch.

Prepare the xenon lamp protective container provided by the lamp manufacturer.

Remove the lamphouse top cover by undoing the six security screws using the special torx wrench provided with each followspot.
Using a 9/16" wrench, disconnect the lamp cable from the top of the ignitor. Allow the cable to hang freely but do not allow the cable to hit the lamp glass in any way.
Loosen the socket cap screw on the collar of the lamp rear support.

Loosen the two socket cap screws evenly on the front lamp support block.

Holding the negative terminal (front) in the right hand, ease the positive terminal (rear) out of the collar keeping hold of the lamp at both ends at all times.
With the right hand ease the negative terminal out of the front support block.
Using the left hand gently pull the lamp out from the back of the reflector.

IF THE TERMINAL APPEARS TO BE STUCK, IT MUST BE LOOSENED. DO NOT USE EXCESSIVE FORCE TO PULL OR TWIST THE LAMP TO FREE IT.

AVOID THE LAMP GLASS FROM HITTING THE EDGES OF THE REFLECTOR AS IT IS REMOVED FROM THE LAMPHOUSE. A soft cloth may be used.

Lay the lamp carefully in its protective container and secure it closed.

If the lamp is being removed for transportation, make sure that the front and rear lamp terminal screws are tightened and place the 3/8" nut and washers back onto the ignitor and tighten.

The Juliat Cyrano follow spots have the easiest accessibility to the lamps. Two latches hold the lamp cover closed. Once open you will see the control board and lamp.

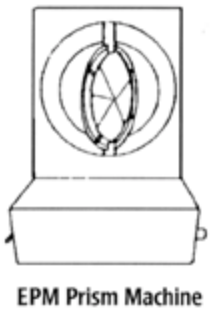
Removal/ installation of the lamps is accomplished by loosening the top brass nuts on the long standoffs. Pulling them up to the top and had tightening them on the threads provided. (Do not Remove them). Once they are out of the way there are two clamps that hold the lamp to the lower part of the lamp base, these swing out of the way. The lamp itself is held by the two large heat sinks that are split in half. Once the lamp is removed, take note of the condition of the reflector. It is my experience that the reflectors loose the reflective coating and may need replacement. Good ones are shiny like a “mirror”. A bad reflector will look like an old duplex box on the wall.

The lamp is pulled out of the heat sinks and the new one is then reinserted into each heat sink. The lamp will seem a little loose in these, which is okay. When you are ready to reinstall the lamp, make sure the PST or the little glass nub is at about 11:00 O’clock. Once the lamp is set into the lower half of the lamp base the upper half is gently replaced. The brass screws are threaded onto the lower part of the stand-offs and snugged down. DO NOT Tighten truss bolt tight. They are left snug for heat expansion! These lamps have no optimization settings.

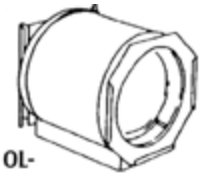
Lycian Short Throw ballast is integrated onto light,

Pani Follow Spot

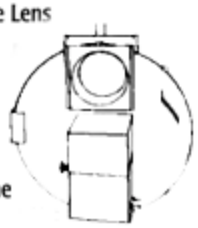
Morphous Ultra Quartz, Incandescent follow spot.



EPM Prism Machine



OL-
Objective Lens



EDM
Disc
Machine

Below is a portion of table 400.4 that lists some of the applicable cable for theatrical use See APENDIX for more detail and if further detail is necessary consult the National Electrical Code 2002.

Trade Name	Type Letter	Voltage	AWG or kcmil	Number of conductors	Insulation	Nominal Insulation Thickness			Braid on Each Conductor	Outer Covering	Use		
						AWG or kcmil	mm	mils					
Junior hard service cord	SJOW See Note 13	300	18-10	2-6	Thermoset	18-12	0.76	30	None	Thermoset	Pendant or portable	Damp and wet locations	Hard usage
	SJOO	300										Damp locations	
	SJOOW See Note 13	300										Damp and wet locations	
	SJT	300			Thermoplastic	10	1.14	45		Thermo-plastic		Damp locations	
	SJTW See Note 13	300										Damp and wet locations	
	SJTO	300				18-12	0.76	30		Oil-resistant thermo-plastic		Damp locations	
	SJTOW See Note 13	300										Damp and wet locations	
	SJTOO	300			Oil-resistant thermo-plastic							Damp locations	
	SJTOOW See Note 13	300										Damp and wet locations	
Hard Service Cord	SO See Note 4	600	18-2	2 or more	Thermoset	18-16	0.76	30		Oil-resistant thermoset	Pendant or portable	Damp locations	Extra hard usage
	SOW See Note 4 See Note 13	600										Damp and wet locations	
	SOO See Note 4	600			Oil-resistant thermoset	14-10 8-2	1.14 1.52	45 60				Damp locations	
	SOOW See Note 4 See Note 13	600										Damp and wet locations	

A portion of table 400.4 that lists applicable cable for theatrical use. See APPENDIX for more detail.

Size AWG or kcmil	60°C (140°F)			75°C (167°F)			90°C (194°F)		
	D1	E2	F3	D1	E2	F3	D1	E2	F3
12		31	26		37	31		42	35
10		44	37		52	43		59	49
8	60	55	48	70	65	57	80	74	65
6	80	72	63	95	88	77	105	99	87
4	105	96	84	125	115	101	140	130	114
3	120	113	99	145	135	118	165	152	133
2	140	128	112	170	152	133	190	174	152
1	165	150	131	195	178	156	220	202	177
1/0	195	173	151	230	207	181	260	234	205
2/0	225	199	174	265	238	208	300	271	237
3/0	260	230	201	310	275	241	350	313	274
4/0	300	265	232	360	317	277	405	361	316

The exemplary cables are permitted to be use for such things as: wiring of luminaries (lighting fixtures), connection of portable lamps, portable and mobile appliances, data processing cables, or connection to moving parts. Obviously plugs may be attached to both ends. You should not use flexible cables though to substitute for permanent wiring in structures. Also splices within a flexible cord length should not be used when a cord is damaged replace it. Protecting the cords from damage is relatively simply use bushings in conduit boxes when one making a portable receptacle box, use rubber matting and the like and avoid running cable around sharp objects without protection to avoid damage.
Also a flexible cable may be used for chain-supported luminaries (lighting fixtures). More detail can be found in Article 400.7 through 400.11 in the National Electrical Code 2002.
While making cables, hooking-up to service panels or the like you will be called upon to identify load carrying conductors, usually a solid color or with tracer lines/ stripes. You should also be able to identify with some certainty the ground. Like all things commonly used in electricity a standard is established by the NEC. Article 250.119 defines the identification of equipment grounding conductors.

Size(AWG)	Thermo-	Thermoset Types: C,		Types
		Thermoplastic Types		
		A	B	
27	0.5			
20		5**	***	
18		7	10	10
17			12	13
16		10	13	15
15				17
14		15	18	20
12		20	25	30
10		25	30	35
8		35	40	
6		45	55	
4		60	70	
2		80	95	

Table 400.5(A) Allowable ampacities for flexible Cords and Cables based on
Ambient Temperature of 30C (86°F).
*Tinsel Cord
**Elevator cables only

(C) Only qualified persons service the installation, one or more insulated conductors in a multi-conductor cable at the time of installation, shall be permitted to be permanently identified as equipment grounding conductors at each

The allowable currents under subheading A apply to 3-conductor cords and other multi-conductor cord connected to utilization equipment so that only 3 conductors are current carrying. The allowable
Currents under subheading B apply to 2-conductor cords and other multiconductor cords connected to utilization equipment so that only 2 conductors are current carrying.
Article 250.119 states: Identification of Equipment Grounding conductors.
Unless required elsewhere in this Code, equipment grounding conductors shall be permitted to be bare, covered, or insulated, Individually covered or insulated equipment grounding conductors shall have a continuous outer finish that is either green or green with one or more yellow stripes except as permitted in this section.

(A) Conductors Larger Than 6 AWG. An insulated or covered conductor larger than 6 AWG copper or aluminum shall be permitted at the time of installation, to be permanently identified as an equipment grounding conductor at each end and at every point where the conductor is accessible, Identification shall encircle the conductor and shall be accomplished by one of the following:
    (1) Stripping the insulation or covering from the entire exposed length.
    (2) Coloring the exposed insulation or covering green.

Marking the exposed insulation or covering with green tape or green adhesive labels.

(B) Multi-conductor Cable. Where the condition of maintenance and supervision ensure that

Rating or setting of Automatic Overcurrent device in circuit. Ahead of Equipment, conduit etc. **Not exceeding Amperes**	Size (AWG or Kcmil) Copper
15	14
20	12
30	10
40	10
60	10
100	8
200	6
300	4
400	2

end and at every point where the conductors are accessible by one of the following means:

(1) Stripping the insulation from the entire exposed length.
(2) Coloring the exposed insulation green.
(3) Marking the exposed insulation with green tape or green adhesive labels.

(D) Flexible Cord. An un-insulated equipment-grounding conductor shall be permitted, but if individually covered; the covering shall have a continuous outer finish that is either **green or green with one or more yellow stripes.**

Article 250.122 Size of Equipment Grounding Conductors.

(A) General. Copper, aluminum, or copper-clad aluminum equipment grounding conductors of the wire type shall not be smaller that shown in Table 250.122 but shall not be required to be larger than the circuit conductors supplying the equipment. Where a race way or a cable armor or sheath is used as the equipment grounding conductor, as provided in 250.118 and 250.113 (A) it shall comply with 250.4 (A) (5) or 250.4(B) (4).

For most of, if not all of our applications in the theatre all cable is copper, due to this I will only include the portion of table 250.122 which lists copper and its capacity in amperes and up to 1000 amps in capacity and section "E". For a complete overview of this article consult the NEC 2002.

(C) Multiple Circuits. Where a single equipment-grounding conductor is run with multiple circuits in the same raceway or cable, it shall be sized for the largest overcurrent device protecting conductors in the raceway or cable.

(E) Flexible Cord and Fixture Wire. Equipment grounding conductors that are part of flexible cords or used with fixture wire in accordance with 240.5 shall be not smaller that 18 AWG copper and not smaller than the circuit conductors.

250.124 Equipment Grounding conductor continuity.

(A) Separable Connections. Separable connections such as those provided in drawout equipment or attachment plugs and mating connectors and receptacle shall provide for first-make, last break of the equipment-grounding conductor.

First make, last-break shall not be required where interlocked equipment, plugs, receptacles, and connectors preclude energization with grounding continuity.

250.126 Identification of Wiring Device Terminals.

The terminal for the connection of the equipment grounding conductor shall be identified by one of the following methods:

(1) A green, not readily removable terminal screw with a hexagonal head.
(2) A green, hexagonal, nor readily removable terminal nut.
(3) A green pressure wire connector. If the terminal for the grounding conductor is not visible, the conductor entrance hole shall be marked the work *green* or *ground*, the letters *G* or *GR*

or the grounding symbol shown in Figure 250.126, or otherwise identified by a distinctive green color. If the terminal for the equipment grounding conductor is readily removable, the area adjacent to the terminal shall be similarly marked (as seen to the right).

250.138 Cord-and-Plug-Connected Equipment.

Non-current-carrying metal parts of cord-and-plug-connected equipment, shall be grounded by one of the methods in 250.138 (A) or (B).

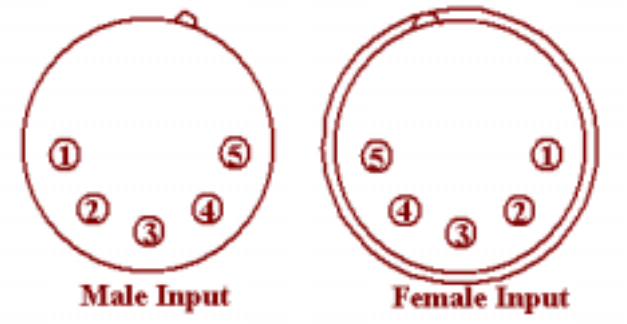
(A) By means of an Equipment Grounding Conductor. By means of an equipment-grounding conductor run with the power supply conductors in a cable assembly or flexible cord properly terminated in a grounding-type attachment plug with one fixed grounding contact.

(B) By Means of a Separate Flexible Wire or Strap. By means of a separate flexible wire or strap, insulated or bare, protected as well as practicable against physical damage where part of equipment

250.146Connecting Receptacle Grounding Terminal to Box.
An equipment bonding jumper shall be used to connect the g rounding terminal of a grounding-type receptacle to a grounded box unless grounded as in 250.146 (A) through (D).
250.146 Connecting Receptacle Grounding Terminal to Box, means that unless your receptacle is in direct contact with the box in which it will be mounted in a jumper is necessary to ensure the ground. For example, an extension cord with a quad box on the end will be used to illustrate the point. It is standard practice to use a quad box cover to mount both receptacles, neither the spring-type grounding strap or the yokes (ears) are in direct contact with the box. The receptacles are separate from the box, as such a bonding jumper is necessary to complete the ground and affect a solid mechanical contact between the receptacles and the box. This example, works the same way when the quad box cover is attached to a box mounted to a wall with conduit running it to.

Control Signal General

A majority of lighting equipment uses a digital protocol called DMX 512, which is based on the RS485 computer standard for serial communications. The data transmissions are transmitted through a pair of wires, pins 2 data – (usually black) and pin 3 data + (usually white). There is also a shield that is connected to pin 1 and two spare data cables terminated at pins 4 & 5.



It is suggested by USITT (United States Institute for Theatre Technology) not to use 3 pin connectors, due to the cable's poor data transmission characteristics If the cable satisfies the USITT standard of: a 22-24 AWG, a twisted pair, 120ohms, shielded EIA 485 cable it should work though. However, you will find suppliers that use, it and therefore it could be a source of equipment errors.

When using DMX 512 a terminator is to be used, and more often than not the lack of a termination is the most common fault in a newly hooked up DMX 512 system. A terminator is a resistor fitted between the two data lines (pins 2 & 3 of and XLR 5 pin connector) at the end of the cable furthest from the transmitter at the end of a *daisy chain.* If a terminator is not fitted at the end of a daisy chain, then the data signal arrives at the end and a reflection is caused, sending the data back to the signal transmitter (console). This is a problem because the reflection may equal in magnitude the real data signal and cancel out the real one. Therefore, the job of the terminator is to "soak up or absorb the signal at the extreme ends of the data path. A terminator may be a 5 pin male XLR connector with a resistor connected to pins 2 & 3 contained within a connector shell. If the termination is made internally in a device, it is enabled via a switch that may be labeled "end-of-line", last rack, or terminator on/off.

The value for the termination optimally should be at 90-120ohms ¼ watt. The console serves as a terminator at the beginning of the data run, so it does not require one.

In the event of a problem to help determine fault, a simple and overlooked quick check is to unplug the cable from the data source and take a meter to the cable end. Check between pins 2 & 3, the resistance should be at 90-120 ohms. This will vary according to cable length and cable wire gauge used for the data run.

When a single cable run is used from the console to the last receiving device, the cable should have a maximum of 32 units on it. The receivers, are usually connected though the previous device in a daisy chain. This is normally accomplished using and input and an output connector or pass through. **The theoretical maximum length is 3,281' feet, however it is recommended not to exceed 1,640' feet, at the greater length signal** amplifiers (repeaters) are suggested by the standard.

When laying out DMX 512 cable avoid, if possible running signal cable with power cabling, particularly load cable from dimmers, due to the possibility of induced interference. The use of Y cable or DMX 512

twofers is not recommended because it introduces reflections and causes signal problems. A splitter amplifier can be used to create two different branches for the control data to be sent on. Another source of interference is radio transmissions that may cause data errors.

Address setting

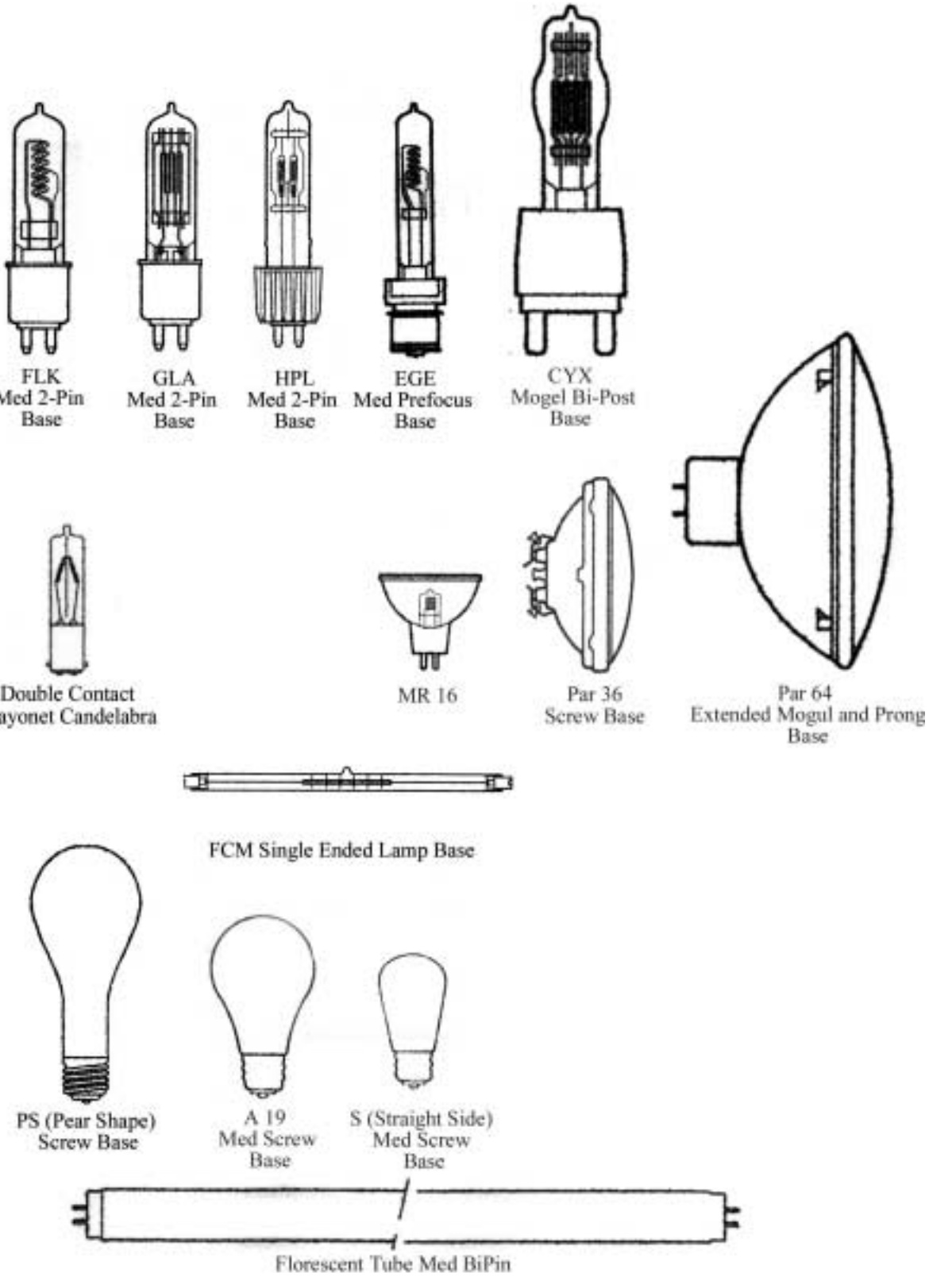
All DMX 512 devices, except those that read all 512 channels have a way to set their addresses to respond to que data transmitted by a control console. One method is to employ a base or starting address, where the device will start with that address for each sequential dimmer or parameters contained in that device. Digital display and keys, these generally may use any starting address in the first universe of DMX control channels, were the address settings are one on many menu driven selections that may be made. Thumbwheel switches are another means to address a device, which is very simple to use and allow direct access to the address to be set. The thumb wheels are usually in set of three and one simply spins the thumb wheel set an address, due to the numerical range built into a thumbwheel, address's may be set from 000-999. However, not all numerical combinations may be valid and may set test modes are give you universe off sets for more address flexibility.

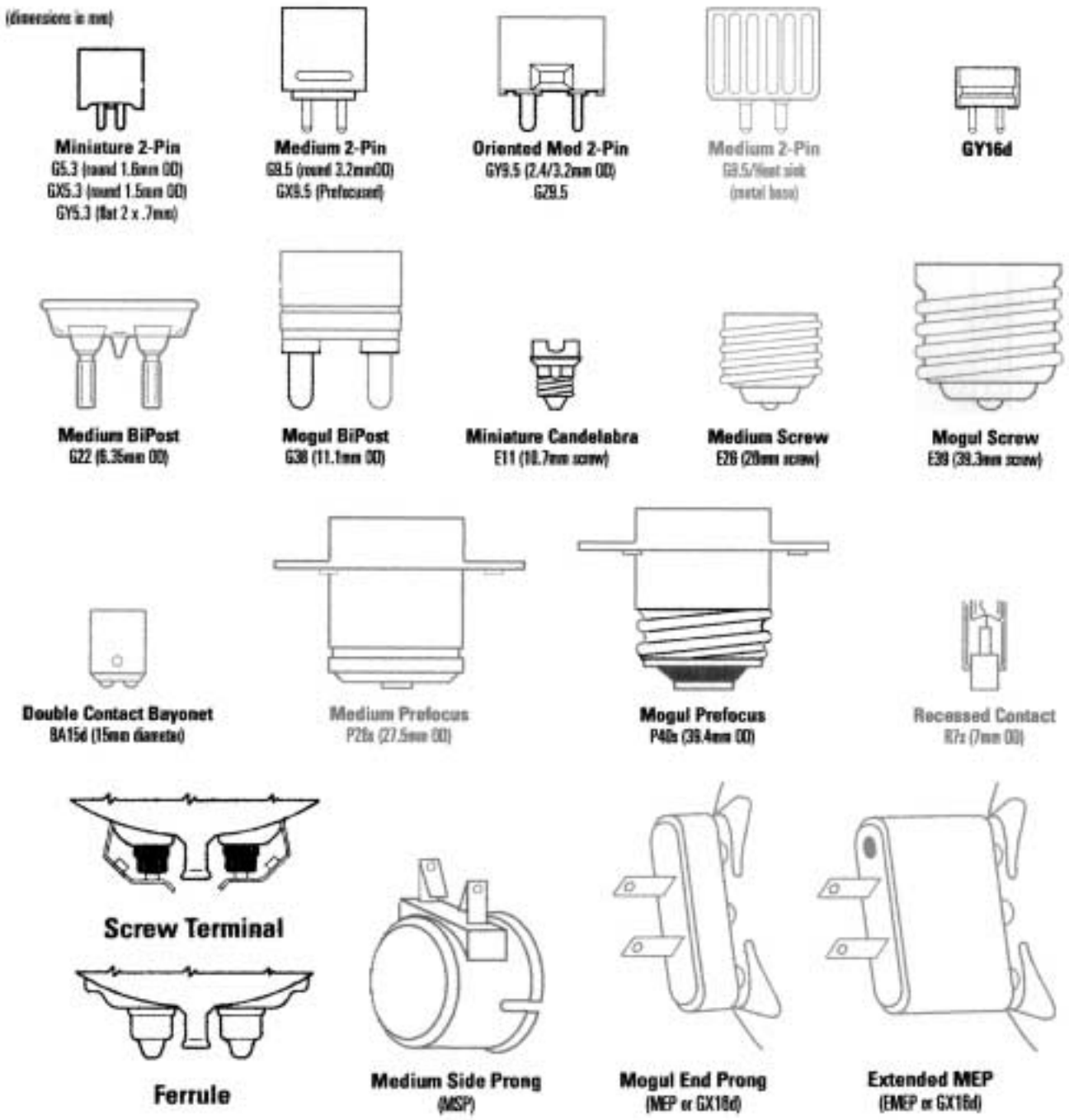
Dipswitches are another popular means to set an address. These small rocker switches are grouped in banks and each switch is given a numerical weight and is either on or off. This scheme is not universally implemented by all manufactures in the same way. However a general rule is: switch 1=address 1, switch 2=address 2, switch 3=address 4, switch 4= address 8, switch 5= address 16, switch 6= address 32, switch 7= address 64, switch 8= address 128, switch 9= address 256. Using the first nine addresses, as an example will illustrate this. Note: it is assumed that using the USITT binary address scheme, that address one (1) is all dipswitches as off or 0. Also, the addresses may either start from the left or right, in which case the same number assignments are still used.

