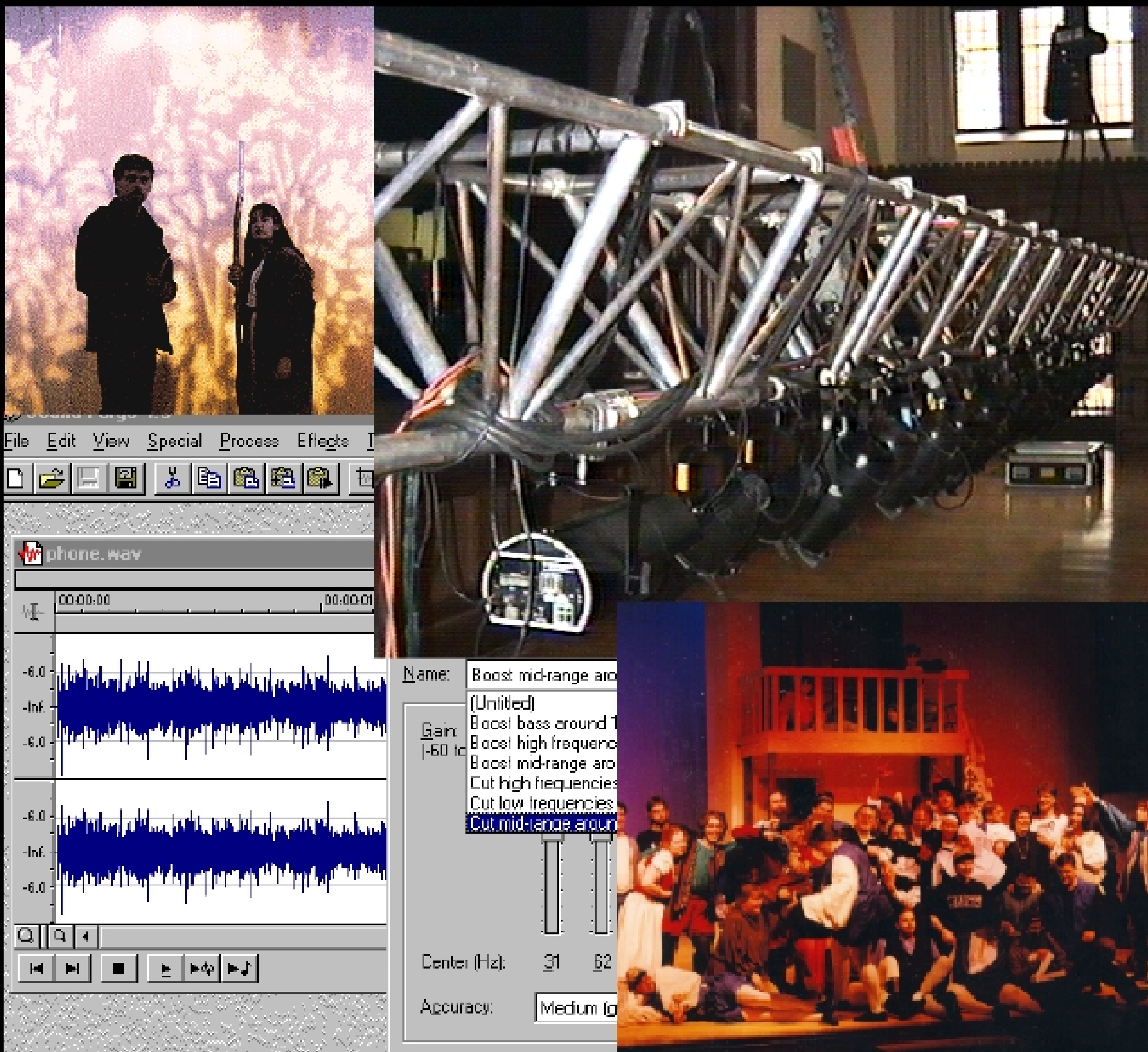
WPI

Technical Theatre Handbook



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A Digital Equipment Corporation Alpha workstation running Linux and an Intel i486 running Microsoft Windows NT were used in the preparation of this book. The text was edited in GNU Emacs and typeset in LaTeX . Many of the photographs were taken using a Canon digital still camera. The remaining images were scanned using a Hewlett-Packard ScanJet II color image scanner. All photos were processed using Adobe Photoshop and XV. Diagrams were created using XFig. A Hewlett Packard Laserjet 5L laser printer and a Tektronix Phaser 340 color wax transfer printer were used to print the book.

to all of the great people involved in the various WPI theatre groups

and

to Kim, who kept me sane.

Contents

Chapter 1

Introduction

1.1 Goals

One of the major goals of this book is to provide a fairly complete introduction to most aspects of technical theatre. This introduction is given mainly in a general sense, but is supplemented with specifics relating to theatre at WPI. This treatment of the topics can provide an inexperienced person an excellent base of knowledge from which to start working on productions. It is important to remember, though, that the book is not meant to replace actual experience. Most areas of technical theatre require a fair degree of work to achieve proficiency. In other words, reading the lighting chapter isn't going to replace spending lots of hours working with experienced lighting designers or master electricians. However, each chapter of the book is intended to introduce the basic goals, equipment, vocabulary and design theory for each area of technical theatre. Therefore, it is highly recommended that people working in WPI technical theatre for the first time read through most of the book, paying closest attention to the areas in which they will work.

In addition to being a "newbie guide" to technical theatre, this book is also a valuable reference to relatively experienced techs. Several issues of safety are covered, which are *extremely* important, and often ignored. It is hoped that this book will be read by most people involved with WPI technical theatre, and as a result, the overall awareness of safety issues will increase.

The last major goal of the book is to provide a bridge between what is practiced in WPI theatre and what is practiced in professional theatres. Budgetary and time constraints are major contributors to the gap between the two, with the blind following of tradition also playing a role. It is hoped that this book can provide some inspiration to strive for something *more* than what has been done in the past at WPI, edging the technical end of productions one notch closer to complete professionalism.

1.2 Sources

Three main sources of information were used for the writing of this book. First, personal experience played a key role in the writing of some of the chapters. Secondly, WPI's own experts were consulted – those people who have spent countless hours working on productions. Lastly, many books, catalogs and other reference materials were read, to provide a greater sense of perspective for what is practiced outside of WPI.

Over the past several years, as I worked on several productions in various positions, I gained a certain appreciation for technical theatre as a whole. With this appreciation of the whole came a knowledge of a lot of the finer, more pedantic points of various areas of technical theatre. Constant involvement with productions proved over and over that there were a lot of things that people, unbeknownst to them, just didn't know. This brought about a desire to put together a compendium, a single source that could be consulted when issue arose. Filling this compendium with much of the knowledge, tips, and tricks I had learned over the years seemed quite a logical place to start.

Many extremely dedicated people are what make WPI theatre productions happen, and these people proved to be invaluable sources of information for this book. Several key people were chosen and interviewed. Each was asked to provide a general overview of what they thought their specific area of interest was all about. Specific issues that they thought the book should discuss were covered in these interviews. In addition, they were each asked to provide any tips, tricks, or humorous anecdotes relating to their specific areas of interest. This information was collected, read, and used as a sort of living reference guide for the writing of the book. It is this, combined with personal experience, that give the book it's tilt towards theatre at WPI.

When the writing of the book began, it was known that a balance between WPI specifics and the "real world" was desirable. To achieve this, a large amount of reference material was consulted. Books, catalogs, and World Wide Web sites were the major sources of information consulted to achieve this balance. Where differences between WPI theatre practices and those mentioned in books differered, it was so noted. This use of outside sources provided the perspective necessary to give the book a firm footing in both WPI and professional practices.

1.3 Methods

Achieving an adequate balance of breadth and depth was, perhaps, the most difficult task in writing this book. It was difficult to resist the tendency to try to include *every* last detail about a particular topic. It was also difficult to choose topics to leave out of the text. At the same time, however, the book needed to be completed in a seven week time-frame due to the schedule of the IQP.

Several topics were chosen to be discussed in the book. These topics were chosen because they were deemed to be the most important to cover in a general technical theatre book. Thus, the final form has individual chapters dedicated to: the set and scenery, costuming, rigging, lighting, audio, power, and special effects. Topics such as properties and running crew would have been included had time allowed, but the overall usefulness of the book does not suffer due to their absence.

It was decided early on that the chapters of the book should be as independent as possible. This independence allows individual chapters of the book to be handed out for reading in a classroom situation. This is ideal, especially for classes that require non-theatre people to do hands-on work for a production. Generally, a student chooses an area of interest and works a set number of hours in that area. This work time could be made more productive and useful if the student, before working, read the relevent chapters from this book. This might also serve to reduce the frustration level of the regular theatre crowd, as the people involved will be, on the whole, more knowledgable of theatre practices.

With the topics chosen, it came time to gather information to write the text, as well as acquire photographs and diagrams to supplement the text. Information was collected from a variety of sources, as described in the previous section. Once the mass of material was collected, it had to be sorted and filtered for content. Condensing mounds of information down to a single chapter was quite a challenging and formidable task. The information included in the book had to be general enough to provide a good degree of breadth, but it couldn't be "down to the nuts and bolts" specific.

The same philosophy went in to creating and choosing photographs and diagrams to include. In cases where a single photograph or diagram could replace many paragraphs of text, their inclusion made perfect sense. Other photographs and diagrams were useful simply because they provide visual context to the topics discussed in the text. Many photographs were taken of the equipment specifically used at WPI. The intent of this was so that anyone who had read this book would be able to start working productions at WPI and have a fair idea of exactly what different pieces of equipment looked like.

Each chapter started as an outline, which was filled in and changed as work progressed. Using this method, rather than simply diving in and writing, allowed the book to have a fairly consistent structure. The arrangement of most of the chapters is *equipment first, design second*. The book probably could have been written with the opposite organizational scheme, but it seemed most logical to do it this way, as it's practically impossible to design something that uses unfamiliar equipment.

As each chapter neared completion, it recieved two proofreadings. Errors were corrected and suggestions for improvement were heeded. After the bulk of the writing was completed, the final editing phase began. In this phase, the overall consistency of the book was checked. Also, the book was indexed, figures were credited, and the bibliography was assembled in this stage. Last-minute polishing and touch-up work, followed by the creation of the book cover and acknowledgements section rounded out the project.

1.4 Conclusions

While this is the first chapter that appears in the book, it was the last to be written. As this project draws to a close, I can only hope that the book will be used to educate those with an interest in technical theatre. I also hope that the book can serve as a useful reference to more experienced members of the WPI technical theatre community. It is with this thought that I dedicate the book to the that community, and hope that the text of this document is maintained so that it reflects the current state of theatre tech at WPI.

Chapter 2

Costumes

"Who would have thought a fearsome lizard such as Gutrah could have sprung forth from an old undershirt, some stuffing, and some hideously tacky fabric?" – Sarah Schlesinger, speaking of costuming for the hilarious *Destruction of Tokyo*, from WPI Masque's *New Voices 12*.

Figure 2.1: A scene from the 1996 WPI Masque production of Rostund's *Cyrano de Bergerac*, showing a variety of costumes.

2.1 Introduction

Costuming is an area of technical theatre that is perhaps second to only the set in terms of audience visibility. Many skills go in to designing and producing the clothing that cast members wear for a production. While many of these skills are largely artistic, there are several technical considerations that can be conveyed in written form.

Depending on the size of a production, there may be one or dozens of people working on costumes. The person in charge of coming up with the concepts and overall vision for the costumes is the *costume designer*. Several other people generally assist the costume designer in procuring and constructing costumes as envisioned in the design. In many small productions, the costume designer may end up doing a lot of the actual work involved with getting the costumes together for the cast.

In some cases, the job of the costume designer is finished once the costumes are complete. However, it is often the case that the costume designer and costume crew help out during the production to help people change costumes, fix any problems, etc. The division of responsibility differs greatly from theatre to theatre and production to production. Additionally, there are a great many differences between college theatre and professional theatre in this regard.

2.2 Procurement

In college theatre, a common method for costuming a cast is to find people who will donate or loan pieces of the various costumes. It is common to find experienced cast members who have acquired various costume pieces over their years in the theatre, and many are willing to lend items for the sake of the production. Local theatres also often have useful costume elements that they may be willing to lend out. Borrowing is an excellent way to save money, but extra care must be taken to make sure the borrowed materials are treated well and returned to their owner at the end of the production.

In the event that pieces can't be obtained in this manner and the costume designer has a budget to work with, many useful costume elements can be purchased. A variety of common stores sell items which can be used as costume elements. Clothing stores at malls, army/navy stores, thrift stores, and the Salvation Army are all places that should be checked if pre-made items are being purchased for costuming.

Often something that is purchased serves only as a starting point for a costume element. The costume piece may need further modification, if deemed by the costume designer. Even if modification is necessary, it saves time and effort to modify something pre-made rather than make the whole piece from scratch.

2.3 Fabrics

The types of fabric chosen for costume elements are important, whether the elements are store-bought or made specifically for the production. Inappropriate fabrics can make actors unhappy or make the costume look bad.