256	128	64	32	16	8	4	2	1	Address
0	0	0	0	0	0	0	0	0	**1**
0	0	0	0	0	0	0	0	1	**2**
0	0	0	0	0	0	0	1	0	**3**
0	0	0	0	0	0	0	1	1	**4**
0	0	0	0	0	0	1	0	0	**5**
0	0	0	0	0	0	1	0	1	**6**
0	0	0	0	0	0	1	1	0	**7**
0	0	0	0	0	0	1	1	1	**8**
0	0	0	0	0	1	0	0	0	**9**

Within the DMX standard, there are allowances for additional addresses. These additional addresses are found in Ports. A Port is a usually a numbered output on the back of a console. Often times ports are used to divide up addresses, one group for fixed lighting fixtures, color changers and finally for moving lights. Using the ports in this fashion provides for a means of organizing the addresses and provides for a fast means of recall as to where devices are located in the address organization. The following is a brief example of this:

Device address	Port 1	Port 2	Port 3	Port 4	Port 5	Port 6
1	1	513	1025	1537	2049	2561
2	2	514	1026	1538	2050	2562
3	3	515	1027	1539	2051	2563
4	4	516	1028	1540	2052	2564
5	5	517	1029	1541	2053	2565
6	6	518	1030	1542	2054	2566
7	7	519	1031	1543	2055	2567
8	8	520	1032	1544	2056	2568
9	9	521	1033	1545	2057	2569


FLK
Med 2-Pin
Base
GLA
Med 2-Pin
Base
HPL
Med 2-Pin
Base
EGE
Med Prefocus
Base
CYX
Mogel Bi-Post
Base
Double Contact
Bayonet Candelabra
MR 16
Par 36
Screw Base
Par 64
Extended Mogul and Prong
Base
FCM Single Ended Lamp Base
PS (Pear Shape)
Screw Base
A 19
Med Screw
Base
S (Straight Side)
Med Screw
Base
Florescent Tube Med BiPin


(dimensions in mm)
Miniature 2-Pin
G5.3 (round 1.6mm OD)
GX5.3 (round 1.5mm OD)
GY5.3 (flat 2 x .7mm)
Medium 2-Pin
G9.5 (round 3.2mmOD)
GX9.5 (Prefocused)
Oriented Med 2-Pin
GY9.5 (2.4/3.2mm OD)
G29.5
Medium 2-Pin
G9.5/Heat sink
(metal base)
GY16d
Medium BiPost
G22 (6.35mm OD)
Mogul BiPost
G38 (11.1mm OD)
Miniature Candelabra
E11 (10.7mm screw)
Medium Screw
E26 (26mm screw)
Mogul Screw
E39 (39.3mm screw)
Double Contact Bayonet
BA15d (15mm diameter)
Medium Prefocus
P28s (27.5mm OD)
Mogul Prefocus
P40s (39.4mm OD)
Recessed Contact
R7s (7mm OD)
Screw Terminal
Ferrule
Medium Side Prong
(MSP)
Mogul End Prong
(MEP or GX16d)
Extended MEP
(EMEP or GX16d)

Arc lamp Sources

The usual general-purpose HID lamps are mercury vapor, metal halide and high-pressure sodium. You can purchase these at home centers, although usually only I wattages up to 400 watts. These versions of HID lamps are optimized for high efficiency, long life and to be inexpensive. However, the arc surface brightness of these lamps is roughly equal to the surface brightness of incandescent lamp filaments and general-purpose halogen lamp filaments. For our applications in spotlights, it is necessary to have a much more concentrated light source. This is where specialized HID lamps such as short arc lamps and HMI lamps come in. These types of Metal Halide lamps such as the MSR, MSD, CSI and HMI to name a few of the ones commonly used.

Short arc lamps consist of a roughly spherical quartz bulb with two heavy-duty electrodes spaced only a few millimeters apart at the tips. The bulb may contain xenon or mercury or both. Mercury short arc lamps have an argon gas fill for the arc to start in.

> HMI lamps are metal halide lamps with a more compact and more intense arc. There are all sorts of HMI and similar lamps, including HTI lamps and the lamps used in HID auto headlights.

HTI lamps can be used beyond their rated lifetime, since a violent failure of the lamp is very unlikely. (This differs from HMI lamps, which should not be used beyond 25% of their rated lifetime.)
Can use GS (gap shortened) technology to improve luminance by about 50 percent.

Cold start: Ignition takes a maximum of 1 second. Only a few kilovolts needed. After ignition, filler substances vaporize within 1 to 3 minutes. At the same time voltage, “electrical output” [stet], and luminous flux increase. Lamp current and color temperature start from a high level and fall.

Hot start: needs 20 kilovolts to more than 65 kilovolts.

HMI bulbs operate not with a filament but by ‘striking’ and maintaining a DC plasma current between two electrodes. This is inherently more dangerous than AC current. The conversion to DC requires a ballast between the lamp and mains. The ballast must be earthed for safety reasons. All ballasts have an earth monitor lamp, and the lamp should not be operated if there is no earth detected. The wire wound ballasts have a permanent orange lamp that is a power to earth connection (either loss of earth or mains ‘live’ will extinguish it). It must be noted this may trip some modern earth leakage detectors. Electronic ballasts usually have a momentary action earth detector switch/lamp.

Needs ballast to act as a current limiter.

Power Factor and Harmonic Current on the Neutral Wire
Until relatively recently many electronic ballasts were made without power factor correction circuits. Because of its heavily capacitive front-end components, an electronic ballast puts current and voltage out of phase with one another. As a result, it typically has a power factor of 0.6 or less, meaning the ballast has to draw 40% more power than it uses. Associated with poor power factor are harmonic currents, which build up on the neutral wire. Sixty-five to 80% of the current does not cancel out between phases, even when all hot legs are evenly loaded. This means that when operating a large number of electronic ballasts, the neutral wire will need to be doubled or even tripled to carry the additive current

Ballast Electronics
Magnetic ballast is a very simple device. Input power is routed through the main breakers, which protect the circuit in the event of a short. From there power is routed to the transformer. The transformer provides the start-up charge for the igniter circuit, and then acts as a choke, regulating current to the lamp, once the

light is burning. Power from the transformer is routed to the main contactors (which are controlled by a low-voltage control circuit) and to the igniter circuit wire.

An electronic ballast on the other hand is quite a bit more complicated (Figure 2). Input current feeds through a full wave bridge rectifier, which inverts the negative half of the AC sine wave and makes it positive (the waveform looks like figure 1b at this point) then into a bank of capacitors which start to remove the 60 Hz rise and fall and flatten out the voltage-making it essentially DC. Current regulation is provided next, typically using a Field Effect Transistor (FET). At the final stage four specialized transistors (insulated gate bipolar transistors, or IGBTs) form a high-speed switching device, which turns the flat current into an alternating square wave. The frequency of the square wave is controlled by output control circuits attached to the ballasts little electronic cerebral cortex-the motherboard. The square wave frequency is not referenced to the line Hertz rate. This means electronic ballast will correct for a generator, which is slightly off speed. Through out the ballast, control and safety circuits run back to the motherboard. There are seven wires that run to the head. They are: two (thicker) power wires, VOH (voltage out hot) and VOR (voltage out return); a ground wire; the igniter's power line; and three 15-volt logic signal wires: switch common (15V from ballast); On momentary (remote On switch at the head); and safe on (which is wired to the micro-switch in the lens door and to the Off switch on the head. Both switches must be closed for the main contactors in a magnetic ballast to close (in the case of an electronic ballast, the power modules act as an electronic circuit breaker).

In the head, VOR and VOH run directly to the terminals of the globe (Figure 3). The ground wire is connected to the lamp housing. The igniter's power line and VOR are connected to the primary step-up transformer of the igniter circuit. This transformer steps voltage up to about 5000 volts. From there, current runs through a spark gap to a secondary transformer which boosts voltage up to the starting voltage of the lamp-in the order of 17kV.When the operator pushes the strike button two things happen: the contactors in the (magnetic) ballast are closed (in an electronic ballast the control board turns on the power control circuits-FETs and IGBTs-which applies voltage to VOR and VOH), and a 200V to 350V strike voltage is sent to the head on the igniter power line
Taking it in extreme slow motion, the strike sequence happens as follows. The ignition voltage climbs from zero, increasing until the voltage potential is sufficient to bridge the spark gap. When a spark bridges the gap, a very high voltage start charge is delivered to the electrodes of the lamp from the secondary transformer. After 1 to 1.5 seconds a timer circuit removes igniter power from the circuit. Once the flow of electrons is initiated in the bulb, the ballast starts to hold back current. The lamp arc stabilizes and voltage rises to nor- mal operating value
The spark gap is set to deliver the proper strike voltage for the bulb. To some extent increasing the spark gap can improve hot restrike characteristics, because it increases strike voltage, however adjusting the spark gap involves special tools and an experienced technician; the parts are fragile and extremely small. Too narrow a gap will pro duce insufficient voltage to arc the bulb; with too wide a gap, the voltage will not bridge the spark gap. The lamp is turned off when the SAFE ON line is interrupted-either by the lens door micro-switch or by the OFF button on the head or ballast. This opens the main contactors in magnetic ballast or shuts off the power control circuits in electronic ballast.

Dimmers

Lighting Equipment Safety

Arc Lamp Sources

HTI lamps can be used beyond their rated lifetime, since a violent failure of the lamp is very unlikely. (This differs from HMI lamps, which should not be used beyond 25% of their rated lifetime.)
For safety reasons, HMI lamps should be replaced when operated more than 25 percent of their rated lifetime due to the risk of lamp explosion due to recrystallization of the quartz glass.
Never bump, drop, apply excessive stress, or scratch the lamp. This could cause the lamp to burst! Do not operate any lamps with any traces of scratches, cracks, or physical damage.

Bulbs should not be touched by hand under any circumstances, else they will discolor, overheat and shatter. The gas in the bulbs is under low pressure when cold but very high pressure when hot. In use the bulbs are actually red hot, and potentially dangerous. The bulbs should be allowed to cool for 10 min. or so before attempting to open the lamp unit. Either the safety glass or full scrim should always be fitted if people are to be in front of the lights.

Xenon arc lamps

Xenon arc lamps could burst when not in operation causing serious injuries! It is critical to follow safety instructions when handling Xenon arc lamps

Xenon arc lamps have a high internal pressure. Depending upon the lamp, the internal pressure can exceed 10 ATM or 147 PSI, even when not in operation.

Always wear eye/face and body protection when handling Xenon arc lamps!

Never bump, drop, apply excessive stress, or scratch the lamp. This could cause the lamp to burst!

Always transport the lamp in the provided protective case or cover until installation!

Save the protective case or cover and packaging materials (box) for lamps that have been used to their rated service life. Use the protective case when disposing of the lamps.

Some Xenon arc lamps produce Ozone that is considered toxic at relatively high concentration levels. Use ozone-producing lamps in lamp housings equipped with exhaust systems.

Xenon arc lamps should not be used beyond their rated service life. Operation beyond the rated service life will cause the lamp to burst.

Xenon Arc Lamp Disposal

The following is Ushio's recommendations for disposal of their lamps:

Wear a protective mask, leather gloves and protective clothing when handling a spent lamp.

Place the used lamp in its original protective case and original cardboard packaging (box) that was provided when the lamp was new.

Firmly attach tape around the original cardboard box to seal the lamp securely.

From approximately three (3) feet in height, drop the cardboard box, with the lamp and protective case inside, onto a hard floor to break the lamp.

Shake the cardboard box to determine if the lamp is broken.

During the course of working you will be called upon to make extension cords with plugging boxes at the end. When these boxes use parallel blade plugs or Edison plugs, it is important to only knock out the necessary holes in the duplex boxes. When a mistake is made for safety the hole should be filled with the appropriate metal plug.

Article 110.12b states: unused cable or raceway openings in boxes, raceways, auxiliary gutters, cabinets, cutout boxes, meter socket enclosures, equipment cases, or housings shall be effectively closed to afford protection substantially equivalent to the wall of the equipment. Where metallic plugs or plates are used with nonmetallic enclosures, they shall be recessed at least 6mm or (1/4) from the outer surface of the enclosure.

Hook-up Procedures

Standard practice in the past when hooking up feeder tails to the disconnect lugs has been to simply tighten the lugs until they seem "tight enough" If one has the desire, than the National Electrical Code has specified torques for connecting wires to bus bars the following are two of those tables:

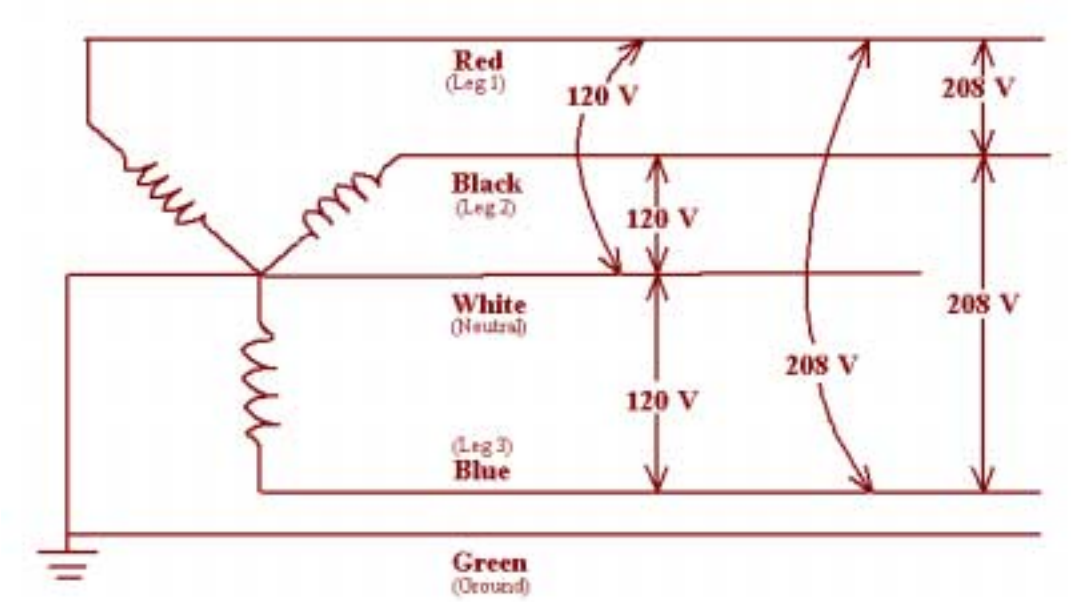
Article 110 Table 1.4 Torques for Recessed Allen head Screws.

Socket Size Across Flats (in.)	Torque (lb-in)
1/8	45
5/32	100
3/16	120
7/32	150
¼	200
5/16	275
3/8	375
½	500
9/16	600

Article 110 Table 1.5 Lug-Bolting Torques for Connections of Wire connectors to Busbars.

Bolt Diameter	Tightening Torque (lb-ft)
No. 8 or smaller	1.5
No. 10	2.0
¼ in or less	6
5/16 in.	11
3/8	19
7/16	30
½	40
9/16 or larger	55

In most circumstances you will be called upon to hook-up a set of tails that have Cam Lock brand locking connectors on one end and on the other bare ends. The tail's, which are thought of as a set, will usually consist of five cables. Four of these cables are marked as following: black, red, blue for the "hot phases" and white as the neutral. The previous four cables for lighting power are usually 4/0 in size. In addition, the ground cable that is green or green with yellow stripes is the final cable in the "set" of five. When used with a load service of 4/0, the ground is sized no smaller 2/0. However on occasion when the loads are less than 200 amps, 2/0 will be used for the load phases, neutral cables and the ground or earth cable. The actual, routine for connecting the set of tails is as follows. But first a little ditty to remember: Green is ground the world round. What this means is, **always** hook-up the ground first to the ground bus bar in the disconnect box. After this the Neutral, to the neutral bus bar followed by the Red, Black, and Blue phases.



Above illustrates theoretical meter readings, and readings apply to the Green to Hot Phases as well.

Also once the tails are bolted into the lugs, the feeder run out as a safety measure one should check that any disconnect switches within the portable system are turned off. Once you have established that they are the service should be energized with the road personal prior consent. At a convenient point within the system, all service disconnects that are energized should be metered for proper AC voltages. This should be done between the Ground/Green cable and neutral/White: a meter reading of 0 (zero) AC volts is what is desired here. Although you may find some voltage induced from other building services. The next check is between the Neutral/ White and the three phases/Red, Black and Blue. In a perfect world you will see something in the range of 110v to122v AC any thing over 125 you should check the service before allowing the balance of the loads to be energized! Assuming all voltages were correct, one should then do the same voltage check phase to ground. This will establish that you have a good system ground that you have connected into. Then finally phase to phase and this meter reading should be near 208v AC. Depending on load demands placed on the electrical service you will see variances from the above optimal meter readings.

As a safety measure and as a precaution to the equipment that is being used the road/ equipment supervisor, crew chief, department head from the road show etc. Should always be involved with the initial hook-up, energization of equipment to assure them that the job is properly done. Above all ask if there is anything unusual that you need to be aware of!

In some venues you will be required to use a disconnect panel that will require connectors that use a interlock that will prevent you from making the above connections out of order. It is not unusual for the house that you are working in, to have adapters that go from the interlocked connectors to standard cam-lock connectors.

When it is time to disconnect the tails from the service disconnects on the wall for lighting, sound, carpentry motors etc. The order in which you hooked them up will be reversed so the Hot phases will be removed from the lugs first, neutral and then the ground. In this fashion a bonded equipment ground will exist in the system until the end in the event the feeder runs have not been disconnected from the tails.

On very rare occasions you may be presented with a set of tails that deviate from the standard North American color code for power phasing and neutral. This will be as follows: Red, Black/ Hot-Phases, Yellow/ Hot-Phase and Blue as the Neutral. Now to recall the little ditty: Green is Ground The World Round. Green will still be ground. These bare-ended tails are the standard in England and Europe.

When hooking up tails in the field you there may be the need to make use of delta power for lighting power and control. When you are in doubt of the power type that is going to be used meter between each phase/leg of power to ground to determine the voltages contained within the disconnect that is going to be used. If a high leg is encountered use a different disconnect if possible. It there are no other choices then

you will need to double up on the other two legs of power to obtain a phase to ground reading of 120 volts. According to the NEC, there should be a permanent marking of some sort, on the bus bar.
The above is a minimum that should be done when doing the power hook-ups, and is a result of my experiences in doing a very routine job in a safe manner.
Article 110.15 states: On a 4-wire, delta-connected system where the midpoint of one phase winding is grounded to supply lighting and similar loads, the conductor or busbar having the higher phase voltage to ground shall be durably and permanently marked by an outer finish that is orange in color or by other effective means. Such identification shall be placed at each point on the system where a connection is made if the grounded conductor is also present.
In addition, while hooking up some types of power you may encounter the lack of a ground that is clearly marked in a green color that is typically ground. In these cases in some electrical systems, you will encounter a ground conductor that is marked using white or gray outer finish that may be applied as stripes on the conductor used as ground.
In addition, while engaged in hooking up tails to service disconnects, busbars you may be required to find a place to connect a ground tail. This conductor that has been marked with green tape and typically has a green connector at the opposite end is usually terminated in the box. However, a mechanical connection may be used externally. This connection is typically made using an Allen lug at the end of the bare ended cable and the ring end of the lug being fastened to a lighting C-clamp. The C-clamp is then either fastened to the conduit that is carrying the building service into the service disconnect or a water pipe is used. When an external connection is necessary instead of the busbars, it is important to ensure that the point of connection has any non-conductive coating removed.
In some circumstances, you may be required to hook-up tails to a generator. When doing so, it may be necessary to verify the grounds have been properly installed. This is an easy process, typically there have been more than one placed in the earth. Simply use a meter set on the Ohm scale and verify that there is 25 Ohms or less between the two ground electrodes in the ground.
Follows are the two portions of the National Electrical Code that explains in greater detail the above paragraphs. If greater detail is necessary consult the NEC or Local codes for greater detail:
Article 200.6b states: an insulated grounded conductor larger than 6 AWG shall be identified either by a continuous white or gray outer finish or by three continuous white stripes on other than green insulation along its entire length or at the time of installation by a distinctive white marking at its terminations. This marking shall encircle the conductor or insulation.
Article 250.4 General Requirements for Grounding and Bonding, section A, and excerpts from section B.

(A) Grounded Systems

(1) Electrical System Grounding. Electrical system that are grounded shall be connected to earth in a manner that will limit the voltage imposed by lightning, line surges or unintentional contact with higher-voltage lines and that will stabilize the voltage to earth during normal operation.
(2) Grounding of Electrical Equipment. Non-current carrying conductive materials enclosing electrical conductors or equipment, or forming part of such equipment, shall be connected to earth so as to limit the voltage to ground on these materials.
(3) Bonding of electrical Equipment. Non-current-carrying conductive materials enclosing electrical conductors or equipment or forming part of such equipment, shall be connected together and to the electrical supply source in a manner that establishes and effective ground-fault current path
(4) Bonding of Electrical Conductive Materials and Other Equipment. Electrically conductive materials that are likely to become energized shall be connected together and to the electrical supply source in a manner that establishes an effective ground-fault path.
(5) Effective Ground-Fault Path. Electrical equipment and wiring and other electrical conductive material likely to become energized shall be installed in a manner that creates a permanent, low-impedance circuit capable of safely carrying the maximum ground-fault current likely to be imposed on it from any point on the wiring supply source. The earth shall not be used as the sole equipment grounding conductor or effective ground-fault current path.

(B) Ungrounded Systems

(4) Path for Fault Current. Electrical equipment, wiring, and other electrically conductive material likely to become energized shall be installed in a manner that crates a permanent, low-impedance circuit from any point on the wiring system to the electrical supply source to facilitate the operation of over-current devices should a second fault occur on the wiring system. The earth shall not be used as the sole equipment grounding conductor or effective fault-current path.

Article 250.12 states: nonconductive coatings (such as paint, lacquer, and enamel) on equipment to be grounded shall be removed from threads and other contact surfaces to ensure good electrical continuity or be connected by means of fittings designed so as to make such removal unnecessary.
Article 250.56 states: A single electrode consisting of a rod, pipe, or plate that does not have a resistance to ground of 25 Ohms or less shall be augmented by one additional electrode of any of the types specified by 250.52 (A)(2) through (A)(7). Where multiple rod, pipe or plate electrodes are installed to meet the requirements of this section, they shall not be less than 1.8 m (6 feet) apart.

Lighting Rigging and Truss systems

On-sight Lighting Techniques

The work as a theatrical electrician should be performed in an efficient and neat manner why? Because the crew chief or client will want it redone if it is sloppy, which means that it may be unsafe or visually a mess to the clients intended audience. If for no other reason then the following article from the National Electrical Code (NEC 2002), which could adversely affect the ability of the show to go on.

Article 110.12 mechanical Execution of Work

Electrical equipment shall be installed in a neat and workmanlike manner.

The code continues to state the following:

The regulation in 110.12 calling for neat and workmanlike installations has appeared in the NEC as currently worded for more than half-century. It stands as a basis for pride in one's work and has been emphasized by persons involved in the training of apprentice electricians for many years.
Many code conflicts or violations have been cited by the authority having jurisdiction based on the authority's interpretation of "neat and workmanlike Manner." Many electrical inspection authorities use their own experience or precedents in their local areas as the basis for their judgments.
This would apply if a city inspector were to check our work and decided that in his judgment, the work is sloppy and constitutes a hazard.