For a majority of costumes, lightweight cotton or cotton blends are ideal fabrics. They are sturdy, easy to sew, they breathe well, and they are easy to wash. This means that the costumes can last a long time, and actors won't roast on stage. Especially heavy fabrics should usually be avoided because they tend to be expensive and hot for an actor to wear. There are times, however, when fabrics of significant weight are preferable (i.e. when the piece being made needs to have a definite structure to it, such as a suit jacket or a heavy cape.). Conversely, extremely lightweight fabrics should usually be avoided because they tend not to be sturdy enough. Lightweight fabrics tend to be most useful to add emphasis, either to strengthen or soften the lines of the design or to highlight certain colors within the costume.

In general, fabrics with intricate prints are avoided, as the detail is lost when viewed by the audience due to the distance between the actors and the audience. Solid colors are usually used creatively for added effect, or the lack of detail is simply ignored.

2.4 Color

Choosing colors for costume elements requires a careful balancing of artistic qualities, physical properties, and psychological association. In keeping with the theme of this book, the artistic aspect will not be stressed. Additionally, the psychological aspect is a design issue, and as such, it is covered in a later section.

Since it is rare for the stage to be lit with perfectly white light, the interaction of lighting color and costume color must be considered. To understand how colors of light and colors of costume elements will interact, basic theories of both must be understood. A pigment can either reflect or absorb colors of light. A color will appear more brilliant when lit by a light of its own color. For example, if a red costume is lit with red light, the costume will appear as a very brilliant red. Similarly, if a color is lit with its complementary colors of light, it will appear very dark, as the light is mostly absorbed.

Often it is difficult or impossible to find fabric in the desired color. When this is the case, *dyes* can be used to color material to almost any shade. Several brands of commercial dyes are available, such as the infamous **RIT** dye. Most come in powder form, requiring mixing with water before use. If several colors of the same dye type are available, they can be *mixed* to form new colors. Dyes mix by what is known as the *subtractive mixing process.* If the three primary dye colors (red, blue and yellow) are mixed in equal quantities, black is the result. Secondary colors (green, magenta and orange) by mixing the primaries. Still more colors can be formed by mixing the secondaries with themselves, or with the primaries. There are an infinite number of colors that can be created with this scheme. Figure 2.2 depicts the mixing of primary colors to obtain secondary colors.

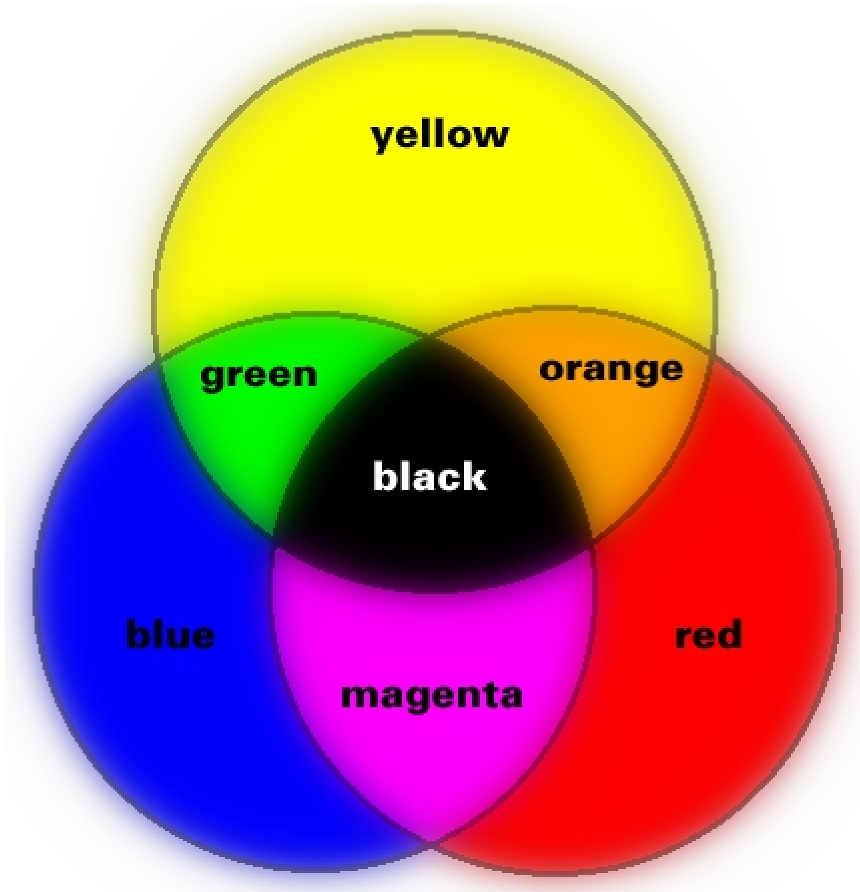

Figure 2.2: Subtractive mixing of the primary and secondary pigment and dye colors.

2.5 Patterns

A variety of pre-designed *patterns* are available for just about every type of clothing. These patterns can be used very effectively for costuming applications, either as-is or with modifications. Patterns are available at almost every fabric store, and through mail-order catalogs.

In some cases, the costume designer for a production will produce rough patterns for costumes. These patterns can be used as-is if they are appropriately made, but often will require adjustments and other changes.

2.6 Fitting

One of the most important aspects of costuming is making sure the costumes fit the actors properly. This requires a fair degree of skill and practice, but there are several useful points that can make the job easier.

In cases where costumes are being sewn for a production, measurements of the actors should be taken. There are two general sets of measurements that are taken — one set for upper body (for shirts, jackets, etc.), and one for the lower body (pants, skirts, etc.) The measurements that affect the fitting of clothing vary slightly between men and women.

Upper body measurements for men include the following: shoulder-to-shoulder, arm length, neck circumference, chest circumference, and back-to-waist length. A shoulder-to-shoulder measurement should be taken to provide a working width for the piece of clothing being created. Next, a measurement should be taken from the bone in the back of the neck to the wrist, to attain a sleeve length. Also helpful are circumference measurements of the chest and neck. Lastly, a measurement from the bone in the back of the neck to the waist helps to ensure that the garment will be of sufficient length for the actor.

There are fewer lower body than upper body measurements to be taken. A waist circumference measurement aids in making pants that will stay on the actor rather than fall down. Additionally, *inseam* (from crotch to ankle) and *outseam* (from waist to ankle) measurements help to fit the garment properly to the actor's leg length.

The upper body measurements that need to be taken for women are similar to those for men. The only major difference is that, with women, a bust measurement needs to be taken. Women's lower body measurements are taken in a similar fashion, with the addition of hip measurements. These additional measurements are necessary to assure proper fit due to the natural differences in shape between male and female bodies.

If the fitting skills of the designer or seamster are not particularly good, it is desirable for fairly loose-fitting costumes to be designed. It is much more preferable to have a costume fit loosely and look halfway decent than be too tight, look terrible and rip during a performance!

2.7 Rehearsal Clothing

Another important thing to consider is the clothing worn during rehearsals. So the actors may get a feel for what their final costumes will feel like when they are performing, it is common practice for them to wear similar articles of clothing during rehearsals. This lies mostly outside of the realm of responsibility of the costume designer. However, it is the costume designer's responsibility to let the director and cast know what they will be wearing so they can wear something appropriate to rehearsals.

2.8 Design

Like any other design position, many factors must be taken into consideration when designing costumes. A balance of the artistic and the practical must be struck.

2.8.1 How to Begin

The best thing to do to start a costume design is to read the script a few times. Having an understanding of the motivations, actions and outlook of the characters is essential to effective costume design. Often many images of how the cast should be costumed will come to mind after these initial readings. The director and design staff should also be consulted to understand their views of the characters.

Once the characters of the production are understood, the next step should be determining things to accentuate and decentuate with each character and actor. For example, if a character is heroic, it is common to costume them such that their form is seen as triangular — very strong at the top. Age can be accentuated by creating the illusion of additional body weight in different places. Young men tend to be skinny while men in their late 20's or 30's generally start to take on some weight. Young women are often viewed as having flowing lines while older women are often depicted as being heavier on top. If a woman is to play the role of a child, the top half of her body should be decentuated (with an ace bandage).

2.8.2 Color

It is common practice to consider colors for the costume elements. In addition to the interactions of the costume and light colors previously discussed, psychological associations of color should be considered. These associations are largely subliminal, but definitely effective to reinforce aspects of a character's personality. For example, in most cultures, black represents fear, death and uncertainty. Black could play a dominant role in the color scheme of an evil character, hopefully with the effect of enhancing the character's nastiness. Figure 2.3 lists some common color associations.

2.8.3 Practicality

Several issues of practicality should be thought through, before, during, and after the more artistic phases of the design process. For example, if the character gets into a fight and gets thrown all around the stage, a costume made out of a reasonably durable material will be necessary. Another important thing to

black	depressing, solemn, dead, evilness
white	pure, alive, truthful
red	warm, passionate, seductive, sexual, angry
blue	cool, tranquil
magenta	richness, royalty
green	peaceful, hopeful

Figure 2.3: Table of common colors and common associations. These colors, when used in costumes, can be used to accentuate certain features of a characters personality.

consider are entrances and exits on the set. Large hoop skirts and the like often will not fit conveniently through a doorway, and thus may cause problems for the actor.

Another important issue to consider is that of size of ornaments and other details on the costumes. Most will have to be made larger-than-life if they are to be seen, as small detail tends to get lost on stage.

2.8.4 Documents

The costume designer, if working solely in a design position, will typically need to produce several documents so that the rest of the costume crew may acquire or make the costumes. These documents, ranging from simple sketches and notes to color sketches and pictures, are the most important means of communication between the costume designer and the rest of the design staff. Figure 2.4 shows a typical costume sketch.

It is not uncommon for a costume designer to take or find photographs of costume styles they wish to replicate, and leave it in the hands of the seamsters and costume crew to come up with them. In other cases, a very specific design may be required, and the designer may go out of their way to make patterns or other detailed drawings indicating how the piece should be constructed.

It is very valuable to the actors and technical production staff to have sketches of the costumes available well before the production begins. The overall direction of the production can be a lot clearer in the minds of those on the production staff if everyone involved knows what all of the designers (including costumes) are working on.

In many smaller productions, the costume designer ends up working on the costume crew, or *is* the costume crew. Sometimes in these cases, much of the documentation process is ignored because it's just one person. This has the advantage of making the costume designer's job somewhat easier, but does not allow the rest of the production staff to have some sort of visual reference as to what direction the costume design is taking.

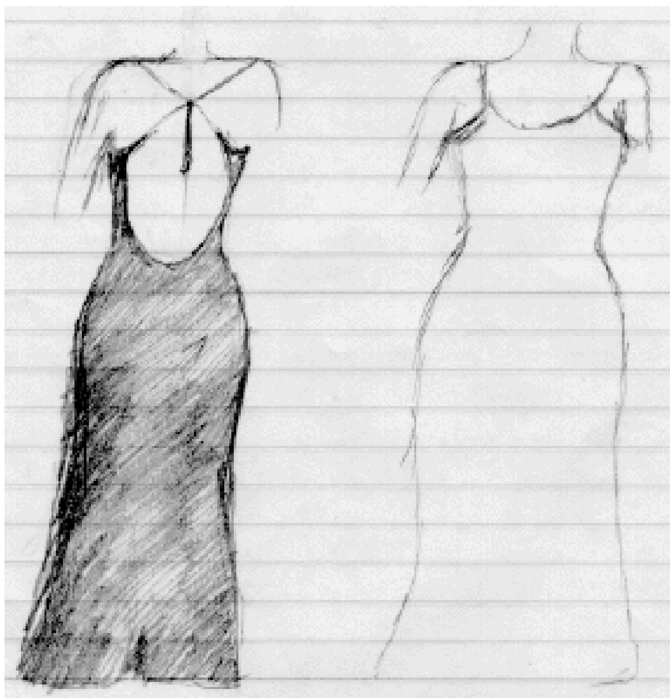

Figure 2.4: An example costume design sketch.

Chapter 3

The Set

"We really don't need that extra bracing... They're just actors..." – Dan Afonso, WPI technical theatre personality, speaking of how **not** to build a set.