Practical skills

- **Learning Objectives/Outcomes**

Learn and practice skills taught in the previous sections to reinforce the knowledge gained and introduce apprentices to practical skills necessary to perform on the job training in a safe and expedient fashion.
In certain environments it is advantages to be able to perform trouble shooting on various forms of equipment. Whether directly supervised by a client or road personnel whom you are working for. There

are various forms types to perform on electrical equipment you may be working on. These may range from a simple cross plugging of two adjoining loads to using a meter to check for various elements of electricity.
When using a meter one may meter for a voltage being present using either the AC meter scale, or the DC meter scale. In our application it is typical that any loads that are connected to a dimmer or road rack are using AC current to supply voltage to the load. The DC meter scale is typically used to determine if voltage is present in battery-powered devices used on stage.
The third most common meter scale used is the Ohm scale or continuity beeper tester found on most meters today. These scales are used to check for a continuous circuits or wiring pairs found in most of our jumper cables, multi-cables and the like. This test is to only be performed when the **circuit is off or de-energized.**

Continuity Tests
A wire conductor that is continuous without a break has a practical resistance of 0Ω. Thus, the ohmmeter can be used to test for continuity. This test should be conducted on the lowest ohms range. A break in the wire will give a reading of infinite resistance, indicating an open circuit. This type of test is useful if you are trying to locate a cable that may or may not have a lamp plugged into the end. If the multi-cable has a load on each circuit, then you will see 0Ω across all hot and neutral pairs or connectors. If one does not show 0Ω, then that will be the cable that has a burn out or no lamp plugged into the end.
You may also use the same idea to perform a continuity test on a long run of cable by temporarily connecting a lamp to each cable and metering the cables one at a time with a meter to find each opposing end of the cable. Another method is to use a piece of wire to create a temporary short at each female cable end and run the same test. Once again only perform continuity test to a **circuit that is off or de-energized.**

Cable and Loads
In the course of setting up lighting systems you will be required to layout feeder cable and other load cables to lighting fixtures. Often times you will need to trust that the supervisor from the equipment supplier has done their homework. However, due to onsite job changes or from lack of doing a site survey they have found there are impediments to completing cabling of the different lighting loads that are placed. You will be called upon to cable the different lighting apparatuses, in order to bring power to them. Often times the dimmer locations planed and actual locations are the ones that change the most and require the longest runs. This were the next formula will come in handy if one has any question concerning safety of length of the run or if the dimmers/ lamps output seem to be not as “bright as it should be”.
For three phase loads:

$$\frac{(18.7) \times \text{Load in Amps} \times \text{distance is feet}}{\text{Cable size in circular mills}}$$

The following are some typical sizes that we work with:
4/0 = 211,600 circular mills
2/0 = 133,000 circular mills
#2 = 66,360 circular mills
When one needs to calculate for a single-phase load, use 21.6 as the load factor in place of 18.7.

Dimmer Load Calculations
Consideration also needs to be given when the lighting loads are plugged into the dimmers. One important consideration is to balance the loads/equipment being plugged. When one is using only one type of lighting fixture this is easily done because all dimmers are the same as seen in the previous example, contained in the electrical safety section. Once again determine a safe load in a three-phase system using the following formula:

Total Watts÷Volts÷number of phases=Amps

An easy example of this is:

48 1000watt or 1K par cans = 48,000 watts

48,000 watts ÷ 120 volts = 400 amps

12 Colorams= xx

4 I Beams

Amps ÷ 3 Phases = amps per phase

The above example assumes the pars are plugged into dimmers spread over all 3 Phases. You should also leave a margin for safety.

Electrical Terminations

There are many way's to terminate a wire to a plug. Some of these are binding screws, crimp terminals, pressure terminals and solder. We will list them in order and their advantages and disadvantages. Binding screws are convenient, easy to rewire and cheap, disadvantages to them are prone to creeping loose, and torque limited. Crimp terminals have perfect electrical connection when they are properly made however they have poor rewire-ability in some instances and require the correct tool to make the crimp. Pressure terminals have excellent electrical connection and are easy to reuse. They are prone to breaking the wire strands, but this may be overcome with a wire shoe or furrel. Solder has the advantages of a means to make a termination without special tools. However it requires a high competency to correctly make a solder joint that will last. Solder joints can be prone to breaking when exposed to direct wear and tear.

Termination test

Sometimes it is advantages to determine how a panel mounted male, multi-cable end has been landed to a terminal block in a lighting fixture.

You would connect one terminal of the meter to terminal A or 1 depending on how it is marked to where the first wire is that you want to locate. The other meter test lead is then brought in contact with each of the wire ends or pins in the connector, once for each termination. A 0Ω reading on the meter indicated continuity of a direct electrical path between the two ends of the wire. Unless a short-circuit exists between wires, the continuity test will identify the two ends of the same wire. If you find a short between two wires and one end is terminated into a terminal block, then remove one of the two wires and re-test the offending wire or groups of wires.

DMX 512 Fault Finding

Troubleshooting DMX signals is difficult due to its make up digital packets. However a multi-meter may be used to track down some common problems.

Voltage tests

With the consoles and all the devices connected together measure the D.C. Voltage between pins 2 and 3 (multi-meter black test lead on negative pin 2, multi-meter red test lead on positive pin 1) you should find the following conditions:

All DMX channels at zero the meter should read a low or negative voltage.

All DMX channels at full, the voltage should increase but it may still be negative.

Although the measurements have no absolute meaning there should be a noticeable change in voltage. Make sure that all channels are set to either full or at zero. If possible use and analog multi-meter because a digital meter may not give repeatable readings and the analog one will average the readings. Repeat the meter readings between pins 1 to 2 and pins 1 to 3 using pin 2 and 3 as a norm to compare the other pin combinations to. In other words a board level zero setting should give minimal meter reading while the at full board reading should give a corresponding increase in meter reading.

Resistance tests

With the console unplugged from the snake and all DMX 512 devices connected to the data lines, measure across the console-end male connector. The following results should be seen:

Article 250.8 states: Grounding, conductors and bonding jumpers shall be connected by exothermic welding, listed pressure connectors, listed clamps, or other listed means. Connection devices or fitting that depend solely on solder shall not be used. Sheet mental screws shall not be used to connect grounding conductors to enclosures.

Focusing

Knots:

- Bowline
- Clove
- Figure “8”
- Truckers Knot

256	128	64	32	16	8	4	2	1	Address
0	0	0	0	0	0	0	0	0	1
0	0	0	0	0	0	0	0	0	2
0	0	0	0	0	0	0	0	0	3
0	0	0	0	0	0	0	0	0	4
0	0	0	0	0	0	0	0	0	5
0	0	0	0	0	0	0	0	0	6
0	0	0	0	0	0	0	0	0	7
0	0	0	0	0	0	0	0	0	8
0	0	0	0	0	0	0	0	0	9
0	0	0	0	0	0	0	0	0	10
0	0	0	0	0	0	0	0	0	11
0	0	0	0	0	0	0	0	0	12
0	0	0	0	0	0	0	0	0	13
0	0	0	0	0	0	0	0	0	14
0	0	0	0	0	0	0	0	0	15
0	0	0	0	0	0	0	0	0	16
0	0	0	0	0	0	0	0	0	17
0	0	0	0	0	0	0	0	0	18
0	0	0	0	0	0	0	0	0	19
0	0	0	0	0	0	0	0	0	20
0	0	0	0	0	0	0	0	0	21
0	0	0	0	0	0	0	0	0	22
0	0	0	0	0	0	0	0	0	23
0	0	0	0	0	0	0	0	0	24
0	0	0	0	0	0	0	0	0	25
0	0	0	0	0	0	0	0	0	26
0	0	0	0	0	0	0	0	0	27
0	0	0	0	0	0	0	0	0	28
0	0	0	0	0	0	0	0	0	29
0	0	0	0	0	0	0	0	0	30
0	0	0	0	0	0	0	0	0	31
0	0	0	0	0	0	0	0	0	32
0	0	0	0	0	0	0	0	0	33
0	0	0	0	0	0	0	0	0	34
0	0	0	0	0	0	0	0	0	35
0	0	0	0	0	0	0	0	0	36
0	0	0	0	0	0	0	0	0	37
0	0	0	0	0	0	0	0	0	38
0	0	0	0	0	0	0	0	0	39
0	0	0	0	0	0	0	0	0	40
0	0	0	0	0	0	0	0	0	41
0	0	0	0	0	0	0	0	0	42
0	0	0	0	0	0	0	0	0	43
0	0	0	0	0	0	0	0	0	44
0	0	0	0	0	0	0	0	0	45
0	0	0	0	0	0	0	0	0	46
0	0	0	0	0	0	0	0	0	47
0	0	0	0	0	0	0	0	0	48
0	0	0	0	0	0	0	0	0	49
0	0	0	0	0	0	0	0	0	50

256	128	64	32	16	8	4	2	1	Address
0	0	0	0	0	0	0	0	0	51
0	0	0	0	0	0	0	0	0	52
0	0	0	0	0	0	0	0	0	53
0	0	0	0	0	0	0	0	0	54
0	0	0	0	0	0	0	0	0	55
0	0	0	0	0	0	0	0	0	56
0	0	0	0	0	0	0	0	0	57
0	0	0	0	0	0	0	0	0	58
0	0	0	0	0	0	0	0	0	59
0	0	0	0	0	0	0	0	0	60
0	0	0	0	0	0	0	0	0	61
0	0	0	0	0	0	0	0	0	62
0	0	0	0	0	0	0	0	0	63
0	0	0	0	0	0	0	0	0	64
0	0	0	0	0	0	0	0	0	65
0	0	0	0	0	0	0	0	0	66
0	0	0	0	0	0	0	0	0	67
0	0	0	0	0	0	0	0	0	68
0	0	0	0	0	0	0	0	0	69
0	0	0	0	0	0	0	0	0	70
0	0	0	0	0	0	0	0	0	71
0	0	0	0	0	0	0	0	0	72
0	0	0	0	0	0	0	0	0	73
0	0	0	0	0	0	0	0	0	74
0	0	0	0	0	0	0	0	0	75
0	0	0	0	0	0	0	0	0	76
0	0	0	0	0	0	0	0	0	77
0	0	0	0	0	0	0	0	0	78
0	0	0	0	0	0	0	0	0	79
0	0	0	0	0	0	0	0	0	80
0	0	0	0	0	0	0	0	0	81
0	0	0	0	0	0	0	0	0	82
0	0	0	0	0	0	0	0	0	83
0	0	0	0	0	0	0	0	0	84
0	0	0	0	0	0	0	0	0	85
0	0	0	0	0	0	0	0	0	86
0	0	0	0	0	0	0	0	0	87
0	0	0	0	0	0	0	0	0	88
0	0	0	0	0	0	0	0	0	89
0	0	0	0	0	0	0	0	0	90
0	0	0	0	0	0	0	0	0	91
0	0	0	0	0	0	0	0	0	92
0	0	0	0	0	0	0	0	0	93
0	0	0	0	0	0	0	0	0	94
0	0	0	0	0	0	0	0	0	95
0	0	0	0	0	0	0	0	0	96
0	0	0	0	0	0	0	0	0	97
0	0	0	0	0	0	0	0	0	98
0	0	0	0	0	0	0	0	0	99
0	0	0	0	0	0	0	0	0	100

256	128	64	32	16	8	4	2	1	Address
0	0	0	0	0	0	0	0	0	101
0	0	0	0	0	0	0	0	0	102
0	0	0	0	0	0	0	0	0	103
0	0	0	0	0	0	0	0	0	104
0	0	0	0	0	0	0	0	0	105
0	0	0	0	0	0	0	0	0	106
0	0	0	0	0	0	0	0	0	107
0	0	0	0	0	0	0	0	0	108
0	0	0	0	0	0	0	0	0	109
0	0	0	0	0	0	0	0	0	110
0	0	0	0	0	0	0	0	0	111
0	0	0	0	0	0	0	0	0	112
0	0	0	0	0	0	0	0	0	113
0	0	0	0	0	0	0	0	0	114
0	0	0	0	0	0	0	0	0	115
0	0	0	0	0	0	0	0	0	116
0	0	0	0	0	0	0	0	0	117
0	0	0	0	0	0	0	0	0	118
0	0	0	0	0	0	0	0	0	119
0	0	0	0	0	0	0	0	0	120
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0	0	0	0	0	0	0	0	0	122
0	0	0	0	0	0	0	0	0	123
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0	0	0	0	0	0	0	0	0	129
0	0	0	0	0	0	0	0	0	130
0	0	0	0	0	0	0	0	0	131
0	0	0	0	0	0	0	0	0	132
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0	0	0	0	0	0	0	0	0	137
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0	0	0	0	0	0	0	0	0	142
0	0	0	0	0	0	0	0	0	143
0	0	0	0	0	0	0	0	0	144
0	0	0	0	0	0	0	0	0	145
0	0	0	0	0	0	0	0	0	146
0	0	0	0	0	0	0	0	0	147
0	0	0	0	0	0	0	0	0	148
0	0	0	0	0	0	0	0	0	149
0	0	0	0	0	0	0	0	0	150

256	128	64	32	16	8	4	2	1	Address
0	0	0	0	0	0	0	0	0	151
0	0	0	0	0	0	0	0	0	152
0	0	0	0	0	0	0	0	0	153
0	0	0	0	0	0	0	0	0	154
0	0	0	0	0	0	0	0	0	155
0	0	0	0	0	0	0	0	0	156
0	0	0	0	0	0	0	0	0	157
0	0	0	0	0	0	0	0	0	158
0	0	0	0	0	0	0	0	0	159
0	0	0	0	0	0	0	0	0	160
0	0	0	0	0	0	0	0	0	161
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0	0	0	0	0	0	0	0	0	163
0	0	0	0	0	0	0	0	0	164
0	0	0	0	0	0	0	0	0	165
0	0	0	0	0	0	0	0	0	166
0	0	0	0	0	0	0	0	0	167
0	0	0	0	0	0	0	0	0	168
0	0	0	0	0	0	0	0	0	169
0	0	0	0	0	0	0	0	0	170
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0	0	0	0	0	0	0	0	0	172
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0	0	0	0	0	0	0	0	0	184
0	0	0	0	0	0	0	0	0	185
0	0	0	0	0	0	0	0	0	186
0	0	0	0	0	0	0	0	0	187
0	0	0	0	0	0	0	0	0	188
0	0	0	0	0	0	0	0	0	189
0	0	0	0	0	0	0	0	0	190
0	0	0	0	0	0	0	0	0	191
0	0	0	0	0	0	0	0	0	192
0	0	0	0	0	0	0	0	0	193
0	0	0	0	0	0	0	0	0	194
0	0	0	0	0	0	0	0	0	195
0	0	0	0	0	0	0	0	0	196
0	0	0	0	0	0	0	0	0	197
0	0	0	0	0	0	0	0	0	198
0	0	0	0	0	0	0	0	0	199
0	0	0	0	0	0	0	0	0	200

256	128	64	32	16	8	4	2	1	Address
0	0	0	0	0	0	0	0	0	201
0	0	0	0	0	0	0	0	0	202
0	0	0	0	0	0	0	0	0	203
0	0	0	0	0	0	0	0	0	204
0	0	0	0	0	0	0	0	0	205
0	0	0	0	0	0	0	0	0	206
0	0	0	0	0	0	0	0	0	207
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0	0	0	0	0	0	0	0	0	209
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0	0	0	0	0	0	0	0	0	211
0	0	0	0	0	0	0	0	0	212
0	0	0	0	0	0	0	0	0	213
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0	0	0	0	0	0	0	0	0	215
0	0	0	0	0	0	0	0	0	216
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0	0	0	0	0	0	0	0	0	220
0	0	0	0	0	0	0	0	0	221
0	0	0	0	0	0	0	0	0	222
0	0	0	0	0	0	0	0	0	223
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0	0	0	0	0	0	0	0	0	229
0	0	0	0	0	0	0	0	0	230
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0	0	0	0	0	0	0	0	0	235
0	0	0	0	0	0	0	0	0	236
0	0	0	0	0	0	0	0	0	237
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0	0	0	0	0	0	0	0	0	239
0	0	0	0	0	0	0	0	0	240
0	0	0	0	0	0	0	0	0	241
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0	0	0	0	0	0	0	0	0	244
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0	0	0	0	0	0	0	0	0	246
0	0	0	0	0	0	0	0	0	247
0	0	0	0	0	0	0	0	0	248
0	0	0	0	0	0	0	0	0	49
0	0	0	0	0	0	0	0	0	250

256	128	64	32	16	8	4	2	1	Address
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0	0	0	0	0	0	0	0	0	259
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0	0	0	0	0	0	0	0	0	261
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0	0	0	0	0	0	0	0	0	263
0	0	0	0	0	0	0	0	0	264
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0	0	0	0	0	0	0	0	0	266
0	0	0	0	0	0	0	0	0	267
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0	0	0	0	0	0	0	0	0	270
0	0	0	0	0	0	0	0	0	271
0	0	0	0	0	0	0	0	0	272
0	0	0	0	0	0	0	0	0	273
0	0	0	0	0	0	0	0	0	274
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0	0	0	0	0	0	0	0	0	276
0	0	0	0	0	0	0	0	0	277
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0	0	0	0	0	0	0	0	0	293
0	0	0	0	0	0	0	0	0	294
0	0	0	0	0	0	0	0	0	295
0	0	0	0	0	0	0	0	0	296
0	0	0	0	0	0	0	0	0	297
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0	0	0	0	0	0	0	0	0	300

256	128	64	32	16	8	4	2	1	Address
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0	0	0	0	0	0	0	0	0	311
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0	0	0	0	0	0	0	0	0	349
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256	128	64	32	16	8	4	2	1	Address
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0	0	0	0	0	0	0	0	0	352
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0	0	0	0	0	0	0	0	0	365
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256	128	64	32	16	8	4	2	1	Address
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0	0	0	0	0	0	0	0	0	449
0	0	0	0	0	0	0	0	0	450
									451
									452
									452
									453
									454
									455

256	128	64	32	16	8	4	2	1	Address
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0	0	0	0	0	0	0	0	0	457
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0	0	0	0	0	0	0	0	0	465
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0	0	0	0	0	0	0	0	0	474
0	0	0	0	0	0	0	0	0	475
0	0	0	0	0	0	0	0	0	476
0	0	0	0	0	0	0	0	0	477
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0	0	0	0	0	0	0	0	0	504
0	0	0	0	0	0	0	0	0	505
									506
									507
									508
									509
									510

Device Address	Port 1	Port 2	Port 3	Port 4	Port 5	Port 6
1	1	513	1025	1537	2049	2561
2	2	514	1026	1538	2050	2562
3	3	515	1027	1539	2051	2563
4	4	516	1028	1540	2052	2564
5	5	517	1029	1541	2053	2565
6	6	518	1030	1542	2054	2566
7	7	519	1031	1543	2055	2567
8	8	520	1032	1544	2056	2568
9	9	521	1033	1545	2057	2569
10	10	522	1034	1546	2058	2570
11	11	523	1035	1547	2059	2571
12	12	524	1036	1548	2060	2572
13	13	525	1037	1549	2061	2573
14	14	526	1038	1550	2062	2574
15	15	527	1039	1551	2063	2575
16	16	528	1040	1552	2064	2576
17	17	529	1041	1553	2065	2577
18	18	530	1042	1554	2066	2578
19	19	531	1043	1555	2067	2579
20	20	532	1044	1556	2068	2580
21	21	533	1045	1557	2069	2581
22	22	534	1046	1558	2070	2582
23	23	535	1047	1559	2071	2583
24	24	536	1048	1560	2072	2584
25	25	537	1049	1561	2073	2585
26	26	538	1050	1562	2074	2586
27	27	539	1051	1563	2075	2587
28	28	540	1052	1564	2076	2588
29	29	541	1053	1565	2077	2589
30	30	542	1054	1566	2078	2590
31	31	543	1055	1567	2079	2591
32	32	544	1056	1568	2080	2592
33	33	545	1057	1569	2081	2593
34	34	546	1058	1570	2082	2594
35	35	547	1059	1571	2083	2595
36	36	548	1060	1572	2084	2596
37	37	549	1061	1573	2085	2597
38	38	550	1062	1574	2086	2598
39	39	551	1063	1575	2087	2599
40	40	552	1064	1576	2088	2600
41	41	553	1065	1577	2089	2601
42	42	554	1066	1578	2090	2602
43	43	555	1067	1579	2091	2603
44	44	556	1068	1580	2092	2604
45	45	557	1069	1581	2093	2605
46	46	558	1070	1582	2094	2606
47	47	559	1071	1583	2095	2607
48	48	560	1072	1584	2096	2608
49	49	561	1073	1585	2097	2609
50	50	562	1074	1586	2098	2610

Device Address	Port 1	Port 2	Port 3	Port 4	Port 5	Port 6
51	51	563	1075	1587	2099	2611
52	52	564	1076	1588	2100	2612
53	53	565	1077	1589	2101	2613
54	54	566	1078	1590	2102	2614
55	55	567	1079	1591	2103	2615
56	56	568	1080	1592	2104	2616
57	57	569	1081	1593	2105	2617
58	58	570	1082	1594	2106	2618
59	59	571	1083	1595	2107	2619
60	60	572	1084	1596	2108	2620
61	61	573	1085	1597	2109	2621
62	62	574	1086	1598	2110	2622
63	63	575	1087	1599	2111	2623
64	64	576	1088	1600	2112	2624
65	65	577	1089	1601	2113	2625
66	66	578	1090	1602	2114	2626
67	67	579	1091	1603	2115	2627
68	68	580	1092	1604	2116	2628
69	69	581	1093	1605	2117	2629
70	70	582	1094	1606	2118	2630
71	71	583	1095	1607	2119	2631
72	72	584	1096	1608	2120	2632
73	73	585	1097	1609	2121	2633
74	74	586	1098	1610	2122	2634
75	75	587	1099	1611	2123	2635
76	76	588	1100	1612	2124	2636
77	77	589	1101	1613	2125	2637
78	78	590	1102	1614	2126	2638
79	79	591	1103	1615	2127	2639
80	80	592	1104	1616	2128	2640
81	81	593	1105	1617	2129	2641
82	82	594	1106	1618	2130	2642
83	83	595	1107	1619	2131	2643
84	84	596	1108	1620	2132	2644
85	85	597	1109	1621	2133	2645
86	86	598	1110	1622	2134	2646
87	87	599	1111	1623	2135	2647
88	88	600	1112	1624	2136	2648
89	89	601	1113	1625	2137	2649
90	90	602	1114	1626	2138	2650
91	91	603	1115	1627	2139	2651
92	92	604	1116	1628	2140	2652
93	93	605	1117	1629	2141	2653
94	94	606	1118	1630	2142	2654
95	95	607	1119	1631	2143	2655
96	96	608	1120	1632	2144	2656
97	97	609	1121	1633	2145	2657
98	98	610	1122	1634	2146	2658
99	99	611	1123	1635	2147	2659
100	100	612	1124	1636	2148	2660

Device Address	Port 1	Port 2	Port 3	Port 4	Port 5	Port 6
101	101	613	1125	1637	2149	2661
102	102	614	1126	1638	2150	2662
103	103	615	1127	1639	2151	2663
104	104	616	1128	1640	2152	2664
105	105	617	1129	1641	2153	2665
106	106	618	1130	1642	2154	2666
107	107	619	1131	1643	2155	2667
108	108	620	1132	1644	2156	2668
109	109	621	1133	1645	2157	2669
110	110	622	1134	1646	2158	2670
111	111	623	1135	1647	2159	2671
112	112	624	1136	1648	2160	2672
113	113	625	1137	1649	2161	2673
114	114	626	1138	1650	2162	2674
115	115	627	1139	1651	2163	2675
116	116	628	1140	1652	2164	2676
117	117	629	1141	1653	2165	2677
118	118	630	1142	1654	2166	2678
119	119	631	1143	1655	2167	2679
120	120	632	1144	1656	2168	2680
121	121	633	1145	1657	2169	2681
122	122	634	1146	1658	2170	2682
123	123	635	1147	1659	2171	2683
124	124	636	1148	1660	2172	2684
125	125	637	1149	1661	2173	2685
126	126	638	1150	1662	2174	2686
127	127	639	1151	1663	2175	2687
128	128	640	1152	1664	2176	2688
129	129	641	1153	1665	2177	2689
130	130	642	1154	1666	2178	2690
131	131	643	1155	1667	2179	2691
132	132	644	1156	1668	2180	2692
133	133	645	1157	1669	2181	2693
134	134	646	1158	1670	2182	2694
135	135	647	1159	1671	2183	2695
136	136	648	1160	1672	2184	2696
137	137	649	1161	1673	2185	2697
138	138	650	1162	1674	2186	2698
139	139	651	1163	1675	2187	2699
140	140	652	1164	1676	2188	2700
141	141	653	1165	1677	2189	2701
142	142	654	1166	1678	2190	2702
143	143	655	1167	1679	2191	2703
144	144	656	1168	1680	2192	2704
145	145	657	1169	1681	2193	2705
146	146	658	1170	1682	2194	2706
147	147	659	1171	1683	2195	2707
148	148	660	1172	1684	2196	2708
149	149	661	1173	1685	2197	2709
150	150	662	1174	1686	2198	2710

Device Address	Port 1	Port 2	Port 3	Port 4	Port 5	Port 6
151	151	663	1175	1687	2199	2711
152	152	664	1176	1688	2200	2712
153	153	665	1177	1689	2201	2713
154	154	666	1178	1690	2202	2714
155	155	667	1179	1691	2203	2715
156	156	668	1180	1692	2204	2716
157	157	669	1181	1693	2205	2717
158	158	670	1182	1694	2206	2718
159	159	671	1183	1695	2207	2719
160	160	672	1184	1696	2208	2720
161	161	673	1185	1697	2209	2721
162	162	674	1186	1698	2210	2722
163	163	675	1187	1699	2211	2723
164	164	676	1188	1700	2212	2724
165	165	677	1189	1701	2213	2725
166	166	678	1190	1702	2214	2726
167	167	679	1191	1703	2215	2727
168	168	680	1192	1704	2216	2728
169	169	681	1193	1705	2217	2729
170	170	682	1194	1706	2218	2730
171	171	683	1195	1707	2219	2731
172	172	684	1196	1708	2220	2732
173	173	685	1197	1709	2221	2733
174	174	686	1198	1710	2222	2734
175	175	687	1199	1711	2223	2735
176	176	688	1200	1712	2224	2736
177	177	689	1201	1713	2225	2737
178	178	690	1202	1714	2226	2738
179	179	691	1203	1715	2227	2739
180	180	692	1204	1716	2228	2740
181	181	693	1205	1717	2229	2741
182	182	694	1206	1718	2230	2742
183	183	695	1207	1719	2231	2743
184	184	696	1208	1720	2232	2744
185	185	697	1209	1721	2233	2745
186	186	698	1210	1722	2234	2746
187	187	699	1211	1723	2235	2747
188	188	700	1212	1724	2236	2748
189	189	701	1213	1725	2237	2749
190	190	702	1214	1726	2238	2750
191	191	703	1215	1727	2239	2751
192	192	704	1216	1728	2240	2752
193	193	705	1217	1729	2241	2753
194	194	706	1218	1730	2242	2754
195	195	707	1219	1731	2243	2755
196	196	708	1220	1732	2244	2756
197	197	709	1221	1733	2245	2757
198	198	710	1222	1734	2246	2758
199	199	711	1223	1735	2247	2759
200	200	712	1224	1736	2248	2760

Device Address	Port 1	Port 2	Port 3	Port 4	Port 5	Port 6
201	201	713	1225	1737	2249	2761
202	202	714	1226	1738	2250	2762
203	203	715	1227	1739	2251	2763
204	204	716	1228	1740	2252	2764
205	205	717	1229	1741	2253	2765
206	206	718	1230	1742	2254	2766
207	207	719	1231	1743	2255	2767
208	208	720	1232	1744	2256	2768
209	209	721	1233	1745	2257	2769
210	210	722	1234	1746	2258	2770
211	211	723	1235	1747	2259	2771
212	212	724	1236	1748	2260	2772
213	213	725	1237	1749	2261	2773
214	214	726	1238	1750	2262	2774
215	215	727	1239	1751	2263	2775
216	216	728	1240	1752	2264	2776
217	217	729	1241	1753	2265	2777
218	218	730	1242	1754	2266	2778
219	219	731	1243	1755	2267	2779
220	220	732	1244	1756	2268	2780
221	221	733	1245	1757	2269	2781
222	222	734	1246	1758	2270	2782
223	223	735	1247	1759	2271	2783
224	224	736	1248	1760	2272	2784
225	225	737	1249	1761	2273	2785
226	226	738	1250	1762	2274	2786
227	227	739	1251	1763	2275	2787
228	228	740	1252	1764	2276	2788
229	229	741	1253	1765	2277	2789
230	230	742	1254	1766	2278	2790
231	231	743	1255	1767	2279	2791
232	232	744	1256	1768	2280	2792
233	233	745	1257	1769	2281	2793
234	234	746	1258	1770	2282	2794
235	235	747	1259	1771	2283	2795
236	236	748	1260	1772	2284	2796
237	237	749	1261	1773	2285	2797
238	238	750	1262	1774	2286	2798
239	239	751	1263	1775	2287	2799
240	240	752	1264	1776	2288	2800
241	241	753	1265	1777	2289	2801
242	242	754	1266	1778	2290	2802
243	243	755	1267	1779	2291	2803
244	244	756	1268	1780	2292	2804
245	245	757	1269	1781	2293	2805
246	246	758	1270	1782	2294	2806
247	247	759	1271	1783	2295	2807
248	248	760	1272	1784	2296	2808
249	249	761	1273	1785	2297	2809
250	250	762	1274	1786	2298	2810

Device Address	Port 1	Port 2	Port 3	Port 4	Port 5	Port 6
251	251	763	1275	1787	2299	2811
252	252	764	1276	1788	2300	2812
253	253	765	1277	1789	2301	2813
254	254	766	1278	1790	2302	2814
255	255	767	1279	1791	2303	2815
256	256	768	1280	1792	2304	2816
257	257	769	1281	1793	2305	2817
258	258	770	1282	1794	2306	2818
259	259	771	1283	1795	2307	2819
260	260	772	1284	1796	2308	2820
261	261	773	1285	1797	2309	2821
262	262	774	1286	1798	2310	2822
263	263	775	1287	1799	2311	2823
264	264	776	1288	1800	2312	2824
265	265	777	1289	1801	2313	2825
266	266	778	1290	1802	2314	2826
267	267	779	1291	1803	2315	2827
268	268	780	1292	1804	2316	2828
269	269	781	1293	1805	2317	2829
270	270	782	1294	1806	2318	2830
271	271	783	1295	1807	2319	2831
272	272	784	1296	1808	2320	2832
273	273	785	1297	1809	2321	2833
274	274	786	1298	1810	2322	2834
275	275	787	1299	1811	2323	2835
276	276	788	1300	1812	2324	2836
277	277	789	1301	1813	2325	2837
278	278	790	1302	1814	2326	2838
279	279	791	1303	1815	2327	2839
280	280	792	1304	1816	2328	2840
281	281	793	1305	1817	2329	2841
282	282	794	1306	1818	2330	2842
283	283	795	1307	1819	2331	2843
284	284	796	1308	1820	2332	2844
285	285	797	1309	1821	2333	2845
286	286	798	1310	1822	2334	2846
287	287	799	1311	1823	2335	2847
288	288	800	1312	1824	2336	2848
289	289	801	1313	1825	2337	2849
290	290	802	1314	1826	2338	2850
291	291	803	1315	1827	2339	2851
292	292	804	1316	1828	2340	2852
293	293	805	1317	1829	2341	2853
294	294	806	1318	1830	2342	2854
295	295	807	1319	1831	2343	2855
296	296	808	1320	1832	2344	2856
297	297	809	1321	1833	2345	2857
298	298	810	1322	1834	2346	2858
299	299	811	1323	1835	2347	2859
300	300	812	1324	1836	2348	2860

Device Address	Port 1	Port 2	Port 3	Port 4	Port 5	Port 6
301	301	813	1325	1837	2349	2861
302	302	814	1326	1838	2350	2862
303	303	815	1327	1839	2351	2863
304	304	816	1328	1840	2352	2864
305	305	817	1329	1841	2353	2865
306	306	818	1330	1842	2354	2866
307	307	819	1331	1843	2355	2867
308	308	820	1332	1844	2356	2868
309	309	821	1333	1845	2357	2869
310	310	822	1334	1846	2358	2870
311	311	823	1335	1847	2359	2871
312	312	824	1336	1848	2360	2872
313	313	825	1337	1849	2361	2873
314	314	826	1338	1850	2362	2874
315	315	827	1339	1851	2363	2875
316	316	828	1340	1852	2364	2876
317	317	829	1341	1853	2365	2877
318	318	830	1342	1854	2366	2878
319	319	831	1343	1855	2367	2879
320	320	832	1344	1856	2368	2880
321	321	833	1345	1857	2369	2881
322	322	834	1346	1858	2370	2882
323	323	835	1347	1859	2371	2883
324	324	836	1348	1860	2372	2884
325	325	837	1349	1861	2373	2885
326	326	838	1350	1862	2374	2886
327	327	839	1351	1863	2375	2887
328	328	840	1352	1864	2376	2888
329	329	841	1353	1865	2377	2889
330	330	842	1354	1866	2378	2890
331	331	843	1355	1867	2379	2891
332	332	844	1356	1868	2380	2892
333	333	845	1357	1869	2381	2893
334	334	846	1358	1870	2382	2894
335	335	847	1359	1871	2383	2895
336	336	848	1360	1872	2384	2896
337	337	849	1361	1873	2385	2897
338	338	850	1362	1874	2386	2898
339	339	851	1363	1875	2387	2899
340	340	852	1364	1876	2388	2900
341	341	853	1365	1877	2389	2901
342	342	854	1366	1878	2390	2902
343	343	855	1367	1879	2391	2903
344	344	856	1368	1880	2392	2904
345	345	857	1369	1881	2393	2905
346	346	858	1370	1882	2394	2906
347	347	859	1371	1883	2395	2907
348	348	860	1372	1884	2396	2908
349	349	861	1373	1885	2397	2909
350	350	862	1374	1886	2398	2910

Device Address	Port 1	Port 2	Port 3	Port 4	Port 5	Port 6
351	351	863	1375	1887	2399	2911
352	352	864	1376	1888	2400	2912
353	353	865	1377	1889	2401	2913
354	354	866	1378	1890	2402	2914
355	355	867	1379	1891	2403	2915
356	356	868	1380	1892	2404	2916
357	357	869	1381	1893	2405	2917
358	358	870	1382	1894	2406	2918
359	359	871	1383	1895	2407	2919
360	360	872	1384	1896	2408	2920
361	361	873	1385	1897	2409	2921
362	362	874	1386	1898	2410	2922
363	363	875	1387	1899	2411	2923
364	364	876	1388	1900	2412	2924
365	365	877	1389	1901	2413	2925
366	366	878	1390	1902	2414	2926
367	367	879	1391	1903	2415	2927
368	368	880	1392	1904	2416	2928
369	369	881	1393	1905	2417	2929
370	370	882	1394	1906	2418	2930
371	371	883	1395	1907	2419	2931
372	372	884	1396	1908	2420	2932
373	373	885	1397	1909	2421	2933
374	374	886	1398	1910	2422	2934
375	375	887	1399	1911	2423	2935
376	376	888	1400	1912	2424	2936
377	377	889	1401	1913	2425	2937
378	378	890	1402	1914	2426	2938
379	379	891	1403	1915	2427	2939
380	380	892	1404	1916	2428	2940
381	381	893	1405	1917	2429	2941
382	382	894	1406	1918	2430	2942
383	383	895	1407	1919	2431	2943
384	384	896	1408	1920	2432	2944
385	385	897	1409	1921	2433	2945
386	386	898	1410	1922	2434	2946
387	387	899	1411	1923	2435	2947
388	388	900	1412	1924	2436	2948
389	389	901	1413	1925	2437	2949
390	390	902	1414	1926	2438	2950
391	391	903	1415	1927	2439	2951
392	392	904	1416	1928	2440	2952
393	393	905	1417	1929	2441	2953
394	394	906	1418	1930	2442	2954
395	395	907	1419	1931	2443	2955
396	396	908	1420	1932	2444	2956
397	397	909	1421	1933	2445	2957
398	398	910	1422	1934	2446	2958
399	399	911	1423	1935	2447	2959
400	400	912	1424	1936	2448	2960

Device Address	Port 1	Port 2	Port 3	Port 4	Port 5	Port 6
401	401	913	1425	1937	2449	2961
402	402	914	1426	1938	2450	2962
403	403	915	1427	1939	2451	2963
404	404	916	1428	1940	2452	2964
405	405	917	1429	1941	2453	2965
406	406	918	1430	1942	2454	2966
407	407	919	1431	1943	2455	2967
408	408	920	1432	1944	2456	2968
409	409	921	1433	1945	2457	2969
410	410	922	1434	1946	2458	2970
411	411	923	1435	1947	2459	2971
412	412	924	1436	1948	2460	2972
413	413	925	1437	1949	2461	2973
414	414	926	1438	1950	2462	2974
415	415	927	1439	1951	2463	2975
416	416	928	1440	1952	2464	2976
417	417	929	1441	1953	2465	2977
418	418	930	1442	1954	2466	2978
419	419	931	1443	1955	2467	2979
420	420	932	1444	1956	2468	2980
421	421	933	1445	1957	2469	2981
422	422	934	1446	1958	2470	2982
423	423	935	1447	1959	2471	2983
424	424	936	1448	1960	2472	2984
425	425	937	1449	1961	2473	2985
426	426	938	1450	1962	2474	2986
427	427	939	1451	1963	2475	2987
428	428	940	1452	1964	2476	2988
429	429	941	1453	1965	2477	2989
430	430	942	1454	1966	2478	2990
431	431	943	1455	1967	2479	2991
432	432	944	1456	1968	2480	2992
433	433	945	1457	1969	2481	2993
434	434	946	1458	1970	2482	2994
435	435	947	1459	1971	2483	2995
436	436	948	1460	1972	2484	2996
437	437	949	1461	1973	2485	2997
438	438	950	1462	1974	2486	2998
439	439	951	1463	1975	2487	2999
440	440	952	1464	1976	2488	3000
441	441	953	1465	1977	2489	3001
442	442	954	1466	1978	2490	3002
443	443	955	1467	1979	2491	3003
444	444	956	1468	1980	2492	3004
445	445	957	1469	1981	2493	3005
446	446	958	1470	1982	2494	3006
447	447	959	1471	1983	2495	3007
448	448	960	1472	1984	2496	3008
449	449	961	1473	1985	2497	3009
450	450	962	1474	1986	2498	3010

Device Address	Port 1	Port 2	Port 3	Port 4	Port 5	Port 6
451	451	963	1475	1987	2499	3011
452	452	964	1476	1988	2500	3012
453	453	965	1477	1989	2501	3013
454	454	966	1478	1990	2502	3014
455	455	967	1479	1991	2503	3015
456	456	968	1480	1992	2504	3016
457	457	969	1481	1993	2505	3017
458	458	970	1482	1994	2506	3018
459	459	971	1483	1995	2507	3019
460	460	972	1484	1996	2508	3020
461	461	973	1485	1997	2509	3021
462	462	974	1486	1998	2510	3022
463	463	975	1487	1999	2511	3023
464	464	976	1488	2000	2512	3024
465	465	977	1489	2001	2513	3025
466	466	978	1490	2002	2514	3026
467	467	979	1491	2003	2515	3027
468	468	980	1492	2004	2516	3028
469	469	981	1493	2005	2517	3029
470	470	982	1494	2006	2518	3030
471	471	983	1495	2007	2519	3031
472	472	984	1496	2008	2520	3032
473	473	985	1497	2009	2521	3033
474	474	986	1498	2010	2522	3034
475	475	987	1499	2011	2523	3035
476	476	988	1500	2012	2524	3036
477	477	989	1501	2013	2525	3037
478	478	990	1502	2014	2526	3038
479	479	991	1503	2015	2527	3039
480	480	992	1504	2016	2528	3040
481	481	993	1505	2017	2529	3041
482	482	994	1506	2018	2530	3042
483	483	995	1507	2019	2531	3043
484	484	996	1508	2020	2532	3044
485	485	997	1509	2021	2533	3045
486	486	998	1510	2022	2534	3046
487	487	999	1511	2023	2535	3047
488	488	1000	1512	2024	2536	3048
489	489	1001	1513	2025	2537	3049
490	490	1002	1514	2026	2538	3050
491	491	1003	1515	2027	2539	3051
492	492	1004	1516	2028	2540	3052
493	493	1005	1517	2029	2541	3053
494	494	1006	1518	2030	2542	3054
495	495	1007	1519	2031	2543	3055
496	496	1008	1520	2032	2544	3056
497	497	1009	1521	2033	2545	3057
498	498	1010	1522	2034	2546	3058
499	499	1011	1523	2035	2547	3059
500	500	1012	1524	2036	2548	3060

Device Address	Port 1	Port 2	Port 3	Port 4	Port 5	Port 6
501	501	1013	1525	2037	2549	3061
502	502	1014	1526	2038	2550	3062
503	503	1015	1527	2039	2551	3063
504	504	1016	1528	2040	2552	3064
505	505	1017	1529	2041	2553	3065
506	506	1018	1530	2042	2554	3066
507	507	1019	1531	2043	2555	3067
508	508	1020	1532	2044	2556	3068
509	509	1021	1533	2045	2557	3069
510	510	1022	1534	2046	2558	3070
511	511	1023	1535	2047	2559	3071
512	512	1024	1536	2048	2560	3072

Formula's for converting Base address into Universe Address			
	Base Address Enter Below	Universe Offset	Universe Address
Port 1		+0	=
Port 2		+ 512	=
Port 3		+ 1024	=
Port 4		+ 1536	=
Port 5		+ 2048	=
Port 6		+ 2560	=

Ohms Law Circle

To use Ohm's law circle place your finger over the value that you want to find **E for voltage**, **I for current** or **R for resistance**, and then the other tow will make up the formula. For example, if you place your finger over the E in the circle, the remainder of the circle will show I × R. If you then multiply the current times the resistance, you will find the value for the voltage. If, you would put your thumb over the finder, over the I, in the circle, and then the remainder of the circle will show E ÷ R. So, to find current we divide voltage by resistance. Lastly, if you place your finger over the R in the circle the remaining part of the circle shows E ÷ I.

Voltage = Current × Resistance or I × R = E
Current = Voltage ÷ Resistance or E ÷ R = I
Resistance = Voltage ÷ Current or E ÷ I = R

APPENDIX

American Wire Gauge for Solid Copper conductors

Size AWG	Wire Diameter (inches)	Cross Sectional Area		DC Resistance: Soft copper Max. resistance per 1000 FT at 20 C or)Ohms per 1000 FT)
		Circular Mils	Square Inch	
4/0	0.4600	211,600	0.1662	0.04993
3/0	0.4096	167,800	0.1318	0.06296
2/0	0.3648	133,100	0.0145	0.07939
1/0	0.3249	105,400	0.08289	0.1001
1	0.2893	83,690	0.06573	0.1262
2	0.2576	66,379	0.05213	0.1592
3	0.2294	52,634	0.04134	0.2007
4	0.2043	41,472	0.03278	0.2531
6	0.1620	26,250	0.02062	0.4025
8	0.1285	16,510	0.01297	0.6400
10	0.1019	10,380	0.008155	1.018
12	0.08081	6530	0.005129	1.283
14	0.06408	4107	0.005225	2.573

Wire Color	Pin	Symbol	Screw (US)
brown	live	L	yellow or brass
blue	neutral	N	silver
yellow/green	ground	⏚	green

Table 3: Cord cap connections

The following are excerpts from the National Electrical Code 2002 table 400.4 is the source only cables that are Hard Usage and Extra Hard Usage have been extracted from that table. “Lamp Cord” has been included as an exemplary cable that is not “Not Hard Usage”, although it is used in the Theatrical Trade for varying purposes, such and Orchestra Pit Stand lights, which often carry a Underwriters Laboratory seal.

If further referencing is necessary for suitability consult the Local and National code books to determine this. Do not strictly rely upon the section of the table included here as your one source of information.

APPENDIX 400.4

Trade Name	Type Letter	Voltage	AWG or kcmil	Number of conductors	Insulation	Nominal Insulation Thickness			Braid on Each Conductor	Outer Covering	Use		
						AWG or kcmil	mm	mils					
Lamp Cord	C	300 600	18-16 14-10	2 or more	Thermoset or thermoplastic	18-16 14-10	0.76 1.14	30 45	Cotton	None	Pendant or portable	Dry locations	**NOT HARD USAGE**
Portable Power cable	G	2000	12-500	2-6 plus grounding conductors	Thermoset	12-2 1-4/0 250-500	1.52 2.03 2.41	60 80 95		Oil resistant thermoset	Portable extra hard usage		
	G-GC	2000	12-500	3-6 plus grounding conductors and 1 ground check conductor	Thermoset	12-2 1-4/0 250-500	1.52 2.03 2.41	60 80 95		Oil resistant thermoset			
Thermoset jacketed heater cord	HSJ	300	18-12	2, 3, or 4	Thermoset	18-16	0.76	30	None	Cotton and Thermoset	Portable or portable heater	Damp locations Damp and wet locations	Hard usage
Hard service cord	S See Note 4	600	18-12	2 or more	Thermoset	18-16 14-10 8-2	0.76 1.14 1.52	30 45 60	None		Pendant or portable	Damp locations	Extra hard usage
Flexible stage and lighting power cable	SC	600	8-250	1 or more		8-2 1-4/0 250	1.52 2.03 2.41	60 80 90		Thermoset	Portable extra hard usage		
	SCE	600			Thermoplastic elastomer					Thermo-plastic elastomer			
	SCT	600			Thermoplastic					Thermo-plastic			

APPENDIX 400.4 cont.

Trade Name	Type Letter	Voltage	AWG or kcmil	Number of conductors	Insulation	Nominal Insulation Thickness			Braid on Each Conductor	Outer Covering	Use		
						AWG or kcmil	mm	mils					
Hard service cord	SE See Note 4	600	18-2	2 or more	Thermoplastic elastomer	18-16 14-10 8-2	0.76 1.14 1.52	30 45 60	None	Thermo-plastic elastomer	Pendant or portable	Damp locations	Extra hard usage
	SEW See Note 4 See Note 13	600										Damp and wet locations	
	SEO See Note 4	600								Oil resistant thermo-plastic elastomer		Damp locations	
	SEOW See Note 4 See Note 13	600										Damp and wet locations	
	SEOO See Note 4	600			Oil resistant Thermoplastic elastomer							Damp locations	
	SEOOW See Note 4 See Note 13	600										Damp and wet locations	
Junior hard service cord	SJ	300	18-10	2-6	Thermoset	18-12	0.76	30	None	Thermoset	Pendant or portable	Damp locations	Hard usage
	SJE	300			Thermo-plastic elastomer					Thermo-plastic elastomer		Damp locations	
	SJEW See Note 13	300										Damp and wet locations	
	SJEO	300								Oil resistant thermo-plastic elastomer		Damp locations	
	SJEOW See Note 13	300										Damp and wet locations	
	SJEOO	300			Oil resistant thermo-plastic elastomer							Damp locations	
	SJEOOW See Note 13	300										Damp and wet locations	
	SJO	300			Thermoset					Oil resistant thermoset		Damp locations	

Trade Name	Type Letter	Voltage	AWG or kcmil	Number of conductors	Insulation	Nominal Insulation Thickness			Braid on Each Conductor	Outer Covering	Use		
						AWG or kcmil	mm	mils					
Junior hard service cord	SJOW See Note 13	300	18-10	2-6	Thermoset	18-12	0.76	30	None	Thermoset	Pendant or portable	Damp and wet locations	Hard usage
	SJOO	300										Damp locations	
	SJOOW See Note 13	300										Damp and wet locations	
	SJT	300			Thermoplastic	10	1.14	45		Thermo-plastic		Damp locations	
	SJTW See Note 13	300										Damp and wet locations	
	SJTO	300				18-12	0.76	30		Oil-resistant thermo-plastic		Damp locations	
	SJTOW See Note 13	300										Damp and wet locations	
	SJTOO	300			Oil-resistant thermo-plastic							Damp locations	
	SJTOOW See Note 13	300										Damp and wet locations	
Hard Service Cord	SO See Note 4	600	18-2	2 or more	Thermoset	18-16	0.76	30		Oil-resistant thermoset	Pendant or portable	Damp locations	Extra hard usage
	SOW See Note 4 See Note 13	600										Damp and wet locations	
	SOO See Note 4	600			Oil-resistant thermoset	14-10 8-2	1.14 1.52	45 60				Damp locations	
	SOOW See Note 4 See Note 13	600										Damp and wet locations	

APPENDIX 400.4 cont

Trade Name	Type Letter	Voltage	AWG or kcmil	Number of conductors	Insulation	Nominal Insulation Thickness			Braid on Each Conductor	Outer Covering	Use		
						AWG or kcmil	mm	mils					
Hard service cord	ST See Note 4	600	18-2	2 or more	Thermoplastic	18-16 14-10 8-2	0.76 1.14 1.52	30 45 60	None	Thermo-plastic	Pendant or portable	Damp locations	Extra hard usage
	STW See Note 4 See Note 13	600										Damp and wet locations	
	STO See Note 4	600								Oil-resistant thermo-plastic		Damp locations	
Portable power cable	W	2000	12-500 501-1000	1-6 1	Thermoset	12-2 1-4/0 250-500 501-1000	1.52 2.03 2.41 2.80	60 80 95 110		Oil-resistant thermoset	Portable, extra hard usage		
Electric vehicle cable	EV	600	18-500 See Note 11	2 or more plus grounding conductor(s), plus optional hybrid data, signal communications, and optical fiber cables	Thermoset elastomer with optional nylon. See Note 12	18-16 14-10 8-2 1-4/0 250-500	0.76(0.51) 1.14(0.76) 1.52(1.14) 2.03(1.52) 2.41(1.90)	30(20) 45(30) 60(45) 80(60) 95(75) See Note 12	Optional	Thermoset	Electric vehicle charging	Wet locations	Extra hard usage
	EVJ	300	18-12 See Note 11			18-12	0.76(0.51)	30(20) See Note 12					Hard usage
	EVE	600	18-500 See Note 11		Thermoplastic elastomer with optional nylon. See Note 12	18-16 14-10 8-2 1-4/0 250-500	0.76(0.51) 1.14(0.76) 1.52(1.14) 2.03(1.52) 2.41(1.90)	30(20) 45(30) 60(45) 80(60) 95(75) See Note 12		Thermo-plastic elastomer			Extra hard usage

APPENDIX 400.4 cont.