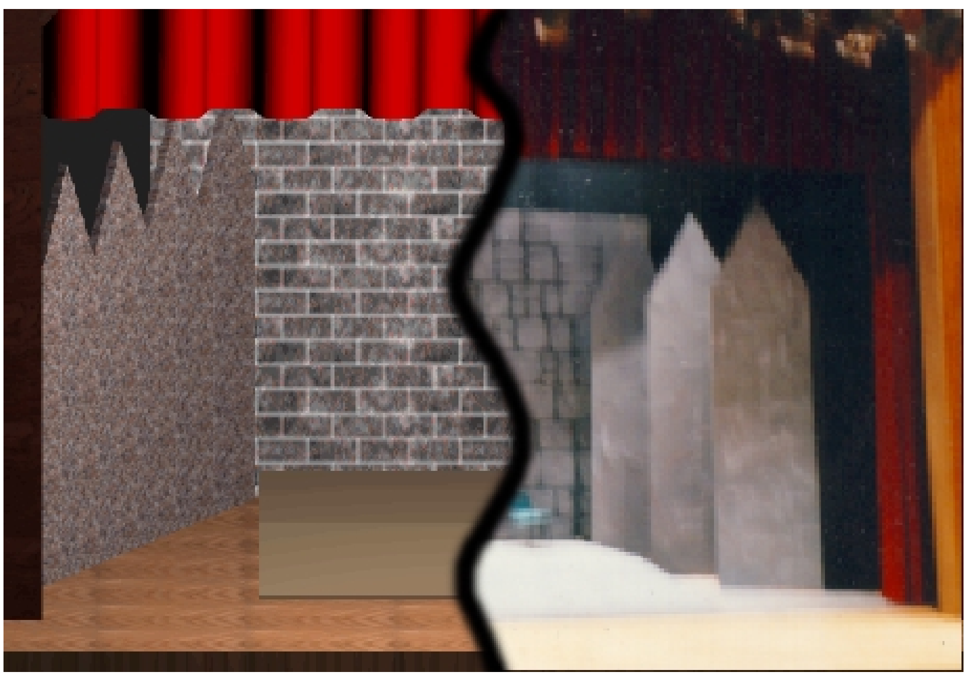

Figure 3.1: A split image showing a computer-generated rendering (left) and a photograph (right) of the set from the 1995 WPI Masque production of Shakespeare's *King Henry V*.

3.1 Introduction

Perhaps the most visible part of any production is *the setting*. The purpose of the set is to provide visual context for the action taking place on stage. If a production is to take place in an apartment, the set may be a very realistic representation of an apartment room.

To create a realistic scene, many different finishing techniques can be applied. These techniques require the use of special paints and painting tools. From the design perspective, an understanding of basic color principles and illusory techniques are necessary.

Often, the set is not only a visual element, but a structural one. Multi-level sets must be designed and built such that they can support the weight of actors on their upper levels. Walls must be structurally sound so that when set doors and windows are slammed, the set doesn't move and shatter the illusion of a real room.

The *Set Designer* is the person most responsible for the final look of the set. The responsibilities of the position include preparing measured drawings for the *Master Carpenter*, who is responsible for getting the set built as designed.

3.2 Set Pieces

In most theatres, modular scenic components are used that can be assembled in a virtually unlimited number of ways. Due to budgetary constraints, some of these components can be re-used for many productions, and it is not uncommon for a theatre's scene shop to contain a large inventory of these set components.

3.2.1 Platforms

Platforms are weight-bearing scenic structures that are used as acting space. Platforms can be used at varying heights, often several feet off of the ground. Platforms can be commercially purchased or built out of lumber. Commercial platforms tend to be bulky, noisy when walked upon, and generally can't be painted, thus the tendency to use wooden platforms.

A typical platform is constructed out of two by six inch lumber frame and covered with 3/4 inch plywood. This construction makes platforms sturdy, and often quite heavy if they are large. Legs can be attached to platforms, usually by the use of large screws. Figure 3.2 shows the construction of a typical platform.

Frequently, four by four inch material is used for platform legs, due to its strength and available area for attaching to the platform, Legs made of four by four lumber need cross-bracing if they are over three feet tall. This bracing can generally be made out of scrap lumber.

Often a stock of legs with standard heights are kept in a theatre's scene shop. Stock of several legs ranging from one to four feet in one foot increments is not at all uncommon, and is what the WPI scene shop stocks. Often times custom heights need to be cut from fresh stock, but generally most work can be done with the supply of standard legs.

Special care must be taken when extremely high platforms are used. The platforms must be adequately braced and supported such that there is no chance of a collapse. Railings should be used on high platforms wherever possible to minimize the chances of an actor falling off of one. For platforms over eight feet tall, four by four material for the legs is mandatory. The platform and legs should be attached to the wall and floor of the stage if possible. Some stages have strips of lumber attached to the upstage wall for the specific purpose of tying set pieces in. However, this is not always possible, especially in cases where a cyclorama or other soft good is flown behind the set. In cases like this, using aircraft cable to attach the platforms to the gridiron is a possible solution. The rigging chapter in this book provides more information relative to this topic.

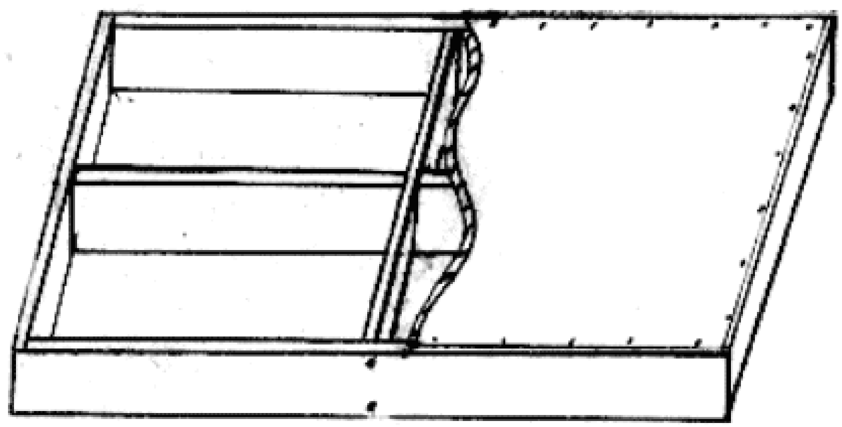

Figure 3.2: Construction of a typical platform. 2 inch lumber is used for the frame and 3/4 inch plywood is used for the top surface.

3.2.2 Flats

To create the illusion of interior and exterior walls, *flats* are used. There are two main types of flats: the *soft flat* and the *hard flat*. Regardless of the type, they serve essentially the same purpose.

Soft flats are constructed out of lumber and fabric. A wood frame supports a piece of stretched cloth that is painted to look like whatever type of wall is necessary. Soft flats have the advantage of being extremely light and easy to transport, but they are not especially durable, requiring quite a bit of care to avoid damage.

Hard flats are constructed mainly of lumber. A typical hard flat is constructed from a sheet of 1/4 inch plywood and a frame of one by three inch lumber. This gives hard flats a distinct advantage over soft flats in that hard flats can take much more abuse without being destroyed. It is also quite a bit easier to build doors and windows into hard flats. Hard flats are used exclusively at WPI because of these advantages. Figure 3.3 shows the construction of a hard flat.