Trade Name	Type Letter	Voltage	AWG or kcmil	Number of conductors	Insulation	Nominal Insulation Thickness			Braid on Each Conductor	Outer Covering	Use		
						AWG or kcmil	mm	mils					
Electric vehicle cable	EVJE	300	18-12 See Note 11	2 or more plus grounding conductor(s), plus optional hybrid data, signal communica-tions, and optical fiber cables	Thermoplastic elastomer with optional nylon. See Note 12	18-12	0.76(0.51)	30(20) See Note 12	Optional	Thermo-plastic elastomer	Electric vehicle charging	Wet locations	Hard usage
	EVT	600	18-500 See Note 11			18-16 14-10 8- 2 1- 4/0 250- 500	0.76(0.51) 1.14(0.76) 1.52(1.14) 2.03(1.52) 2.41(1.90)	30(20) 45(30) 60(45) 80(60) 95(75) See Note 12		Thermo-plastic			Extra hard usage
	EVJT	300	18-12 See Note 11			18-12	0.76(0.51)	30(20) See Note 12					Hard usage

Note 4: Types G, G-GC S, SC, SCE, SCT, SE, SEO, SEOO, SO, SOO, ST, STO STOO, PPE and W shall be permitted for use on theatre stages, in garages and elsewhere flexible cords are permitted by this Code.

Note 11: Conductor size for Types EV, EVJ, EVE, EVJE, EVT, and EVJT cable apply to nonpower-limited circuits only. Conductors of power-limited (data, signal, or communications) circuits may extend beyond the stated AWG size range. All conductors shall be insulated for the same cable voltage rating.

Note 13: Cords that comply with the requirements for outdoor cords and are so listed shall be permitted to be designated as weather and water resistant with the suffix "W" after the code type designation. Cords with the "W" suffix are suitable for use in wet locations.

In table 400.5 below, are the adjustment factors for more than three current-carrying conductors in a flexible cord or cable

Number of Conductors	Percent of Value in Tables 400.5(A) and (B)
4-6	80
7-9	70
10-20	50
21-30	45
31-40	40
41 and above	35

APPENDIX 400.5(A)

Size(AWG)	Thermoplastic Types TPT, TST	Thermoset Types C, E, EO, PD, SJ, SJO, SJOW, SO, SOW, SP-1, SP-2, SP-3, SRD, SV, SVO, SVOO		Types HPD, HPN, HSJ, HSJO, HSJOO
		Thermoplastic Types ET, ETLB, ETP, ETT, SE, SEW, SEO, SEOW, SEOOW, SJE, SJEW, SJEO, SJEOW, SJEOOW, SJT, SJTW, SJTO, SJTOW, SJTOO, SJTOOW,SPE-1, SPE-2, SPE-3, SPT-1, SPT-1W, SPT-2, SPT-2W SPT-3, ST, SRDE, SRDT, STO, STOW, STOO, STOOW, SVE, SVEO, SVT, SVTO, SVTOO		
		A	B	
27	0.5			
20		5**	***	
18		7	10	10
17			12	13
16		10	13	15
15				17
14		15	18	20
12		20	25	30
10		25	30	35
8		35	40	
6		45	55	
4		60	70	
2		80	95	

APPENDIX Table 520.44 correction factors for Multicable that has more than three current carrying conductors

Number of Conductors	Percent of usable Ampacity
4-6	80
7-24	70
25-42	60
43+	50

Table 520.44 Ampacity of Extra Hard Usage when applied to a multiconductor with three current carrying conductors

	Temp. Rating of Cords & Cables		Maximum rating of Over-current protection
Size (AWG)	**75°C (167°F)**	**90°C (194°F)**	**Device** (Breaker Size)
14	24	23	15
12	32	35	20
10	41	47	25
8	57	65	35
6	77	87	45
4	101	114	60
2	133	152	80

APPENDIX 400.5(B)

Size AWG or kcmil	60°C (140°F)			75°C (167°F)			90°C (194°F)		
	D1	E2	F3	D1	E2	F3	D1	E2	F3
12	-	31	26	-	37	31		42	35
10	-	44	37	-	52	43		59	49
8	60	55	48	70	65	57	80	74	65
6	80	72	63	95	88	77	105	99	87
4	105	96	84	125	115	101	140	130	114
3	120	113	99	145	135	118	165	152	133
2	140	128	112	170	152	133	190	174	152
1	165	150	131	195	178	156	220	202	177
1/0	195	173	151	230	207	181	260	234	205
2/0	225	199	174	265	238	208	300	271	237
3/0	260	230	201	310	275	241	350	313	274
4/0	300	265	232	360	317	277	405	361	316
250	340	296	259	405	354	310	455	402	352
300	375	330	289	445	395	346	505	449	393
350	420	363	318	505	435	381	570	495	433
400	455	392	343	545	469	410	615	535	468
500	515	448	392	620	537	470	700	613	536
600	575	-	-	690	-	-	780	-	-
700	630	-	-	755	-	-	855	-	-
750	655	-	-	785	-	-	885	-	-
800	680	-	-	815	-	-	920	-	-
900	730	-	-	870	-	-	985	-	-
1000	780	-	-	935	-	-	1055	-	-

1. The ampacities under subheading D shall be permitted for single conductor types SC, SCE, SCT, PPE and W cable only where the individual conductors are not installed in raceways and are not in physical contact with each other except in lengths not to exceed 600mm (24 in) where passing through the wall of an enclosure.
2. The ampacities under subheading E apply to two-conductor cables and other multiconductor cables connected to utilization equipment so that only two-conductors are current carrying.
3. The ampacities under subheading F apply to three-conductor cables and other multiconductor cables connected to utilization equipment so that only three-conductor are current carrying.

Lens Color Coding

Beam Size	Equivalent 6 X	ETC Color Code	PRG
19°	6 X 16	Red	Red
26°	6 X 12	Black	Blue
36°	6 X 9	None	White
50°	4.5 X 6.5	Yellow	Yellow
10°	6 X 22	Large Lens	
5°	None	Really Large Lens	

Lamp Photometrics, Lamp Type and Weights

Manufacture/ Name	Fixture Type	True Field Angle	Beam Angle	Lamp	Weight
Altman Q 360	4.5 X 6.5	55°	22°	GLC 575	13.5
Altman Q 360	6 X 9	37°	16°	GLC 575	14
Altman Q 360	6 X 12	26°	11°	GLC 575	15
Altman Q 360	6 X 16	19°	8.5°	GLC 575	15
Altman Q 360	6 X 22	11°	8°	GLC 575	15
Altman Shakespeare	50°	50°	23°	GLC 575	15
Altman Shakespeare	40°	38°	20°	GLC 575	15
Altman Shakespeare	30°	28°	13°	GLC 575	15
Altman Shakespeare	20°	20°	13°	GLC 575	15
Altman Shakespeare	12°	12°	7°	GLC 575	21
Altman Shakespeare	10°	10°	7°	GLC 575	16
Altman Shakespeare	5°	6.9°	5°	GLC 575	16
Colortran 5/50	15°	15°	6.8°	FLK 575	19.3
Colortran 5/50	20°	20°	8.3°	FLK 575	19.7
Colortran 5/50	40°	40°	15°	FLK 575	20.3
Colortran 5/50	50°	50°	17.5°	FLK 575	20.9
Colortran 5/50	10°	10°	5.8°	FLK 575	20.9
Colortran 5/50	5°	5°	3.3°	FLK 575	30.1
ETC Source 4	19°	18°	15°	HPL 575	14
ETC Source 4	26°	25°	17°	HPL 575	14
ETC Source 4	36°	35°	25°	HPL 575	14
ETC Source 4	50°	51°	33°	HPL 575	14
ETC Source 4	10°	11°	9°	HPL 575	15
ETC Source 4	5°	7°	6°	HPL 575	19.2
Strand SL	19°	-	-	GLC 575	15.0
Strand SL	26°	-	-	GLC 575	15.0
Strand SL	36°	-	-	GLC 575	15.0
Strand SL	50°	-	-	GLC 575	15.0
Strand SL	10°	-	-	GLC 575	15.0
Strand SL	5°	-	-	GLC 575	17.6
Selecon Pacific	50°	-	-	GLA 575	18.8
Selecon Pacific	40°	-	-	GLA 575	18.8
Selecon Pacific	30°	-	-	GLA 575	18.8

Selecon Pacific	20°	-	-	GLA 575	18.8

ARTICLE 520

Theatres,
Audience Areas of Motion Picture and Television Studios, Performance Areas and Similar Locations

Contents

(P) Qualified Personnel

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VII. Grounding

520.81 Grounding

I. General

520.1 Scope.

This article covers all buildings or that part of a building or structure, indoor or outdoor, designed or used for presentation, dramatic, motion picture projection, or similar purpose and to specific seating areas within motion picture or television studios.

The special requirements of Article 520 apply only to that part of a building used as a theatre or similar purpose and do not necessarily apply to the entire building. For example, the requirements of Article 520 would apply to an auditorium in a school building used for dramatic or other performances. The special requirements of this chapter apply to the stage, auditorium, dressing rooms, and main corridors leading to the auditorium, but no to other parts of the building that are not involved in the use of the auditorium for performances or entertainment. The theatre space may be a traditional theatre, where the audience sits in the auditorium (house) facing the proscenium arch and view the performance on the stage on the other side of the arch, or other space, such as simple stage platform, either indoors or outdoors, with seats on three or four sides facing the platform.

The audience areas of motion picture and television studios (as defined and covered in Article 530) are also covered by the requirement of Article 520.

520.2 Definitions

Border Light. A permanently installed overhead strip light.

Breakout Assembly. An adapter used to connect a multipole connector two or more branch circuits to multiple individual branch-circuit connectors.

Bundle. Cables or conductors that are physically tied, wrapped, taped or otherwise periodically bound together.

Connector strip. A metal wire-way containing pendant or flush receptacles.

Drop Box. A box containing pendant or flush mounted receptacles attached to a multi-conductor cable via strain relief or multi-pole connector.

Footlight. A Border light installed on or in the stage.

Grouped. Cables or conductors positioned adjacent to one another but not in continuous contact with each other

Performance Area. The stage and audience seating area associated with a temporary stage structure, whether indoors or outdoors, constructed of scaffolding, truss, platforms or similar devices that is used for the presentation of theatrical or musical productions or for public presentations.

Portable Equipment. Equipment fed with portable cords or cable intended to be moved from one place to another.

Portable Power Distribution Unit. A power distribution box containing receptacles and over-current devices.

Proscenium. The wall and arch that separates the stage from the auditorium.

Stand Lamp (Work Light). A portable stand that contains a general purpose luminaries (lighting fixture) or lamp holder with guard for the purpose of providing general illumination on the stage or in the auditorium.

Strip Light. A luminaire (lighting fixture) with multipole lamps arranged in a row

Two-fer. An adapter cable containing one male plug and two female cord connectors used to connect two loads to one branch circuit.

520.3 Motion Picture Projectors.

Motion Picture equipment and its installation and use shall comply with Article 540.

520.4 Audio Signal Processing, Amplification and Reproduction Equipment.

Audio signal processing, amplification and reproduction equipment and its installation shall comply with Article 640.

520.5 Wiring Methods

(A) General. The fixed wiring method shall be steal raceways, nonmetallic raceways encased in at least 50 mm (2 in.) of concrete, Type MI cable, MC cable, or AC cable containing an insulated equipment grounding conductor sized in accordance with Table 250.122

Exception: Fixed wiring methods shall be as provided in Article 640 for audio signal processing, amplification, and reproduction equipment, in Article 800 for communication control and signaling circuits, and in Article 760 for f ire alarm circuits.

(B) Portable Equipment. The wiring for portable switchboards, stage set lighting, stage effects, and other wiring not fixed as to location shall be permitted with approved flexible cords and cable as provided elsewhere in Article 520. Fastening such cable and cords by uninsulated staples or nailing shall not be permitted.

(C) Nonrated Construction. Nonmetallic-sheathed cable, Type AC cable, electrical nonmetallic tubing and rigid nonmetallic conduit shall b e permitted to be installed in those buildings or portions thereof that are not required to be of fire-rated construction by the applicable building code. Theatres and similar buildings are usually required to be of fire-rated construction, as determined by applicable building codes; therefore, the fixed wiring methods are limited. See 518.4 for the requirements on wiring methods.

The exception to the requirements for metal-enclosed or concrete-enclosed fixed wiring permits the installation of communications circuits, Class 2 and Class 3 remote-control and signaling circuit, sound reproduction wiring, and fire alarm circuits using wiring methods from the respective articles covering these systems in Chapters 7 and 8. Where portability, flexibility, and adjustments are necessary for portable switchboards, stage lighting, and special effects, suitable cords and cable are permitted. In accordance with 520.5 ©, Type cable, Type AC cable, ENT, and RNC are permitted as the wiring method in buildings or portions of buildings that are not required to be of fire-rated construction. In this application, Type AC cable is not required to contain an insulated equipment grounding conductor.

520.6 Number of Conductors in Raceway.

The number of conductors permitted in any metal conduit, rigid nonmetallic conduit as permitted in this article, or electrical metallic tubing for border or stage pocket circuits or for remote-control conductors shall not exceed the percentage fill shown in Table 1 of Chapter 9. Where contained within an auxiliary gutter or a wireway, the sum of the cross-sectional areas of contained conductors at any cross-sectional areas of all contained conductors at any cross section shall not exceed 20 percent of the interior cross sectional area of the auxiliary gutter or wireway. The 30 conductor limitation of 366.6 and 376.22 shall not apply.

520.7 Enclosing and Guarding Live Parts.

Live part shall be enclosed or guarded to prevent accidental contact by persons and objects. All switches shall be of the externally operable type. Dimmers, including rheostats, shall be placed in cases or cabinets that enclosed all live parts.

520.8 Emergency Systems.

Control of emergency systems shall comply with Article 700.

520.9 Branch Circuits.

A branch circuit on any size supplying one or more receptacles shall be permitted to supply stage set lighting. The voltage rating of the

receptacles shall not be less than the circuit voltage. Receptacle ampere ratings and branch-circuit conductor ampacity shall not be less than the branch-circuit overcurrent device ampere rating. Table 210.21 (B)(2) shall not apply.
The stage lighting and associated equipment, such as stage effects, both fixed and portable, must be as flexible as possible. Connectors are often used for different purposes and are therefore marked on a show-by-show bases as to the voltage, current, and type of current actually employed. The provisions of 520.9 only require that connectors be rated sufficiently for the parameters involved, thus permitting connectors with voltage and current ratings lighter than the branch-circuit rating to be used.
The intent of 520.9 is to exclude the occupancies referenced in Article 520 from all the general requirements relating to connector rating and branch-circuit loading found else where in the *Code*, such as Table 210.21 (B)(2). The requirements of 520.9 modify several other sections such as 210.23(C) and (D), which would disallow 40 ampere and larger branch circuits from serving 5000 watt and larger portable stage lighting equipment found in the theater.
Stage set lighting is usually planned in advance, and the loads on each receptacle are known. Loads are not casually connected, as they might be at a typical general-use wall receptacle. Care is taken to ensure that circuits are not overloaded, thereby avoiding nuisance tripping during a performance.

520.10 Portable Equipment.

Portable stage and studio lighting equipment and portable power distribution equipment shall be permitted for temporary use outdoors, provided the equipment is supervised by qualified personnel while energized and barriered from the general public.
In accordance with 520.10, portable indoor stage or studio equipment that is not marked suitable for wet or damp locations is permitted to be used temporarily in outdoor locations. If rain occurs, this equipment is typically de-energized, and a protective cover is installed before it is re-energized. At the end of the day, this equipment is either de-energized and protected or dismantled and stored.

II Fixed Stage Switchboards

520.21 Dead Front.

Stage switchboards shall be of the dead-front type and shall comply with Part IV or Article 384 unless approved based on suitability as stage switchboard as determined by a qualified testing laboratory and recognized test standards and principles.
Early Stage switchboards were vertical marble or slate slabs mounted on the stage near the proscenium wall, with exposed knife switches and fuseholders mounted on them and with exposed resistance-type dimmer plates across the top. The "dead front" "guarded back" and "metal hood" requirements of the *Code* are intended to provide the operator with some sort of protection from shock, and the heat-producing equipment with some sort of protection from flammable curtains and scenery likely to be above and around the equipment. For these reasons, modern switchboards are totally enclosed.

520.22 Guarding Back of Switchboard.

Stage switchboards having exposed live parts on the back of such boards shall be enclosed by the building walls, wire mesh grills, or by other approved methods. The entrance to this enclosure shall be by means of a self-closing door.

520.23 Control and Overcurrent Protection of Receptacle Circuits.

Means shall be provided at a stage-lighting switchboard to which load circuits are connected for overcurrent protection of stage-lighting branch circuits, including branch circuits supplying stage and auditorium receptacles used for cord and plug connected stage equipment. Where the stage switchboard contains dimmers to control nonstage lighting, the location of the overcurrent protective devices for these branch circuits at the stage switchboard shall be permitted.
The purpose of 520.23 is to ensure that the overcurrent protection devices are readily accessible to stage personnel during the presentation.

520.24 Metal Hood.

A stage switchboard that is not completely enclosed dead-front and dead-rear recessed into a wall shall be provided with a metal hood extending the full length of the board to protect all equipment of the board from falling objects. Because stages are usually crowded and a great deal of flammable material is often present, a stage switchboard is not permitted to have exposed live parts on its front. Moreover, the space at the rear of a stage switchboard must be guarded in order to prevent entrance or contact by unqualified and unauthorized persons. One acceptable method of accomplishing this is by enclosing the space between the rear of the switchboard and the wall in sheet-steel housing with a door at one end.

520.25 Dimmers.

Dimmers shall comply with 520.25(A) through (D).

(A) **Disconnection and Overcurrent Protection**. Where dimmers are installed in ungrounded conductors, each dimmer shall have overcurrent protection not greater that 125 percent of the dimmer rating and shall be disconnected for all ungrounded conductors when the master or individual switch or circuit breaker supply such dimmer is in the open position.

A modern, high-density digital dimmer rack typically contains one dimmer (usually of 20-, 50-, or 100 ampere capacity) for each branch circuit connected to it. The rack is usually serviced by a 3-phase, 4-wire-plus-ground feeder, which is distributed via buses to all dimmers in the rack. Typical dimmer racks contain between 12 and 96 dimmers and may have total power capacities of up to 288 kW. In large theatrical system, many racks may be bused together. A central control electronics module drive multipole dimmers in the rack. A digital data link may connect the dimmer rack to the remotely located computer control console. Exhibit 520.2 shows a high-density digital SCR dimmer switchboard, and exhibit 520.3 shows its schematic diagram.

(B) Resistance- or Reactor- Type Dimmers. Resistance- or series reactor type dimmers shall be permitted to be places in either the grounded or the ungrounded conductor of the circuit. Where designed to open either the supply circuit to the dimmer to he circuit controlled by it, the dimmer shall then comply with 404.1. Resistance- or reactor-type dimmer placed in the grounded neutral conductor of the circuit shall not open the circuit.

(C) Autotransformer-Type Dimmers. The circuit supplying an autotransformer-type dimmer shall not exceed 150 volts between conductors. The grounded conductor shall be common to the input and output circuits. FPN: See 210.9 for circuits derived from autotransformers.

Circuits supplying autotransformer-type dimmers are not permitted to exceed 150 volts between conductors. Any desired voltage may be applied to the lamps, from full-line voltage to voltage so low that the lamps provide no illumination, by means of a movable contact tap. Typical connection for an autotransformer-type dimmer are shown in Exhibit 520.4. This type of dimmer produces very little heat and operates at high efficiency. Its dimming effect, within its maximum rating, is independent of the wattage of the load. Autotransformer-type dimmers are currently seldom used. See commentary that follows 470.4, which discusses saturable reactors that are sometimes used for stage dimmers.

(D) **Solid-State-Type Dimmers.** The circuit supplying a Solid-State—type dimmer shall not exceed 150 volts between conductors unless the dimmer is listed specifically for higher voltage operation. Where a grounded conductor supplies a dimmer, it shall be common to the input and output circuits. Dimmer chassis shall be connected to the equipment grounding conductor.

Modern stage switchboards are usually of the remote-control type. The switchboard is operated from a remote console, typically a computer system such as the one shown in Exhibit 520.5. The switchboard or dimmer

rack is normally located offstage in a dimmer room, where proper climate control can be furnished and noise from the rack cooling fans will not interfere with the performance onstage. Branch circuits are usually connected to the dimmer rack on a "dimmer per circuit" basis. A digital control cable connects the computer and the dimmer rack, allowing the operator to be positioned or stage or in the auditorium for easy viewing of the performance.

A front view of a typical high-density digital SCR dimmer rack is shown in Exhibit 520.2. A schematic for this type of dimmer rack is shown in Exhibit 520.3. Dimmers for individual circuits are contained in dual plug-in dimmer modules. These modules also contain circuit breakers for overcurrent protection and filter chokes to eliminate acoustic noise from the lamp filaments. The digital control electronics are contained in a plug-in module with front-panel controls for configuration and testing.

520.26 Type of Switchboard.

A stage switchboard shall be either one or a combination of the types specified in 520.26(A), (B), and (C).

(A) Manuel. Dimmers and switches are operated by handles mechanically linked to the control devices.

Manuel-type switchboard usually contain resistance-type or autotransformer-type dimmers. Exhibit 520.4 is a schematic of a manual autotransformer-type dimmer.

(B) Remotely controlled. Devices are operated electrically from a pilot-type control console or panel. Pilot control panels either shall be part of the switchboard or shall be permitted to be at another location.

(C) Intermediate. A stage switchboard with circuit interconnections is a secondary (patch panel) or panel board remote to the primary stage switchboard. It shall contain overcurrent protection. Where the required branch-circuit overcurrent protection is provided in the dimmer panel, it shall be permitted to be omitted from the intermediate switchboard.