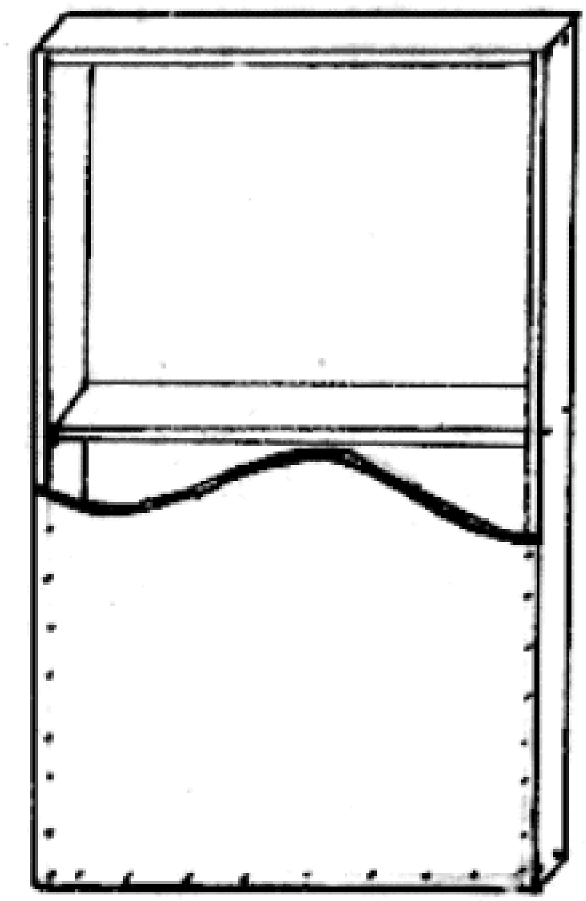

Figure 3.3: Construction of a typical hard flat. 1 inch lumber is used for frame and 1/4 inch plywood is used to cover it.

3.2.3 Stairs

When high platforms are used, it is useful to have some means for actors to get to them, or else there was little point in putting the platform there in the first place. A stair is generally used to provide the necessary access, either from the ground or another platform. There are a variety of methods that can be used to construct stairs. Some form self-supporting units that require little or no mounting to the set while others form units that must be attached to the set at their top and bottom points. Often stair units are constructed for several standard heights and kept on stock in a theatre's scene shop for later re-use.

Stairs must be constructed out of appropriately strong material. Self-supporting stairs often use 1 inch lumber for the step part (called a *tread*), and 2 inch lumber for the supports (called *stringers* or *carriages*).

Any stair higher than a couple of feet off the ground should have a railing on any exposed side. These railings can be constructed out of two by fours for offstage stairs that are hidden from audience view. On-stage railings can be almost as simple if the look is not important, and as complex as any railing in a fancy house. The goal is to provide support for the actor, and make them feel safe when using the stair.

3.2.4 Rakes

A holdover from the early years of theatre is the *raked* stage. A rake is simply an angled stage or section of stage that is used as acting space. Rakes are the reason the familiar stage directions *upstage* and *downstage* are used — downstage is the lowest part of the rake, while upstage is the highest part.

Rakes are typically constructed in a similar fashion to platforms, using plywood and 2 inch lumber. As when constructing platforms, it is important to make a rake strong enough to support several actors.

3.2.5 Other Structures

Many productions call for other miscellaneous set structures such as trees, pillars, water wells, etc. Many different methods and materials can be used to build these objects. The nature of the object somewhat dictates the materials, but there is generally a lot of flexibility in what can be done.

If an object does not need to carry any weight, its frame can generally be made out of thin wood. The wooden frame is then usually covered with some sort of contouring skeleton, such as wire mesh. This skeleton is shaped to the desired contour, and then covered with papier-mâché strips, a fabric and glue combination, or fiberglass. Once dry, the structure can be painted and textured at will. Other interesting effects can be had using different types of foam (*styrofoam*, etc.). Foam can be easily cut, shaped, and finished, allowing realistic rocks and other objects to be created.

If the structure must carry weight, generally a platform is built into the structure where the support is needed. The platform can be covered with the finishing material to blend the look of the structure together.

3.2.6 Floor Coverings

Most stage floors are polished hardwood, which is hardly representative of the desired floor type of most productions. For this reason, the floor is often covered with something more fitting to the scene of the production. Choosing a workable floor material is often difficult, as the material has to be resistant to scuffing, flat, easy to remove, and inexpensive. Often times it is difficult to meet all of these goals, which is a primary reason why the floor is often ignored in productions.

Many different materials can be used for floor coverings. Fabric, pressed hardboard, rugs, carpeting, and vinyl flooring can all be used with good results. Some surfaces, such as hardboard, lend themselves to painting, which makes creating almost any sort of pattern easy.

3.3 Construction

Set construction is an important part of any production. Construction of a large set usually requires a large crew and many hours of work. Diverse skills are necessary for successful set construction. Many different materials are used, and consequently several types of tools are used to work the materials. Safety must be considered at all points during the construction, both for the safety of the construction crew and the cast that will be acting on the completed set.

3.3.1 Materials

Many different types of materials can be used to construct the various elements of a set. Wood, cardboard, paper, plastics and metal are among the materials commonly used in large theatres. Most small theatres tend to limit themselves to wood, cardboard and paper, but there are often exceptions. Proper knowledge of how to work with these materials is essential for a successful and safe set construction.

Wood is a relatively easy material to work with. It is strong, easily cut with the appropriate tools, and readily available. Corrugated or honeycomb cardboard can be used in place of wood in some instances, especially in non-structural set pieces. It is easily cut with a knife, and readily shaped into a variety of forms. A variety of useful foams exist that can be used to construct various decorative set pieces. Plastics and metal are more difficult to work with, and require special tools that are often more difficult to gain access to than those for working wood.

Obtaining the appropriate materials can sometimes be a challenge. Lumber is usually fairly easy to obtain, as there are several lumber yards and homeowner-oriented stores that carry a large selection of materials. Other, more exotic materials may be difficult to track down. Theatre supply houses, craft stores, hobby shops, and industrial supply companies are all excellent resources for hard-to-find materials such as corrugated cardboard, plastics, metal, and foams.

3.3.2 Tools

Many tools are helpful for the construction of sets and set components. Some are specific to a particular type of material, but many are general purpose. Having the appropriate tools on hand tends to make the job of building a set much easier and safer for the set crew, as alternate methods of accomplishing tasks need not be sought.

Some of the standard tools handy for working with any material are: tape measures, squares, levels, awls, chalk lines, clamps, hammers, staplers and electric drills. These tools can be used for many tasks, and no set crew should be without them. Generally having several of each on hand can help a large set crew get their job done in an expedient fashion.

A multitude of saws, planes and sanders are useful for working with wood. Plastics and metal working demand more exotic tools such as metal rolls, metal benders, welders, heat guns, and vacuum forms. Hot knives are useful for smoothly cutting various types of foam. As always, knowing how to properly use these tools is paramount for successful and safe work.

3.4 Finishing

The final step in set construction is to finish the set. The purpose of this step is to add detail, color and texture to the set so that it fits within the look desired by the production design team. Finishing a set tends to rely heavily upon artistic talent rather than technical knowledge, but there are still important technical considerations to be aware of.