An intermediate stage switchboard, usually called a patch panel, is located between the dimmer switchboard and the branch circuits. Its purpose is to either break down larger dimmer circuits to smaller branch circuits or to select branch circuits to be controlled by a dimmer, or both.

520.27 Stage Switchboard Feeders.

(A) Type of Feeder. Feeders supplying stage switchboards shall be one of the types in 520.27 (A)(1) through (A)(3).

(1) Single Feeder. A single feeder disconnected by a single disconnect device.

(2) Multiple Feeders to Intermediate Stage Switchboard (Patch Panel) Multiple feeders of unlimited quantity shall be permitted, provided that all multiple feeders are part of a single system. Where combined, neutral conductors in a given raceway shall be of sufficient ampacity to carry the maximum unbalanced current supplied by multiple feeder conductors in the same raceway, but they need not be greater than the ampacity of the neutral supplying the primary stage switchboard. Parallel neutral conductors shall comply with 310.4

The feeders to patch panels are often many dimmer-controlled circuits at 100 amperes or less, single phase, so they can be distributed to different combinations of the same size or smaller branch circuits. This type of installation usually requires a common neutral, and because of the quantity of circuits, many installations require several parallel neutral are sized as follows:

1. Size the common neutral to the feeder of the primary switchboard.
2. Split this neutral into multipole parallel conductors, one per raceway.
3. Equally divide, per phase, and size each ungrounded conductor of the many single-phase circuits among the raceways.

In no case is it acceptable to install the ungrounded conductors in one raceway and the common neutral in another.

(3) Separate Feeder to Single Stage Switchboard (Dimmer Bank). Installations with separate feeders to a single primary stage switchboard shall have a disconnection means for each feeder. The primary stage switchboard shall have a permanent and obvious liable stating the number and location of disconnecting means. If the disconnection means are located in more than one distribution switchboard, the primary stage switchboard shall be provided with barriers to correspond with these multiple locations.

Larger primary stage switchboards usually consist of several sections, often called dimmer racks, which form a dimmer bank. See Exhibit 520.2. These dimmer racks may be fed separately or be bused together to accept one or more feeder circuits. If an intermediate stage switchboard is connected to a primary stage switchboard, a single large feeder usually supplies the primary stage switchboard, because the intermediate stage switchboard patches only the ungrounded conductors and requires a common neutral. Modern theaters do not use intermediate stage switchboards, and dimmer banks may have one or several feeders.

(B) Neutral. The neutral of feeders supplying solid-state, 3-phase, 4-wire dimming systems shall be considered a current-carrying conductor.

© Supply capacity. For the purpose of computing supply capacity to switchboards, it shall be permissible to consider the maximum load that the switchboard is intended to control in a given installation, provided that the following apply:

(1) All feeders supplying the switchboard shall be protected by an overcurrent device with a rating not greater than the ampacity of the feeder.

(2) The opening of the overcurrent device shall not affect the proper operation of the egress or emergency lighting systems.

FPN: For computation of stage feeder loads, see 220.10.

The feeder for single, primary stage switchboards is sized in accordance with the maximum load the switchboard is intended to control for a specific location. The feeder(s) must be protected by an overcurrent device that has a rating not greater than the feeder ampacity. Operation of the overcurrent device is not allowed to have any effect on egress or emergency lighting system. The neutral of feeder supplying solid-state, 3-phase, 4-wire dimming systems will carry third-harmonic currents that are present even under balanced load conditions.

III Fixed Stage Equipment Other Than Switchboards.

520.41 Circuit Loads.

(A) Circuits Rated 20 Amperes or Less. Footlights, border lights, and proscenium sidelights shall be arranged so that no branch circuit supplying such equipment carries a load exceeding 20 amperes.

(B) Circuits Rated Greater Than 20 Amperes. Where heavy-duty Lampholders only are used, such circuits shall be permitted to comply with Article 210 for circuits supplying heavy-duty Lampholders.

In accordance with 210.23(B) and (C), 30-, 40-, or 50- ampere branch circuits are permitted if heavy-duty lampholders, such as medium- or mogul-base Edison screw shell types, are used for fixed lighting.

520.42 Conductor Insulation.

Foot, border, proscenium, or portable strip lights and connector strips shall be wired with conductors that have insulation suitable for the temperature at which the conductors are operated, but not less than 125°C (257°F). The ampacity of the 125°C (257°F) conductors shall be that of 60°C (140°F) conductors. All drops from connector strips shall be 90°C (194°F) wire sized to the ampacity of 60°C (140°F) cords and cable with no more than 150mm (6 in.) of conductor extending into the connector strip. Section 310.15(B)(2)(a) shall not apply.

FPN: See Table 310.13 for conductor types.

The 125°C (257°F) minimum temperature rating is based on the heat from the lamp raising the ambient temperature in which the wiring is located. Drops from connector strips are usually flexible cord. Although the 90°C-

rated cord is also in the higher ambient, it is not in sufficient contact with other circuits that might also heat it. The derating factors of 310.15 (B)(2)(a) are judged unnecessary because the conductors are not all energized at one time, are not often energized at full intensity (dimmed), and are not energized continuously.

520.43 Footlights.

(A) Metal Trough Construction. Where metal trough construction is employed for footlights, the trough containing the circuit conductors shall be made of sheet metal not lighter than 0.81 mm (0.032 in.) and treated to prevent oxidation. Lampholder terminals shall be kept at least 13 mm (1/2 in.) from the metal of the trough. The circuit conductors shall be soldered to the lampholder terminals.

(B) Other –Than-Metal Trough Construction. Where the metal t rough construction as specified in 520.43 is not used, footlights shall consist of individual outlets with Lampholders wired with rigid metal conduit, intermediate metal conduit, or flexible metal conduit, Type MC cable, or mineral-insulated, metal-sheathed cable. The circuit conductors shall be soldered to the lampholder terminals.

(C) ©Disappearing Footlights. Disappearing footlights shall be arranged so that the current supply is automatically disconnected when the footlights are replaced in the storage recesses designed for them.

The footlights described in 520.43(A) and (B) are generally obsolete units that were built in the field. Modern footlights are compartmentalized, factory-wired assemblies for field installation, as shown in Exhibit 520.6. Footlight assemblies may be permanently exposed or be of the disappearing type. Disappearing footlights are arranged to automatically disconnect the current supply when the footlights are in the closed position, thereby preventing heat entrapment that could cause a fire. Disconnection is accomplished by mercury switches in the terminal compartment.

520.44 Borders and Proscenium Sidelights.

(A) General. Borders and proscenium sidelights shall be as follows:

(1) Constructed as specified in 520.43

(2) Suitably stayed and supported.

(3) Designed so that the flanges of the reflectors or other adequate guards protect the lamps from mechanical damage and from accidental contact with scenery or other combustible material.

Exhibit 520.7 shows a modern border light installed over a stage. Exhibit 520.8 is a cross-sectional view that illustrates construction details. This particular border light is designed for 200-watt lamps. To obtain the highest illumination efficiency, each lamp is provided with its own reflector. Fitted to each reflector is a glass roundel available in any color. Commonly, Lampholders are wired alternately on three or four circuits. A splice box is provide on top of the housing for enclosing connections between the cable supplying the border light and the border light's internal wiring, which consists of wiring from the splice box to the lamp sockets in a trough extending the length of the border.

(B) Cords and Cable for Border Lights.

(1) General. Cords and cables for supply to border lights shall be listed for extra-hard usage. The cords and cables shall be suitably supported. Such cords and cables shall be employed only where flexible conductors are necessary. Ampacity of the conductors shall be as provided in 400.5

To facilitate height adjustment for cleaning and lamp replacement, border lights are usually supported by steel cables, as shown in Exhibit 520.9 Therefore, the circuit conductors supplying the border lights must be carried to the border light in a flexible cable. Each of these flexible cables usually contains many circuits; however, its overall size is limited by its ability to travel up and down without getting tangled.

(2) Cords and Cables Not in Contact with Heat-Producing Equipment. Listed multiconductor extra-hard-usage-type cords and cables not in direct contact with equipment containing heat-producing elements shall be permitted to have their ampacity determined by Table 520.44. Maximum load current in any

conductor with an ampacity determined by table 520.44 shall not exceed the values in Table 520.44.

The provisions of 520.44(B)(2) permit extra-hard usage cord no in direct contact with heat-producing equipment to have their ampacity determined by Table 520.44 instead of 400.5.

Table 520.44 is based on a minimum 50 percent diversity factor. It includes the fact that not all circuits are on at the same time, not all circuits are at full intensity (dimmed), and not all circuits are on for a long period of time. If the load diversity does not follow this pattern, such as border lights that are all left on a full intensity to light the stage for rehearsal, lecture, or classroom purposes, this table must not be used.

520.45 Receptacles. Receptacles for electrical equipment on stages shall be rated in amperes. Conductors supplying receptacles shall be in accordance with Articles 310 and 400.

520.46 Connector Strips, Drop Boxes, Floor Pockets, and Other Outlet Enclosures. Receptacles for the connection of portable stage-lighting equipment shall be pendant or mounted in suitable pockets or enclosures and shall comply with 520.45. Supply cables for connector strips and drop boxes shall be as specified in 520.44(B).

520.47 Backstage Lamps (Bare Bulbs). Lamps (bare bulbs) installed in backstage and ancillary areas where they can come in contact with scenery shall be located and guarded so as to be free from physical damage and shall provide an air space of not less than 50mm (2 in.) between such lamps and any combustible material.

Exception: Decorative lamps installed in scenery shall not be considered to be backstage lamps for the purpose or this section.

520.48 Curtain Machines. Curtain machines shall be listed.

520.49 Smoke Ventilator Control. Where stage smoke ventilators are released by an electrical device, the circuit operating the device shall be normally closed and shall be controlled by at lest two externally operable switches, one switch being placed at a readily accessible location on stage and the other where designated by the authority having jurisdiction. The device shall be designed for the full voltage of the circuit to which it is connected, no resistance being inserted. The device shall be located in the loft above the scenery and shall be enclosed in a suitable metal box having a tight, self-closing door.

In addition to the smoke ventilators being controlled from two externally operable switches at different location, the design of a normally closed circuit opens for any reason, such as a circuit breaker tripping or a fuse blowing.

IV Portable Switchboards on Stage (A Type of Patch Panel)

A panel designed to allow for road show connection of portable stage switchboards to fixed lighting outlets by means of permanently installed supplementary circuits. The panel, supplementary circuits, and outlets shall comply with 520.50(A) through (D).

Also known as a road show interconnect or intercept panel, a road show connection panel is designed to connect the load side of a portable switchboard to the fixed building branch circuits and associated outlets. It may also provide for the fixed branch circuits to be connected to a fixed switchboard when the portable switchboard is not installed.

(A) Load Circuits. Circuits shall terminate in grounding type polarized inlets of current and voltage rating that match the fixed-load receptacle.

The grounding-type polarized inlets may be flush or pendant. The fixed-load receptacle is on the other end of the branch circuit that emanates from the panel.

(B) Circuit Transfer. Circuits that are transferred between fixed and portable switchboards shall have all circuit conductors transferred simultaneously.

In accordance with 520.50(B), simultaneous transfer of all conductors of the circuit, including any grounded conductor, is required.

(C) Overcurrent Protection. The supply devices of these supplementary circuits shall be protected by branch-circuit overcurrent protective devices. The individual supplementary circuit, within the road show connection panel and theatre shall be protected by branch-circuit overcurrent protective

devices of suitable ampacity installed within the road show connection panel.

The branch-circuit overcurrent protection should normally be in the switchboard but because some older units do not have this protection, backup overcurrent protection is provided by 520.50©.
(D) Enclosure. Panel construction shall be in accordance with Article 408.

520.51 Supply.

Portable switchboards shall be supplied only from power outlets of sufficient voltage and ampere rating. Such power outlets shall include only externally operable, enclosed fused switches or circuit breakers mounted on stage or at the permanent switchboard in locations readily accessible from the stage floor. Provisions for connection of an equipment grounding conductor shall be provided. The neutral of feeders supplying solid-state, 3-phase, 4-wire dimmer systems shall be considered a current-carrying conductor.
Power outlets, known in the entertainment industry as company switches or bull switches, are the point in the wiring system where portable feeder cables connect to the fixed building wiring. They may be as simple as an overcurrent-protected multipole receptacle designed to accept the supply cable described in 520.53(P). Exception, or they may be multiple sets of parallel single-conductor feeder cables. These single-conductor feeder cables, as described in 520.53(H), may be terminated via single-pole separable connectors, as described in 520.53(K), or directly to Busbars, fused disconnect switches, or circuit breakers with wire connectors (lugs).
520.52 Overcurrent Protection.
Circuits from portable switchboards directly supplying equipment containing incandescent lamps on not over 300 watts shall be protected by overcurrent protective devices having a rating or setting of not over 20 amperes. Circuits for Lampholders over 300 watts shall be permitted where overcurrent protection complies with Article 210.

520.53 Construction and Feeders.
Portable switchboards and feeder for use on stages shall comply with 520.53(A) through (P).

(A) Enclosure. Portable switchboards shall be placed within an enclosure of substantial construction, which shall be permitted to be arranged so that the enclosure is open during operation. Enclosures of wood shall be completely lined with sheet metal of not less than 0.51mm (0.020 in.) and shall be well galvanized, enameled, or otherwise properly coated to prevent corrosion or be of a corrosion resistant material.
(B) Energized Parts. There shall not be exposed energized parts within the enclosure.
(C) Switches and Circuit Breakers. All Switches and Circuit breakers shall be of the externally operable, enclosed type.
(D) Circuit Protection. Overcurrent devices shall be provided in each ungrounded conductor of every circuit supplied through the switchboard. Enclosures shall be provided for all overcurrent devices in addition to the switchboard enclosure.
(E) Dimmers. The terminals of dimmers shall be provided with enclosures, and dimmer faceplates shall be arranged so that accidental contact cannot be readily made with the faceplate contacts.
(F) Interior Conductors.
(1) Type. All conductors other than Busbars within the switchboard enclosure shall be stranded. Conductors shall be approved for an operating temperature at least equal to the approved operating temperature of the dimming devices used in the switchboard and in no case less than the following:
(1) Resistance-type dimmers---200°C (392°F); or
(2) Reactor-type, autotransformer, and solid-state dimmers--- 125°C (257°F).

All control wiring shall comply with Article 725.
(2) Protection. Each conductor shall have an ampacity not less than the rating of the circuit breaker, switch, or fuse that it supplies. Circuit interrupting and bus bracing shall be in accordance with 110.9 and 110.10. The short-circuit current rating shall be marked on the switchboard.

Conductors shall be enclosed in metal wireways or shall be securely fastened in position and shall be bushed where they pass through metal.

(G) Pilot Light. A pilot light shall be provided within the enclosure and shall be connected to the circuit supplying the board so that the opening of the master switch does not cut off the supply to the lamp. This lamp shall be on an individual branch circuit having overcurrent protection rated or set at not over 15 amperes.

The requirements of 520.53(G) applies only to switchboards with a main disconnect, if provided, on the switchboard. The pilot light serves as a warning at the switchboard that indicated the presence of power before the main disconnect is activated.

(H) Supply conductors.

(1) General. The supply to a portable switchboard shall be by means of listed extra-hard usage cords or cables. The supply cords or cable shall terminate within the switchboard enclosure, in an external operable fused master switch or circuit breaker or in a connector assembly identified for the purpose. The supply cords or cable (and connector assembly) shall have sufficient ampacity to carry the total load connected to the switchboard and shall be protected by overcurrent devices.

As with the supply end described in 520.51, the connection described in 520.53(H)(1) may be as simple as permanently terminated multiconductor supply cord or multipole connector assembly (inlet), or as complex as a set off parallel single conductor feeder cables. These cables may be field-connected to an assembly of single-pole connectors (inlet) or directly connected, with wire connectors, to busbars or a fused switch or breaker.

The requirements of 520.53(H)(1) permits road shows with fixed lighting plans to size the feeder to the actual connected load.

(2) Single-Conductor Cables. Single-conductor portable supply cable sets shall not e smaller than 2 AWG conductors. The equipment grounding conductor shall not be smaller than 6 AWG conductor. Single-conductor grounded neutral cables for a supply shall be sized as per 520.53(O)(2). Where single conductors are paralleled for increased ampacity, the paralleled conductors shall be of the same length and size. Single-conductor supply cables shall be grouped together but not bundled. The equipment grounding conductor shall be permitted to be of a different type, provided it meets the other requirements of this section, and it shall be permitted to be reduced in size as permitted by 250.122. Ground (neutral) and equipment grounding conductors shall be identified in accordance with 200.6, 250.119 and 310.12. Grounded conductors shall be permitted to be identified by marking at lest the firs 150mm (6 in.) from both ends of each length of conductor with white or gray. Equipment grounding conductors shall be permitted to be identified by marking at lest the firs 150mm (6 in.) from both ends of each length of conductor with green or green with yellow strips. Where more than one nominal voltage exists within the same premises, each ungrounded conductor shall be identified by system.

(3) Supply Conductors Not Over 3.0m (10 ft) Long.

Where supply conductors do not exceed 3.0m (10 ft) in length between supply and switchboard or supply and a subsequent overcurrent device, the supply conductors shall be permitted to be reduced in size where all of the following conditions are met:

(1) The ampacity of the supply conductors shall be at least one-quarter of the ampacity of the supply overcurrent protection device.

(2) The supply conductors shall terminate in a single over-current protection device that will limit the load to the ampacity of the supply conductors. This single overcurrent device shall be permitted to supply additional over-current devices on its load side.

(3) The supply conductors shall not penetrate walls, floors, or ceilings or be run through doors or traffic areas. The supply conductors shall be adequately protected from physical damage.

(4) The supply conductors shall be suitably terminated in an approved manner.

(5) Conductors shall be continuous without splices or connectors.

(6) Conductors shall not be bundled.

(7) Conductors shall be supported above the floor in an approved manner.

(4) Supply conductors Not Over 6.0m (20 ft) Long.
Where supply conductors do not exceed 6.0m (20 ft) in length between supply and a subsequent overcurrent protection device, the supply conductors shall be permitted to be reduced in size where all of the following conditions are met:
(1) The ampacity of the conductors shall terminate in a single over-current protection device.
(2) The supply conductors shall terminate in a single overcurrent protection device that limits the load to the ampacity of the supply conductors. This single overcurrent device shall be permitted to supply additional overcurrent devices on its load size.
(3) The supply conductors shall not penetrate walls, floors, or ceilings or be run through doors or traffic areas. The supply conductors shall be adequately protected from physical damage.
(4) The supply conductors shall be suitably terminated in an approved manner.
(5) The supply conductors shall be supported in an approved manner at least 2.1m (7 ft) above the floor except at terminations.
(6) Conductors shall not be bundled.
(7) Tap conductors shall be in unbroken lengths.

Loads of 144 kVA and greater are not uncommon, even on portable switchboard equipment. Installations in the field include lighting for theatrical-type productions with large numbers of stage lighting fixtures. However, only a fraction of the many fixtures installed are used at any one time. The intent of 530.53(H)(3) and (H)(4) is that the supply conductors must be sized according to their overcurrent protection and not by the total connected load. These requirements are similar to the requirements for taps found in 240.21.

The tap rules of 530.53(H)(3) and (H)(4) are designed to allow one or more switchboards with small feeders to be connected to large supplies (company switches). If these "rules" are not complied with, proper overcurrent protection devices, either fixed or portable, must be provided for each of the smaller switchboards.

The requirement that the conductors not be bundled is so that column D of Table 400.5(B) can be employed. If the conductors are bundled, column F and all applicable derating factors would apply. Most devices used in the theatre to terminate single-conductor cables are rated for use at 90°C ampacity. However, if single-conductor cables are terminated directly to a circuit breaker or fused switch, a 75°C ampacity or lower would most likely apply.

(5) Supply Conductors Not Reduced in Size.
Supply conductors not reduced in size under provision 530.53(H)(3) and 530.53(H)(4) shall be permitted to pass through holes in wall specifically designed for the purpose. If penetration is through the fire-resistant-wall, it should be in accordance with 300.21.
(I) Cable Arrangement. Cables shall be protected by bushings where they pass through enclosures and shall be arranged so that tension is not transmitted to the connections. Where power conductors pass through metal, the requirements of 300.20 shall apply.

Tension on the connections is removed by using conventional strain relief devices, or often by lashing the cable to the enclosure with rope.

(J) Number of supply Interconnections. Where connectors are used in a supply conductor, there shall be a maximum number of three interconnections (mated connector pairs) where the total length from supply to switchboard does not exceed 30m (100 ft), one additional interconnection shall be permitted for each additional 30m (100 ft) of supply conductor.

The addition of excessive number of interconnections could jeopardize the mechanical and electrical integrity of the supply conductors.

(K) Single-Pole Separable Connectors. Where single-pole portable cable connectors are used, they shall be listed and of the locking type. Sections 400.10, 406.6 and 406.7 shall not apply to listed single-pole separable connectors and single-conductor cable assemblies utilizing listed single-pole separable connectors. Where

paralleled sets of current-carrying, single-pole separable connectors are provided as input devices, they shall be prominently labeled with a warning indicating the presence of internal parallel connections. The use of single-pole separable connectors shall comply with at least one of the following conditions:
(1) Connection and disconnection of connectors are only possible where the supply connectors are interlocked to the source and it is not possible to connect or disconnect connectors when the supply is energized.
(2) Line connectors are of the listed sequential-interlocked type so that load connectors shall be connected in the following sequence:
a. Equipment grounding conductor connectors.
b. Grounded circuit conductor connection, if provided.
c. Ungrounded conductor connector, and that disconnection shall be in the reverse order.
(3) A caution notice shall be provided adjacent to the line connectors indicating that plug connection shall be in the following order:
a. Equipment grounding conductor connectors.
b. Grounded circuit conductor connection, if provided.
c. Ungrounded conductor connector, and that disconnection shall be in the reverse order.

The requirements in 520.53(k) provide for a special type of connection device suitable for connecting single-conductor feeder cables. The connection device must b e listed and of the locking type, reducing the likelihood of its separating while under load. The connectors must be used in sets because they are only single-pole types. It is important that the grounding conductor be connected first and disconnected last, and that the grounded conductor be connected next to first and disconnected next-to-last. The connector sets must be arranged so as to reduce the likelihood that the connections will be made in the incorrect order, in accordance with one of the following methods.

1. Provide a scheme whereby the main disconnect cannot be energized until all conductors are connected.
2. Provide a scheme whereby the connectors are precluded from being connected in any order than the proper one.
3. Provide a scheme whereby the individual connectors, free of any special electromechanical intervention, are marked with instructions to the user regarding proper connection.

Single-pole separable connectors are quick-connect feeder splicing and terminating devices, not attachment plugs or receptacles. They are designed to be sized, terminated, and inspected by a qualified person before being energized, and are to be guarded from accidental disconnection before being de-energized.

(L) Protection of Supply Conductors and Connectors.
All supply conductors and connectors shall be protected against physical damage by an approved means. This protection shall not be required to be raceways.
Rubber mats and commercially available rubber bridges are often used for the protection of supply conductors and connectors.

(M) Flanged Surface Inlets. Flanged surface inlets (recessed Plugs) that are used accept the power shall be rated in amperes.

(N) Terminals. Terminals to which stage cables are connected shall be located so as to permit convenient access to the terminals.

The requirement in 520.53(N) facilitates the field connection and disconnection of the large feeder cables as the show travels from place to place.

(O) Neutral.

(1) Neutral Terminal. In portable switchboard equipment designed for use with 3-phase, 4-wire with ground supply, the supply neutral terminal, its associated busbar, or equivalent wiring, or both, shall have an ampacity equal to at least twice the ampacity of the largest ungrounded supply terminal.

Exception: Where portable switchboard equipment is specifically constructed and identified to be internally converted in the field, in an approved manner, from use with a balanced 3-phase, 4-wire with ground supply to a balanced single-phase, 3-wire with ground supply, the supply neutral terminal and its associated busbar, equivalent wiring, or both, shall have an ampacity equal to at lest that of the larges ungrounded single-phase supply terminal.

The requirement in 520.53(O)(1) requires careful study because overlapping concepts are involved. If a 3-phase, 4-wireswitchboard of any kind is brought into a space that has only single-phase, 3-wire service, the switchboard will most likely be connected with two phases to one leg and one phase to the other. This connection could double the current flowing through neutral, so the neutral must be double size to allow for this possibility. The exception to 520.53(O)(1) provides for a smaller neutral sized for the single-phase feed where a switchboard contains switching devices that can divide the B-phase load equally between the A-phase and C-phase buses for single-phase operation.

Additionally, 3-phase, 4-wire switchboards that contain solid-state dimming devices must, when connected to a 3-phase, 4-wire supply, be connected to that supply with a multiconductor cable sized by counting the neutral as a current-carrying conductor, or with a set of single-conductor cables where the neutral is sized 130 percent greater than the phases.

For example, a 3-phase, 4-wire switchboard containing six 50 ampere SCR dimmers (100 amperes per phase) without a reassignment switching system would have to have a 200-ampere neutral. (A single-phase, 3-wire-only switchboard would not have to meet this special requirement.) This 200 percent rule would cover all the components making up the neutral conductor system inside o r permanently attached to the switchboard, so as to allow for a full-size, single-phase, 3-wire feed when two of the 3-phase, 4-wire phase conductors are terminated to one single-phase, 3-wire leg. Note that the 200 percent neutral already covers the derating requirements (125 percent for a multiconductor feeder system and 130 percent for a single-conductor feeder system) when used in the 3-phase mode. If a reassignment system were added, the neutral would be required to be only 150 amperes. Again, when used in the 3-phase mode, the derating factors would be covered.

Note that the double-neutral requirement covers the terminal and associated busbar or wiring. This requirement covers the terminal and associated busbar wiring. This requirement begins at the main input terminals or busing, main input inlet connector, or attached main input cord-and-plug set and includes all wiring on the load side of that point. Power supply feeders easily detached a the terminals or inlet connector need not adhere to the 200 percent neutral rule because they can easily be sized on a show-by-show basis for the type of supply encountered. Theses cable must, however, adhere to the requirements of the neutral as a current-carrying conductor, or on the 130 percent single-conductors cable neutral.

(2) Supply Neutral. The power supply conductors for portable switchboards shall be sized considering the neutral as a current-carrying conductor. Where single-conductor feeder cables, not installed in raceways, are used on multiphase circuits, the grounded neutral conductor shall have an ampacity of at lest 130 percent of the ungrounded circuit conductors feeding the portable switchboard.

(P) Qualified Personnel. The routing of portable supply conductors, the making and breaking of supply conductors and other supply connection, and the energization and de-energization of supply services shall be performed by qualified personnel, and portable switchboards shall be so marked, indicating this requirement in a permanent and conspicuous manner.

Exception: *A portable switchboard shall be permitted to be connected to a permanently installed supply receptacle by other than qualified personnel, provided that the supply receptacle is protected for its rated ampacity by an overcurrent device of not greater than 150 amperes, and where the receptacle, interconnection and switchboard further*

(a) Employ listed multipole connectors suitable for the purpose for every supply interconnection, and
(b) Prevent access to all supply connections by the general public, and
(c) Employ listed extra-hard usage multiconductor cords or cables with an ampacity suitable for the type of load and not less than the ampere rating of the connectors.

The intent of 250.53(P) is to divide the acceptable practices in what are most likely to be professional and professional grade educational venues fro those in amateur or amateur grade educational venues. The basic requirements allow for such things as single-conductor feeder systems, feeders sized for the current-connected load, tap rules, and so on, and require the services of a qualified person. The exception to 250.53(P) provides for a conventional feeder system suitable for use by an untrained person.

V Portable Stage Equipment Other Than Switchboards.

520.61 Arc Lamps.

Arc lamps, including enclosed arc lamps and associated ballast, shall be listed. Interconnecting cord sets and interconnecting cords and cable shall be extra-hard usage type and listed.

520.62 Portable Power Distribution Units.

Portable power distribution units shall comply with 520.62(A) through (E).

(A) Enclosure. The construction shall be such that no current-carrying part will be exposed.

(B) Receptacles and Overcurrent Protection. Receptacles shall comply with 520.45 and shall have branch-circuit overcurrent protection in the box. Fuses and circuit breakers shall be protected against physical damage. Cords or cables supplying pendant receptacles shall be listed for extra-hard usage.

(C) Busbars and Terminals. Busbars shall have an ampacity equal to the sum of the ampere ratings of all the circuits connected to the busbar. Lugs shall be provided for the connection of the master cable.

(D) Flanged Surface Inlets. Flanged surface inlets (recessed plugs) that are used to accept the power shall be rated in amperes.

(E) Cable Arrangement. Cables shall be adequately protected where they pass through enclosures and be arranged so that tension on the cable is not transmitted to the terminations.

520.63 Bracket Fixture Wiring.

(A) Bracket Wiring. Brackets for use on scenery shall be wired internally, and the fixture stem shall be carried through to the back of the scenery where a bushing shall be placed on the end of the stem. Externally wired brackets or other fixtures shall be permitted where wired with cords designed for hard usage that extend through scenery and without joint or splice in canopy of fixture back and terminate in an approved-type stage connector located, where practical, with 450mm (18 in) of the fixture.

(B) Mounting. Fixtures shall be securely fastened in place.

520.64 Portable Strips.

Portable Strips shall be constructed in accordance with the requirements for border lights and proscenium sidelights in 520.44(A).
The supply cable shall be protected by bushings where it passes through metal and shall be arranged so that tension on the cable will not be transmitted to the connections.

FPN No 1: See 520.42 for wiring of portable strips
FPN No 2: See 520.68(A)(3) for insulation types required on single conductors.

520.65 Festoons.

Joints in festoon wiring shall be staggered. Lamps enclosed in lanterns or similar devices of combustible material shall be equipped with guards.

Festoon lighting is defined in article 100. Joints in festoon wiring must be staggered and properly insulated. This arrangement ensures that connections will not be opposite one another, which could cause sparking due to improper insulation or unraveling of insulation, which, in turn, could ignite lanterns or other combustible material enclosing lamps. Where Lampholders have terminals of a type that puncture the conductor insulation and make contact with the conductors, stranded conductors should be used.

520.66 Special Effects.

Electrical devices used for simulating lightning, waterfalls and the like shall be constructed and located so that flames, sparks, or hot particles cannot come in contact with combustible material.

520.67 Multipole Branch-Circuit Cable Connectors.

Multipole branch-circuit cable connectors, male and female, for flexible conductors shall be constructed so that tension on the cord or cable is not transmitted to the connections. The female half shall be attached to the load end of the power supply cord or cable. The connector shall be rated in amperes and designed so that differently rated devices cannot be connected together; however, a 20 ampere T-slot receptacle shall be permitted to accept a 15 ampere attachment plug of the same voltage rating. Alternating-current multipole connectors shall be polarized and comply with 406.6 and 406.9.

FPN: See 400.10 for pull at terminals.

520.68 Conductors for Portables.

(A) Conductor Type

(1) General. Flexible conductors, including cable extensions, used to supply portable stage equipment shall be listed extra-hard usage cords or cables.

(2) Stand Lamps. Reinforced cord shall be permitted to supply stand lamps where the cord is not subject to severe physical damage and is protected by an overcurrent device rated at not over 20 amperes.

See 520.2 for the definition of *stand lamp* (work light).

(B) High-Temperature Applications. A special assembly conductors in sleeving not longer than 1.0 m (3.3 ft) shall be permitted to be employed in lieu of flexible cord if the individual wires are stranded and rated not less than 125°C (67°F) and the outer sleeve is glass fiber with a wall thickness of at least 0.635mm (0.025 in).

Portable stage equipment requiring flexible supply connections with a higher temperature rating where one end is permanently attached to the equipment shall be permitted and employ alternate, suitable conductors as determined by a qualified testing laboratory and recognized test standards.

The requirements of 520.68(A)(3) cover the connection of high-temperature equipment including stage lighting fixtures, which often do operate at elevated temperatures. High-temperature (150°C to 250°C) extra-hard-usage cords limited to 3.3 ft in length to reduce the likelihood that they could be placed on the floor or other area where they might be damaged by traffic or moving scenery.

(4) Breakouts. Listed hard usage (junior hard service) cords shall be permitted in breakout assemblies where all of the following conditions are met:

(1) The cords are utilized to connect between a single multipole connector containing two or more branch circuits and multiple 2-pole, 3 wire connectors.
(2) The longest cord in the breakout assembly does not exceed 6.0m (20 ft).
(3) The breakout assembly is protected from physical damage by attachment over its entire length to a pipe or truss, tower, scaffold, or other substantial support structure.
(4) All branch circuits feeding the breakout assembly are protected overcurrent devices rated at not over 20 amperes.

The provision or 520.68(A)(4) applies to multiconductor cable assemblies with multipole connectors that contain more than one branch circuit. The breakout assembly is a multipole connector with several pendant receptacles connected to it, separating the multiple branch circuits into individual branch circuits. It is also possible to use a similar arrangement of pendant plugs to form a breaking assembly on the other end of the multiconductor cable.

(B) Conductor Ampacity. The ampacity of conductors shall be as given in 400.5, except multiconductor, listed, extra-hard usage portable cords that are no in direct contact with equipment containing heat-producing elements shall be permitted to have their ampacity determined by Table 520.44. Maximum load current in any conductor with an ampacity determined by Table 520.44 shall not exceed the values in Table 520.44.

In accordance with 520.68(B), portable, multicircuit, multiconductor cable is permitted to be sized accordance with Table 520.44, similar to the method used for border light cable. If portable, multicircuit, multiconductor cable is located horizontally directly above heat-producing equipment, I lieu of a connector strip, it should be spaced sufficiently above that equipment to avoid the elevated temperatures or should be sized in accordance with 400.5.

Exception: Where alternate conductors are allowed in 520.68(A)(3), their ampacity shall be as given in the appropriate table in the Code for the types of conductors employed.

520.69 Adapters.

Adapters, two-fers and other single- and multiple-circuit outlet devices shall comply with 520.69(A), (B), and (C).

(A) No reduction in Current Rating. Each receptacle and its corresponding cable shall have the same current and voltage rating as the plug supplying it. It shall not be utilized in a stage circuit with a greater rating.

(B) Connectors. All connectors shall be wired in accordance with 520.67.

Adapters are available where cords and connector bodies of one ampacity are connected to a plug of a larger rating. For example, a 12 AWG conductor with an ampacity of 20 amperes could be connected to a 100 ampere circuit. An overload could result in a fire because the circuit breaker or fuse would not provide adequate protection. The plug and receptacle must be of the same rating, in accordance with 520.69(B).

(C) Conductor Type. Conductors for adapter and two-fers shall be listed, extra-hard usage or listed, hard usage (junior hard service) cord. Hard usage (junior hard service) cord shall be restricted in overall length to 1.0 m (3.3 ft).

VI Dressing Rooms

520.71 Pendant Lampholders.
Pendant Lampholders shall not be installed in dressing rooms.

520.72 Lamp Guards.

All exposed incandescent lamps in dressing rooms, where less than 2.5 m (8 ft) from the floor, shall be equipped with open-end guards riveted to the outlet box cover or otherwise sealed or locked in place.

Because of the many types of flammable materials present in dressing rooms, such as costumes and wigs, pendant lampholders are not permitted. Lamps must be provided with suitable open-end guards that permit relamping and are not easily removed. This makes it difficult to circumvent the guard's intended purpose of preventing contact between the lamps and flammable material.

520.73 Switches Required.

All lights and any receptacle adjacent to the mirror(s) and above the dressing table counter(s) installed in dressing rooms shall be controlled by wall switches installed in the dressing room(s). Each switch controlling receptacles adjacent to the mirror(s) and above the dressing table counter(s) shall be provided with a pilot light located outside the dressing room, adjacent to the door to indicate when the receptacles are energized. Other outlets installed in the dressing room shall not be required to be switched.

The requirement in 520.73 only addresses receptacles located adjacent to t he mirror and on the countertop. The receptacles located elsewhere in the room are not subject to the disconnect and pilot light requirements of 520.73. The purpose of the switching requirement is to make sure that all coffee pots, curling irons, hair dryers, and other similar countertops appliances can be readily disconnected at the end of the performance.

VII Grounding

520.81 Grounding.

All metal raceways and metal-sheathed cables shall be grounded. The metal frames and enclosures of all equipment, including border lights and portable luminaries (lighting fixtures), shall be grounded. Grounding, where used, shall be in accordance with Article250.

City of Chicago Electrical Code

ARTICLE 520 ---Theatres, Audience Areas of Motion Picture and Television Studios, Performance Areas and Similar Locations

Part A. General.

18-27-520.1 Scope.

This article covers all buildings or that part of a building or structure designed or used for presentation, dramatic, musical, motion picture projection, or similar purposes and to specific audience seating areas within motion picture or television studios.

18-27-520.2 Definitions.

Border Light. A permanently installed overhead strip light

Bundled. Cables or conductors that are physically tied, wrapped, taped or otherwise periodically bound together.

Breakout Assembly. An adapter used to connect a multiple connector containing two or more branch circuits to multiple individual branch circuit connectors.

Connector Strip. A metal wireway containing pendant or flush receptacles.

Drop Box. A box containing pendant- or flush-mounted receptacles attached to a multiconductor cable via strain relief, or a multipole connector.

Footlight. A border light installed on or in the stage.

Grouped. Cables or conductors positioned adjacent to one another but not in continuous contact with each other.

Portable Equipment. Equipment fed with portable cords or cables intended to be moved from one place to another.

Portable Power Distribution Unit. Apower distribution box containing receptacles and overcurrent devices

Proscenium. The wall and arch that separates the stage from the auditorium (house).

Stand Lamp (Work Light). A portable stand that contains a general-purpose lighting fixture or lamp holder with guard for the purpose of providing general illumination on the stage or in the auditorium.

Strip Light. A lighting fixture with multiple lamps arranged in a row.

Two-Fer. An adapter cable containing one male plug and tow female cord connectors used to connect two loads to one branch circuit.

18-27-520.3. Motion Picture Projectors.

Motion picture equipment and its installation and use shall comply with Article 540.

18-27-520.4. Audio Signal Processing, Amplification, and reproduction Equipment.

Audio signal processing, amplification, and reproduction equipment and its installation shall comply with Article 640.

18-27-520.5. Wiring Methods.

(a) General. The f fixed wiring method shall be metal raceways, and type MI cable. (*Reference use only type MI: Type MI mineral-insulation, metal sheathed cable is a listed factory assembly of one or more conductors insulated with a highly compressed refractory mineral insulation and enclosed in a liquid tight and gastight continuous copper or alloy steel sheath.)*

Exception: Fixed wiring methods shall be as provided in Article 640 for signal processing, amplification and reproduction, in Article 800 for communications circuits, in Article 725 for Class 2 and Class 3 remote control and signaling circuits, and in Article 760 for fire alarm circuits.

(b) Portable Equipment. The wiring for portable switchboards, stage set lighting, stage effects, and other approved flexible cords and cables as provided elsewhere in Article 520. Fastening such cables and cords by uninsulated staples or nailing shall not be permitted.

18-27-520.6. Number of conductors in Raceway.

The number of conductors permitted in any metal conduit, or electrical metallic tubing for border or stage pocket circuits or for remote-control conductors shall not exceed the percentage fill shown in Table 1 of Article 900. Where contained within an auxiliary gutter or a wireway, the sum of the cross-sectional areas of all contained conductors at any cross section shall not exceed 20 percent of the interior cross-sectional area of the auxiliary gutter or wireway. The 30-conductor limitation of Sections 18-27-362.5 and 18-27-374.5 shall not apply.

18-27-520.7. Enclosing and Guarding Live parts.

Live parts shall be enclosed or guarded to prevent accidental contact by persons and objects. All switches shall be of the externally operable type. Dimmers, including rheostats, shall be placed in cased or cabinets that enclose all live parts.

18-27-520.8. Emergency Systems.

Control of emergency systems shall comply with Article 700.

18-27-520.9. Branch Circuits.

A branch circuit of any size supplying one or more receptacles shall be permitted to supply stage set lighting. The voltage rating of the receptacles shall not be less than the circuit voltage. Receptacle amperage ratings and branch-circuit conductor ampacity shall not be less than the branch-circuit overcurrent device ampere rating. Table 18-27-210.21(b)(2) shall not apply.

18-27-520.10. Portable Equipment.

Portable stage and studio lighting equipment and portable temporary use outdoors provided the equipment is supervised by qualified personnel while energized and barriered from the general public.

PART B. FIXED STAGE SWITCHBOARD

18-27-520.21 Dead Front.

Stage switchboards shall be of the dead-front type and shall comply with Part D of Article 384 unless approved based on suitability as a stage switchboard as determined by a qualified testing laboratory and recognized test standards and principles.

18-27-520.22. Guarding Back of Switchboard.

Stage switchboard shall be totally enclosed and have no exposed live parts.

18-27-520.23. Control and Overcurrent Protection of Receptacle Circuits.

Means shall be provided at a stage-lighting switchboard to which load circuits are connected for overcurrent protection of stage-lighting branch circuits, including branch circuits supplying stage and auditorium receptacles used for cord- and plug-connected stage equipment. Where the stage switchboard contains dimmers to control nonstage lighting, the locating of the overcurrent protective devices for these branch circuits at the stage switchboard shall be permitted.

18-27-520.24. Construction.

A stage switchboard shall be constructed to protect all equipment on the board from falling objects.

18-27-520.25. Dimmers.

Dimmers shall comply with (a) through (d) of this section.

(a) Disconnection and overcurrent protection. Where dimmers are installed in ungrounded conductors, each dimmer shall

have overcurrent protection not greater than 125 percent of the dimmer rating, and shall be disconnected from all ungrounded conductors when the master or individual switch or circuit breaker supplying such dimmer is in the open position.

(b) Resistance- or Reactor-type dimmers. Resistance- or series reactor-type dimmers shall be permitted to be placed in either the grounded or the ungrounded conductor of the circuit. Where designed to open either the supply circuit to the dimmer or the circuit controlled by it, the dimmer shall then comply with Section 18-27-380.1. Resistance- or reactor-type dimmers placed in the grounded neutral conductor of the circuit shall not open the circuit.

(c) Autotransformer-Type Dimmers. The circuit supplying an autotransformer-type dimmer shall not exceed 150 volts between conductors. The grounded conductor shall be common to the input and output circuits.

FPN: See Section 18-27-210.9 for circuits derived from autotransformers.

(d) Solid State-Type Dimmers. The circuit supplying a solid-state dimmer shall not exceed 150volts between conductors unless the dimmer is listed specifically for higher voltage operation. Where a grounded conductor supplies a dimmer, it shall be common to the input and output circuits. Dimmer chassis shall be connected to the equipment grounding conductor.

18-27-520.26. Type of Switchboard.

Stage switchboard shall be wither one or a combination of the following types:

(a) **Manuel**. Dimmers and switches are operated by handles mechanically linked to the control devices.

(b) **Remotely Controlled.** Devices are operated electrically from a pilot-type control console or panel. Pilot control panels shall either be part of the switchboard or shall be permitted to be at another location

(c) Intermediate. A stage switchboard with circuit interconnections is a secondary switchboard (patch panel) or panelboard remote to the primary stage switchboard. It shall contain overcurrent protection. Where the required branch-circuit overcurrent protection is provided in the dimmer panel, it shall be permitted to be omitted for the intermediate switchboard.

18-27-520.27. Stage Switchboard Feeders.

(a) Type of Feeder. Feeders supplying stage switchboards shall be one of the following:

(1) Single Feeder. A single feeder disconnected by a single disconnect device.

(2) Multiple Feeders to Intermediate Stage Switchboard (Patch Panel). Multiple feeders of unlimited quantity shall be permitted, provided that all multiple feeders are part of a single system. Where combined, neutral conductors in a given raceway shall be of sufficient ampacity to carry the maximum unbalanced current supplied by multipole feeder conductions in the same raceway, but need not be greater than the ampacity of the neutral supplying the primary stage switchboard. Parallel neutral conductors shall comply with Section 18-27-310.4.

(3) Separate Feeders to Single Primary Stage Switchboard (Dimmer Bank). Installations with separate feeders to a single primary stage switchboard shall have a disconnecting means for each feeder. The primary stage switchboard shall have a permanent and obvious label stating the number and location of disconnecting means. If the disconnecting means are located in more than one distribution switchboard, the primary stage switchboard shall be provided with barriers to correspond with these multiple locations.

(b) Neutral. The neutral of feeders supplying solid-state, 3-phase, 4-wire dimming system shall be considered a current-carrying conductor.

(c) Supply Capacity. For the purposes of computing supply capacity to switchboards, it shall be permissible to consider t he maximum load that the switchboard is intended to control in a given installation, provided that:

(1) All Feeders supplying the switchboard shall be protected by an overcurrent device with a rating not greater than the ampacity of the feeder.

(2) The opening of the overcurrent device shall not affect the proper operation of the egress or emergency lighting systems.

FPN: For computation of stage switchboard feeder loads, see Section 18-27-220.10.

Part C. FIXED STAGE EQUIPMENT OTHER THAN SWITCHBOARDS.

18-27-520.41. Circuit Loads.

(a) Circuits Rated 20 Amperes or Less. Footlights, border lights, and proscenium sidelights shall be so arranged that no branch circuit supplying such equipment will carry a load exceeding 20 amperes.

(b) Circuits Rated Greater than 20 Amperes.

Where heavy-duty lampholders only are used, such h circuits shall be permitted to comply with Article 210 for circuits supplying heavy-duty lampholders.

18-27-520.42. Conductor Insulation.

Foot, border, proscenium, or portable strip light fixtures and connector strips shall be wired with conductors having insulation suitable for the temperature at which the conductors will be operated, but not less than 125° C (257°F). The ampacity of the 125°C (257°F) conductors shall be that of 60°C (140°F) conductors. All drops from connector strips shall be 90°C (194°F) wire sized to the ampacity of 60°C (140°F) cords and cables with no more than 6 in. (152mm) of conductor extending into the connector strip. Section 18-27-310.15(b)(2) shall not apply.

FPN: See Table 18-27-310.13 for conductor types.

18-27-520.43. Footlights.

(a) Metal Trough Construction. Where metal trough construction is employed for footlights, the trough containing the circuit conductors shall be made of sheet metal not lighter than No.20 MSG treated to prevent oxidation. Lampholder terminals shall be kept at least ½ in. (12.7 mm) from the metal of the trough. The circuit conductors shall be soldered to the lampholder terminals.

(b) Other-than-Metal Trough Construction. Where the metal trough construction specified in Section 18-27-520.43(a) is not used, footlights shall consist of individual outlet with lampholders wired with rigid metal conduit, intermediate metal conduit, or where flexibility is required, flexible metal conduit, or mineral-insulated, metal sheathed cable. The circuit conductors shall be soldered to the lampholder terminals.

(c) Disappearing Footlights. Disappearing footlights shall be so arranged that the current supply will be automatically disconnected when the footlights are replaced in the storage recesses designed for them.

18-27-520.44. Borders and Proscenium Sidelights.

(a) General. Borders and proscenium sidelights shall be as follows:

(1) Constructed as specified in Section 18-27-520.43;

(2) Suitably stayed and supported; and

(3) Designed so that the flanges of the reflectors or other adequate guards will protect the lamps form mechanical damage and from accidental contact with scenery or other combustible material

(b) Cables for Border Lights.

(1) General. Cords and cables for supply to border lights shall be listed for extra-hard usage. The cords and cables shall be suitably supported. Such cords and cables shall be employed only where flexible conductors are necessary. Ampacity of the conductors shall be as provided in Section 18-27-400.5.