3.4.1 Painting

One of the areas of theatre understood by the fewest people is scene painting. Painting is as much of an art form as it is a science. Knowing how to choose paints, choosing colors that will look good under the stage lighting, and understanding how to properly apply paint are all important skills for a scene painter.

Types of Paint

There are many types of paint available, each with a different chemical composition and purpose. Even with these differences, paints are made up of essentially the same components. A *dye* or *pigment* is used to give the paint its color. A *binder* is used to make the paint adhere to the surface to which it is applied. Lastly, the *vehicle* is the liquid substance that carries the binder and coloring, allowing it to actually be painted onto a surface. Different kinds of paint use different coloring, binders and vehicles, thus the availability of different types of paint (latex, oil-based, vinyl, gloss, semi-gloss, etc.).

Large theatres often mix their own paints by buying raw binder, pigments, etc. Most smaller theatres, however, buy pre-mixed paints. Acrylic, latex and vinyl are the types of paint most frequently used for theatre. Oil-based paints are generally not used in a theatre setting because of their hazardous fumes and slow drying time. Many vibrant colors are available in acrylic, latex and vinyl paints, making them a very popular choice for theatre applications.

While oil-based paints are not usually used, sometimes oil-based *stains* are. Stains differ from paints in that they are soaked into the material being covered and not bonded to the outside. Stains can offer very pleasing effects when used on wood, as they let the natural grain of the wood show through.

Mixing Paints

Within a given type of paint, colors can be *mixed*. Pigments and dyes mix by what is known as the *subtractive mixing process*. When pigments are mixed, the wavelengths of color interact, causing some to cancel each other out. Most people are familiar with the *primary colors* of pigment: red, blue and yellow. When pure colors are mixed in equal quantities, black is the result. The primaries can be combined to form the *secondary* colors of magenta, orange and green. Further mixing of the primaries and secondaries yields *tertiary* colors such as blue-violet, brown, etc. Figure 3.4 shows a subtractive-mixing color wheel.

Applying Paint

Many tools are used to apply paint to surfaces. The most common and familiar is the *paint brush*. Other common tools are the *paint roller*, the *sponge*, and various types of *sprayers*.

Each tool is suited to a particular purpose, but often can be used for others. Some tools offer interesting effects that can be easily taken advantage of in a theatre setting. Below is a list of some common painting tools and their uses:

- **Brushes** are often thought of as the workhorse of painting, as they can be used for almost any job. Large brushes work well for covering large areas in a short time, while small brushes are suited to fine detail work.
- **Rollers** are suited to covering large areas in a very short period of time for simple coverage, or for special texturing effects. Excellent for floors, walls, etc.
- **Sprayers** can be used to cover large areas in a very short period of time. Their nature makes them suited for painting strangely shaped objects as well as blending colors.
- **Sponges** can be used for adding textural effects as well as blending applied paint.

A set is generally painted in a series of steps, starting with a base coat of paint called the *primer*. The purpose of priming is to make the materials used on the set appear more uniform. This is important, as often a mix of new and old materials are used. Next, a *base coat* of paint is applied. Several methods of applying the base coat exist, ranging from using a single color uniformly to blending many colors together. This base coat is the final color on some of the set in areas that have no additional layers painted on top of them. However,

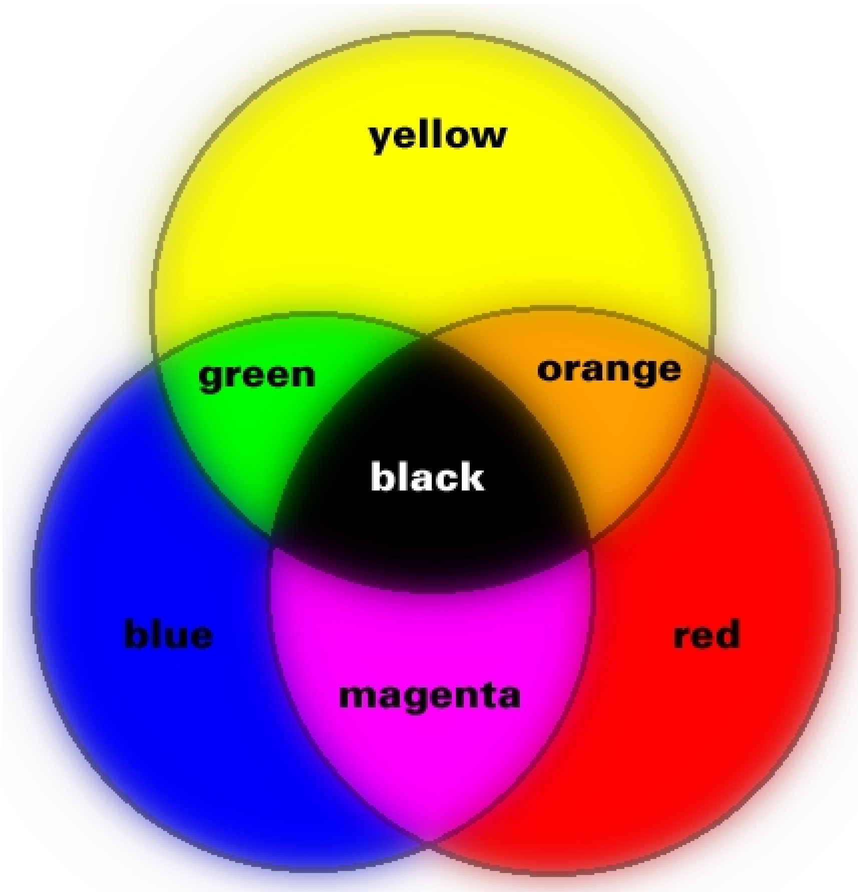

Figure 3.4: Subtractive mixing of the primary pigment and dye colors.

many areas will call for additional *texturing* and *detail work*, to make a set look dirty, old, etc. Many textural effects are illusory rather than realistic. The illusions are accomplished through the use of paint color and appropriate application of the paint. Rock, brick, and wooden panels can all be simulated using textural tricks.

3.5 Draperies

An important and occasionally ignored part of set design and construction is properly setting up the *draperies* (sometimes called *soft goods*). There are many types of draperies, each with a specific purpose. Figure 3.5 shows most types.