	Temp. Rating of Cords & Cables		Maximum rating of Over-current protection
Size (AWG)	**75°C (167°F)**	**90°C (194°F)**	**Device** (Breaker Size)
14	24	23	15
12	32	35	20
10	41	47	25
8	57	65	35
6	77	87	45
4	101	114	60
2	133	152	80

*Ampacity shown is the ampacity for multiconductor cords where only three copper conductors are current-carrying. If the number of current-carrying conductors in a cord exceeds three and the load diversity factor is a minimum of 50 percent, the ampacity of for each conductor shall be reduced as shown in the following table:

Number of Conductors	Percent of usable Ampacity
4-6	80
7-24	70
25-42	60
43+	50

Note: Ultimate insulation temperature. In no case shall conductors be associated together is such a way with respect to the kind of circuit, the wiring method used, or the number of conductors such that the temperature limit of the conductors will be exceeded.

The neutral conductor shall be considers to be a current carrying conductor.

(2) Cords and Cables Not in Contact with Heat Producing Equipment. Listed multiconductor extra-hard usage-type cords and cables not in direct contact with equipment containing heat-producing elements shall be permitted to have their ampacity determined by Table 18-27-520.44. Maximum load current in any conductor with ampacity determined by Table 18-27-520.44 shall not exceed the values in Table 18-27-520.44.

18-27-520.45. Receptacles.

Receptacles for electrical equipment or fixtures on stages shall be rated in amperes and conform to the following:

(1) A continuous load shall not exceed 80 percent of the receptacle rating.

(2) A noncontiunuous load shall not exceed 100 per cent of the receptacle rating.

Conductors supplying receptacle shall be in accordance with Articles 310 and 400.

18-27-520.46. Connector Strips, Drop Boxes, Floor Pockets, and Other Outlet Enclosures.

Receptacles for the connection of portable stage-lighting equipment shall be pendant or mounted in suitable pockets or enclosures and comply with Section 18-27-520.45. Supply cables for connector strips and drop boxes shall be as specified in Section 18-27-520.44(b).

18-27-520.47. Backstage Lamps (Bare Bulbs).

Lamps (bare Bulbs) installed in backstage and ancillary areas where they can come in contact with scenery shall be so located and guarded as to be free from physical damage and shall provide and air space of not less than 2 in. (50.8mm) between such lamps and any combustible material.

18-27-520.48. Curtain Machines.

Curtain Machines shall be listed.

PART D PORTABLE SWITCHBOARDS ON STAGE

18-27-520.50. Road Show Connection Panel (A Type of Patch Panel).

A panel designed to allow for road show connection of portable stage switchboards to fixed lighting outlets by means of permanently installed supplementary circuits. The panel, supplementary circuits, and outlets shall comply with (a) through (d) of this section.

(a) Load Circuits. Circuits shall terminated in grounding-type polarized inlets of current and voltage rating that match the fixed-load receptacle.

(b) Circuit Transfer. Circuits that are transferred between fixed and portable switchboards shall have all circuit conductors, including the neutral transferred simultaneously.

(c) Overcurrent Protection. The supply devices of these supplementary circuits shall be protected by branch-circuit overcurrent protective devices. The individual supplementary circuit, within the road show connection panel and theatre, shall be protected by branch –circuit overcurrent protective devices of suitable ampacity installed within the road show connection panel.

(d) Enclosure. Panel contraction shall be in accordance with Article 384.

18-27-520.51. Supply.

Portable switchboards shall be supplied only from power outlets of sufficient voltage and ampere rating. Such power outlets shall include only externally operable, enclosed fused switches or circuit breaker mounted on stage or at the permanent switchboard I location readily accessible from the stage floor. Provisions for connection of an equipment grounding conductor shall be provided. The neutral of feeder supplying solid state, 3-phase, 4-wire dimmer systems shall be considered a current carrying conductor.

18-27-520.52. Overcurrent Protections.

Circuits from portable switchboards directly supplying equipment containing incandescent lamps or not over 300 watts shall be protected by overcurrent protective devices having a rating or setting o not over 20 amperes. Circuits for lampholder over 300 watts shall be permitted where overcurrent protection complies with Article 210.

18-27-520.53. Construction and Feeders,

Portable switchboards and feeders f or use on stages shall comply with (a) through (p) of this section.

(a) Enclosure. Portable switchboards shall be placed within an enclosure of substantial construction, which shall be permitted to be so arranged that the enclosure is open during operation. Enclosures of wood shall be completely lined with sheet metal of not less than No. 24 MSG and shall be well galvanized to prevent corrosion or be of a corrosion-resistant material.

(b) Energized Parts. There shall not be exposed energized parts within the enclosure.

(c) Switches and Circuit Breakers. All switches and circuit breakers shall be of the externally operable, enclosed type.

(d) Circuit Protection. Overcurrent devices shall be provided in each ungrounded conductor of every circuit supplied through the switchboard. Enclosures shall be provided for all overcurrent devices in addition to the switchboard enclosure.

(e) Dimmers. The terminals of dimmers shall be provided with enclosures, and dimmer faceplates shall be so arranged that accidental contact cannot be readily made with the faceplate contacts.

(f) Interior Conductors.

(1) Type. All conductors other than busbars within the switchboard enclosure shall be stranded. Conductors shall be approved for an operating temperature of the dimming devices used in the switchboard and in no case less than the following:

(1) Resistance-type dimmers – 200°C (392°F); or

(2) Reactor-type, autotransformer, and solid-state dimmers – 125°C (257°F).

All control wiring shall comply with Article 725.

(2) Protection. Each conductor shall have an ampacity not less than the rating of the circuit breaker, switch, or fuse that it supplies. Circuit interrupting and bus bracing shall be in accordance with Section 18-27-110.9 and 110.10. Switchboards with inadequate short-circuit withstand rating shall be protected on the line side by current-limiting devices. The short-circuit withstand rating shall be marked on the switchboard.

Conductors shall be enclosed in metal wireways or be securely fastened in position and shall be bushed where they pass through metal.

(g) Pilot Light. A pilot light shall be provided within the enclosure and shall be so connected to the circuit supplying the board that the opening of the master switch will no cut off the supply to the lamp. This lamp shall be on an individual branch circuit having overcurrent protection rated or set at not over 15 amperes.

(h) Supply Conductors.

(1) General. The supply to a portable switchboard shall be by means of extra-hard usage cords or cables. The supply cords or cable shall terminate within the switchboard enclosure, in an externally operable fused master switch or circuit breaker, or in a connector assembly identified for the purpose. The supply cords or cable (and connector assembly) shall have sufficient ampacity to carry the total load connected to the switchboard and shall be protected by overcurrent devices.

(2) Single-Conductor Cables. Single-conductor portable supply cable set shall not be smaller than No. 1 conductors. The equipment grounding conductor shall not be smaller than No. 6 conductor. Single conductor grounded neutral cables for a supply shall be sized as per Section 18-27-520.539(o)(2).

Where single conductors are paralleled for increased ampacity, the paralleled conductors shall be of the same length, type and size. Single conductor supply cables shall be grouped together but not bundled.

The equipment grounding conductor shall be permitted to be of a different type, provided it meets the other requirements of this section, and it shall be permitted to be reduced in size as permitted by Section 18-27-250.122. Grounded (neutral) and equipment grounding conductors shall be identified in accordance with Sections 18-27-200.6, 250.134(b), and 310.12. Grounded conductors shall be permitted to be identified by marking at least the first 6 in. (152.4 mm) from both ends of each length of conductor with white or natural gray. Equipment grounding conductors shall be permitted to be identified by marking at least the first 6 in. (152.4 mm) from both ends of each length of conductor with green or green with yellow stripes.

Where more than one nominal voltage exists within the same premises, each ungrounded system conductor shall be identified by system.

(3) Supply Conductors Not Over 10ft (3.05 m) Long. Where supply conductors do not exceed 10ft (3.05 m) in length between supply and switchboard or supply and a subsequent overcurrent device, the supply conductors shall be permitted to be reduced in size where all of the following conditions are met:

(a) The ampacity of the supply conductors shall be at least one-quarter of the ampacity of the supply overcurrent protection device.

(b) The supply conductors shall terminate in a single overcurrent protection device that will limit the load to the ampacity of the supply conductors. This single overcurrent device shall be permitted to supply additional overcurrent devices on its load side.

(c) The supply conductors shall not penetrate walls, floors, or ceiling or be rung through doors or traffic areas. The supply conductors shall be adequately protected from physical damage.

(d) The supply conductors shall be suitably terminated in an approved manner.

(e) Conductors shall be continuous without splices or connectors.

(f) Conductors shall not be bundled.

(g) Conductors shall be supported above the floor in an approved manner.

(4) Supply conductors Not Over 20 ft (6.1 m) Long. Where supply conductors do not exceed 20 ft (6.1 m) in length between supply and switchboard or supply and a subsequent overcurrent protection device, the supply conductors shall be permitted to be reduced in size where all of the following conditions are met:

(a) The ampacity of the supply conductors shall be at least one-half the ampacity of the supply overcurrent protection device.

(b) The supply conductors shall terminate in a single overcurrent protection device that will limit the load to the ampacity of the supply conductors. This single overcurrent device shall be permitted to supply additional overcurrent devices on its load side.

(c) The supply conductors shall not penetrate walls, floors, or ceiling or be rung through doors or traffic areas. The supply conductors shall be adequately protected from physical damage.

(d) The supply conductors shall be suitably terminated in an approved manner.

(e) The supply conductors shall be supported in an approved manner at least 7 ft (2.13 m) above the floor except at terminations.

(f) The supply conductors shall not be bundled.

(g) Tap conductors shall be in unbroken lengths.

(i) Cable arrangement. Cables shall be protected by bushings where they pass through enclosures and shall be arranged so that tension on the cable will not be transmitted to the connections. Where power conductors pass through metal, the requirements of Section 18-27-300.20 shall apply.

(j) Number of Supply Interconnections. Where connectors are used in a supply conductor, there shall be a maximum number of three interconnections (mated connector pairs) where the total length from supply to switchboard does not exceed 100 ft (30.5 m). In cases where the total length from supply to switchboard exceeds 100 feet (30.5 m), one additional interconnection shall be permitted for each additional 100 ft (30.5 m) of supply conductor.

(k) Single-Pole Separable Connectors. Where single-pole portable cable connectors are used, they shall be listed and of the locking type. Sections 18-27-400.10 and 410.56 shall not apply to listed assemblies utilizing listed single-pole separable connectors. Where paralleled sets of current-carrying, single-pole separable connectors are provided as input devices, they shall be prominently labeled with a warning indicating the

presence of internal parallel connections. The use of such connectors shall comply with at least on of the following conditions:

(1) Connection and disconnection of connectors are only possible where the supply connectors are interlocked to the source and it is not possible to connect or disconnect connectors when the supply is energized.

(2) Line connectors are of the listed sequential-interlocking type so that load connectors shall be connect in the following sequence:

(a) Equipment grounding conductor connection;

(b) Grounded circuits conductor connection, if provided;

((c) Ungrounded conductor connection, and that disconnection shall be in the reverse order.

(3) A caution notice shall be provided adjacent to the line connectors indicating that plug connection shall be in the following order:

(a) Equipment grounding conductor connection;

(b) Grounded circuits conductor connection, if provided;

(c) Ungrounded conductor connection, and that disconnection shall be in the reverse order.

(I) Protection of Supply conductors and Connectors. All supply conductors and connectors shall be protected against physical damage by an approved means. This protection shall not be required in raceways.

(m) Flanged Surface Inlets. Flanged surface inlets (recessed plugs) that are used to accept the power shall be rated in amperes.

(n) Terminals. Terminals to which stage cables are connected shall be so located as to permit convenient access to the terminals.

(o) Neutral

(1) Neutral Terminal. In portable switchboard equipment designed for use with 3-phase, 4-wire with ground supply, the supply neutral terminal, its associated busbar, or equivalent wiring, or both shall have an ampacity equal to at least twice the ampacity of the larges ungrounded supply terminal.

Exception: Where portable switchboard equipment is specifically constructed and identified to be internally converted in the field in an approved manner, from use with a balance 3-phase 4-wire with ground supply to a balanced single-phase, 3-wire grounded supply, the supply neutral terminal and its associated busbar, equivalent wiring, or both shall have an ampacity equal to at least that of the largest ungrounded single-phase supply terminal.

(2) Supply Neutral. The power supply lines for portable switchboards shall be sized considering the neutral as a current-carrying conductor. Where single-conductor feeder cables, not installed in raceways are used on multiphase circuits, the grounded neutral conductor shall have an ampacity of a least 130 percent of the ungrounded circuit conductors feeding the portable switchboard.

(p) Qualified Personnel. The routing of portable supply conductors, the making and breaking of supply connectors and other supply connections, and the energization and de-energization of supply services shall be performed by qualified personnel, and portable switchboards shall be so marked, indicating this requirement in permanent and conspicuous manner.

PART E. PORTABLE STAGE EQUIPMENT OTHER THAN SWITCHBOARDS.

18-27-520.61. Arc Lamp Fixtures.

Arc lamp fixtures, including enclosed are lamp fixtures and associated ballasts, shall be listed. Interconnecting cord set and interconnecting cords and cables shall be extra-hard usage type and listed.

18-27-520.62. Portable Power Distribution Units.

Portable power distribution units shall comply with (a) through (e) of this section.

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(a) Enclosure. The construction shall be such that no current-carrying part will be exposed.

(b) Receptacles and Overcurrent Protection.

Receptacles shall comply with Section 18-27-520.45 and shall have branch-circuit overcurrent protection in the box. Fuses and circuit breaker shall be protected against physical damage. Cords or cable supplying pendant receptacles shall be listed for extra-hard usage.

(c) Busbars and Terminals. Busbars shall have an ampacity equal to the sum of the ampere ratings of all the circuits connected to the busbar. Lugs shall be provided for the connection of the mast cable.

(d) Flanged Surface Inlets. Flanged surface inlets (recessed plugs) that are used to accept the power shall be rated in amperes.

(e) Cable Arrangement. Cables shall be adequately protected where they pass through enclosures and be arranged so that tension on the cable will not be transmitted to the terminations.

18-27-520.63. Bracket Fixture Wiring.

(a) Bracket Wiring. Brackets for use on scenery shall be carried through to the back of the scenery where a bushing shall be placed on the end of the stem. Externally wired brackets or other fixtures shall be permitted where wired with cords designed for hard usage that extend through scenery and without joint or splice in canopy of future back and terminate in an approved-type stage connector located within 18 in (457 mm) of the fixture.

(b) Mounting. Fixtures shall be securely fastened in place.

18-27-520.64. Portable Strips.

Portable strips shall be constructed in accordance with the requirements for border lights and proscenium side lights in Section 18-27-520.44(a). The supply cable shall be protected by bushings where it passes through metal and shall be so arranged that tension on the cable will not be transmitted to the connections.

FPN No. 1: See Section 18-27-520.42 for wiring of portable strips.

FPN No. 2: See Section 18-27-520.68(a)(3) for insulation types required on single conductors.

18-27-520.65. Festoons.

Joints in festoon wiring shall be staggered. Lamps enclosed in lanterns or similar devices of combustible material shall be equipped with guards.

18-27-520.66. Special Effects.

Electrical devices used for simulating lighting, waterfalls, and the like shall be constructed and located so that flames, sparks, or hot particles cannot come in contact with combustible material.

18-27-520.67. Multipole Branch-Circuit Cable Connectors.

Multipole branch-circuit cable connectors, male and female, for flexible conductors shall be constructed so that tension on the cord or cable will not be transmitted to the connections. The female half shall be attached to the load end of the power supply cord or cable. The connector shall be rated in amperes and designed so that differently rated devices cannot be connected together. Alternating current multipole connectors shall be polarized and comply with Sections 18-27-410.56(g) and 410.58

FPN See Section 18-27-400.10 for pull at terminals.

18-27-520.68. Conductors for Portables

(a) Conductor Type.

(1) General. Flexible conductors, including cable extensions, used to supply portable stage equipment shall be listed extra-hard usage cords or cables.

(2) Stand Lamps. Reinforce cord shall be permitted to supply stand lamps where the cord is not subject to sever physical damage and is protected by and overcurrent device rated at no over 20 amperes.

(3) High-Temperature Applications. A special assembly on conductors in sleeving not longer that 3.3 ft (1 m) shall per permitted to be employed in lieu of flexible cord if the individual wires are stranded and rated not less than 125°C (257°F) and the outer sleeve is glass fiber with a wall thickness of at least 0.025 in (0.635mm).

Portable stage equipment requiring flexible supply conductors with a higher temperature rating where one end is permanently attached to t he equipment shall be permitted to employ alternate suitable conductors as determined by a qualified testing laboratory and recognized test standards.

(4) Breakouts. Listed, hard usage (junior hard service) cords shall b e permitted in breakout assemblies where all of the following conditions are met:

(a) The cords are utilized to connect between a single multipole connector containing two or more branch circuits and multipole two-pole, 3-wire connectors.

(b) The longest cord in the breakout assembly does not exceed 20 ft (6.1m).

(c) The breakout assembly is protected from physical damage by attachment over its entire length to a pipe, truss, tower, scaffold, or other substantial support structure.

(b) Conductor Ampacity. The ampacity of conductors shall be as given in Section 18-27-400.5, except multiconductor, listed extra-hard usage portable cords, that are not in direct contact with equipment containing heat-producing elements, shall be permitted to have their ampacity determined by Table 18-27-520.44. Maximum load current in any conductor shall not exceed the values in Table 18-27-520.44.

18-27-520.69. Adapters

Adapters, Two-fers, and other single and multiple circuit outlet devices shall comply with (a), (b), and (c) of this section:

(a) No Reduction in Current Rating. Each receptacle and its corresponding cable shall have the current and voltage rating as the plug supplying it. It shall not be utilized in a stage circuit with a greater current rating.

(b) Connectors. All connectors shall be wired in accordance with Sections 18-27-520.67.

(c) Conductor Type. Conductors for adapter and two-fers shall be listed, extra-hard usage or listed, hard usage (junior hard service) cord. Hard usage (junior hard service) cord shall be restricted in overlength to 3.3 ft (1 m).

PART F. DRESSING ROOMS

18-27-520.71. Pendant Lampholders.

Pendant lampholders shall not be installed in dressing rooms.

18-27-520.72. Lamp Guards.

All exposed incandescent lamp in dress rooms, where less than 8 ft (2.44 m) from the floor shall be equipped with open-end guards riveted to the outlet box cover or otherwise sealed or locked in place.

18-27-520.73. Switches Required.

All lights and any7 receptacles adjacent to the mirror(s) installed in dressing rooms shall be controlled by wall switches installed in the dressing room(s). Each switch controlling

receptacles adjacent to the mirrors(s) and above the dressing table counter(s) shall be provided with a pilot light located outside the dressing room, adjacent to the door to indicate when the receptacles are energized. Other outlets installed in the dressing room shall not be required to be switched.

PART G. GROUNDING

18-27-520.81. Grounding.

All metal raceway shall be grounded. The metal frames and enclosures of all equipment, including portable and fixed switchboards, border lights and portable lighting fixtures, shall be grounded. Grounding, where used, shall be in accordance with Article 250.

Bibliography

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Recommended Practice for DMX 512 by Adam Bennette, PLSA/ USITT; 1994
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National Electrical Code Handbook, Ninth edition 2002 NFPA ISBN 0-87765-462-x
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www.plsn.com/cgi/issue/viewissue.cgi?category=13&id=1014056031
Chicago Daily News negatives collection, DN-0003451. Courtesy of the Chicago Historical Society.

Useful Industry Links

- **LUMINAIRES** (GENERICS)
  - Altman Lighting Inc. (USA)
  - Artistic Licence
  - ADB (Belgium)
  - CCT Lighting
  - Full Compass (USA)
  - High End Systems Moving Lights
  - Robert Juliat (France)
  - Opti Projection and effects luminaires and rigging
  - Pulsar (UK) Chroma LED range
  - RazTech (USA) Retail and domestic projectors
  - Reiche & Vogel (Germany)
  - Selecon
  - Strand Lighting
  - Strong Entertainment Lighting - Followspots
  - James Thomas Engineering
  - Zero 88
- **MOVING LIGHTS**
  - ADB (Belgium)
  - Articulight (NJ, USA)
  - Clay Paky
  - Coemar
  - Coe-Tech
  - Color Kinetics
  - FAL
  - Futurelight
  - High End
  - Light Factor
  - Martin (International site)
  - Martin (UK site)
  - Morpheus
  - SGM
  - Vari*Lite
- **LAMPS**
  - GE Lighting
  - Osram
  - Philips
  - Sylvania
- **EFFECTS LUMINAIRES / DISCO**
  - Abstract
  - American DJ

Links Continued

- **LED LIGHTING**
  - Color Kinetics LED Fittings
  - Lighting Effects Distribution LED lighting
  - Lumivision Architectural Lighting (Glasgow, UK)
  - Pulsar (UK) Chroma LED range
  - Selador X7 range of fixtures (San Francisco/Salt Lake City, USA)
- **EFFECTS / GOBOS** / **ELECTRICAL PROPS & PRACTICALS**

(for **Pyrotechnics, Smoke etc.** see Theatrical Effects page)

  - Apollo Design Technology Gels, gobos, scrollers (USA)
  - Californeon Electroluminescent tape
  - Cool Neon Bendable electroluminescent wire
  - DHA Lighting (London, UK)
  - Furnish That Room (UK, Mail Order)
  - GlowShop Ltd. UV effects (Birmingham, UK)
  - Goboland (Belgium, Europe)
  - Howard Eaton Lighting Ltd (UK)
  - Hungaroflash (Hungary, Europe) Strobe effects and controllers
  - HVFX - High voltage special effects
  - Lamps Plus Massive range of light fittings - online catalogue (USA)
  - Le Mark Custom gobos in steel or glass
  - Nocturn (USA) UV Effects
  - Opti Projection and effects luminaires and rigging
  - Par Opti Fibre-optics
  - Projected Image UK Ltd (London, UK) Glass and brass custom gobos
  - S&H Technical Support Starcloths and fibre-optics
  - ShowLED by Amelia LED Starcloths etc.
  - Skytracker Searchlights
  - Surelight Electroluminescent wire (Sheffield, UK)
  - Theatre FX
  - Universal Fibre Optics (UK)
  - UV FX (USA)
  - Wildfire Inc. UV Paint/Make-up/Luminaires

- **COLOUR MEDIA**
  - Apollo Design Technology Gels, gobos, scrollers (USA)
  - Gam (US)
  - Lee Filters (UK) - Excellent online catalogue showing colours grouped together
  - Rosco Laboratories - Rosco Supergel, Cinegel, E Colour
  - Colour Frame sizes - A.C. Lighting

Links Continued

- **CONTROL / DIMMING**
  - ADB (Belgium)
  - Anytronics
  - Artistic Licence (UK)
  - AVAB (Sweden)
  - Avolites
  - Celco
  - Compulite
  - Electrol (USA)
  - ETC
  - Entertainment Technology
  - Flying Pig Systems Lighting Visualisation Software
  - Goddard Design DMX Test / Distribution / Processing equipment (NY, USA)
  - Horizon Technology
  - Leprecon
  - Light Processor
  - Liteputer (Taiwan)
  - MA Lighting
  - Mode Lighting (Herts, UK) Dimmers and controllers
  - NSI
  - Pulsar
  - Rubber Box Co.
  - Strand Lighting
  - Theatrelight (New Zealand)
  - Zero 88

- **EQUIPMENT - ACCESS**
  - Aluminium Access Products - Tallescope sales and service (UK)
- **EQUIPMENT - FLIGHTCASES / TOURING**
  - Dragon Cases - Custom flight case design and manufacture (Wales, UK)
  - Le Mark - Equipment labels and tapes
  - Musicase - Flight cases and bags - Dealers for ROAD READY CASES and GIG SKINZ
  - S.A.M. Custom Flight Cases - Flight cases (Bristol, UK)
  - Triple-A Flight Cases (UK)
- **EQUIPMENT - DESIGN AIDS**
  - Field Template - LX design stencils
- **EQUIPMENT - RIGGING**
  - Applied Electronics - Trussing, lifts etc (USA)
  - CMS - Cable Management Supplies (UK)
  - Doughty Engineering (UK, USA) Rigging products
  - Exhibit and Display Truss - (Pickering, Ontario, Canada)
  - H.O.F.Alutec (Germany) Rigging & Truss systems
  - Opti Trilite truss

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