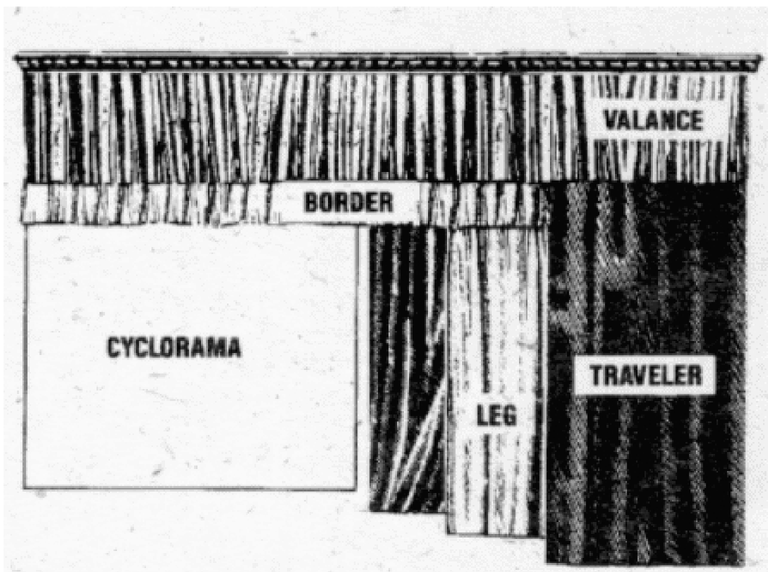

Figure 3.5: The various types of draperies used in theatre.

The *cyclorama* (*cyc*) is the drape that is used behind the set. It is usually made out of a medium-weight white or baby blue material. Special lights are usually aimed at the cyclorama to provide a variety of colorful backgrounds, which are often used as skies or horizons in productions. True cycloramas are U-shaped, and cover the left, right and upstage parts of the stage. At WPI, the proper U-shaped curtain tracks for cycloramas are not installed, so the cyclorama is usually flown flat.

Legs are used to mask offstage areas from sight. They are flown at different heights and locations to conceal offstage space, equipment, etc. *Borders* are used to mask parts of the rigging system and to trim the sightlines such that only the set may be seen by the audience. Often there are several borders (occasionally called *teasers*), used for masking off other fly system battens from audience view. A *traveler* is a type of curtain that moves along a track. Often they are used as main curtains for stages and are configured such that one operating line moves curtains from each side of the stage simultaneously. Lastly, some theatres have *valences*, which are simply dressings used outside of travelers or other main curtains. However, WPI's Alden Hall does not have one of these draperies.

3.6 Design

An effective set is one that provides useful acting space for the cast, conveys the desired look of the setting of the production, and is safe for all who must work on or around it. Balancing these criteria can be difficult, making the best set designers those with a good balance of artistic and practical skills.

3.6.1 How to Begin

The best place to begin gathering set design ideas is by reading the script for the production. Look for specific references to the set, such as mention of doors, windows or stairs. If the scene is outdoors, look for references to rocks, trees, etc. A mental image of the scenes should be conceived as a starting point.

Once some initial ideas for the set have been thought of, the rest of the production design team should be consulted. Most productions are a collaborative effort, so ideas should be shared and discussed as early in the design phase as possible.

3.6.2 Documents

The set designer should ideally produce a set of documents that give precise indication of the construction, positioning and look of the set. To convey this information, several drawings are used, each detailing different aspects of the set design.

The *designer's perspective sketch* is a rough 3-dimensional picture that indicates the general feel of what the set is to look like. Producing this sketch usually requires a fair degree of artistic talent, which is why computer-generated *set renderings* are sometimes used to show the look and feel of a set.

To determine the amount of space that a set may take up on stage, several factors must be considered. Obviously, the physical limitations of the stage must be taken into account. The height of the gridiron, width of the proscenium, and depth of the stage are the most important dimensions to consider. In addition to these limitations, *sight lines* must be considered. Sight lines define the extremes of the stage area that the audience can see. If a set is too big, not everyone in the audience will be able to see all of the action. In theatres that do not have permanent seating, such as Alden Hall at WPI, temporary seating is generally used. Since there is often no standard way for setting this seating up, the *House Manager* should be consulted so that sight lines may be determined.

The *ground plan* is a top-down view of the stage, and shows the location of flats, platforms, etc. Also included are the locations of masking legs, fly system battens, etc. The *sectional* drawing is a side view of the stage, taken from the center point. Heights of battens and legs are indicated on this drawing, mainly for purposes of sightlining. Lastly, *front elevations* are measured drawings of each panel and piece of the set, as seen from the front. These three drawings together are generally enough information to construct the basic set. Figures 3.6, 3.7, and 3.8 show examples of these diagrams. Note that these diagrams are not USITT-standard diagrams, but it is unusual to find USITT standards used at WPI.

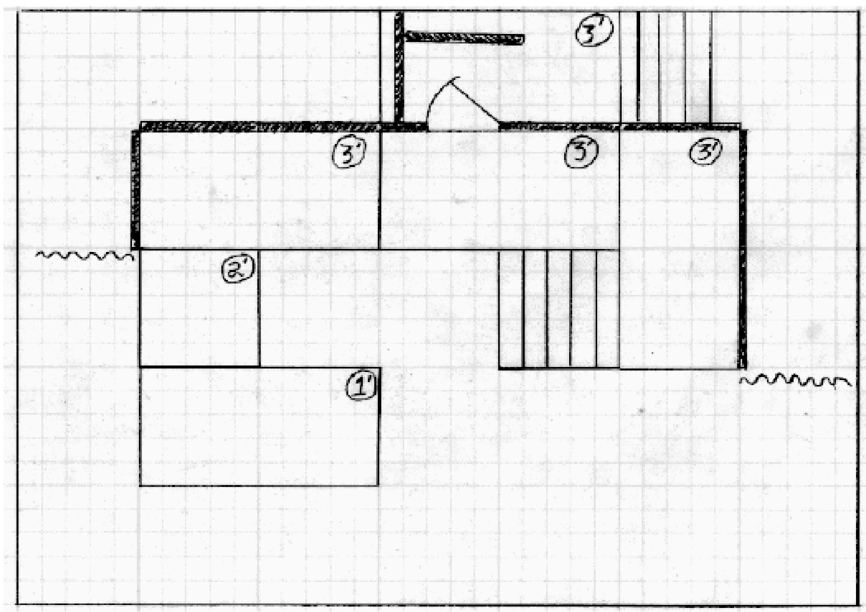

Figure 3.6: An example of a ground plan drawing. The circled numbers indicate height of platforms. Most diagrams have a scale or measurements to indicate sizes.

In some theatres, it is up to the set designer to produce what is known as the *construction drawing*. This diagram details construction methods and materials for each piece of the set. Often, though, the construction methods are left up to the Master Carpenter, unless something specific is necessary. This is the method most frequently used at WPI.

3.6.3 Computer-Aided Design

indexcomputer-aided design!of the set Producing all of the documents that make up a set design can be very tedious. Fortunately, *Computer-Aided Design* (*CAD*) software is available that can remove much of this tedium. CAD software

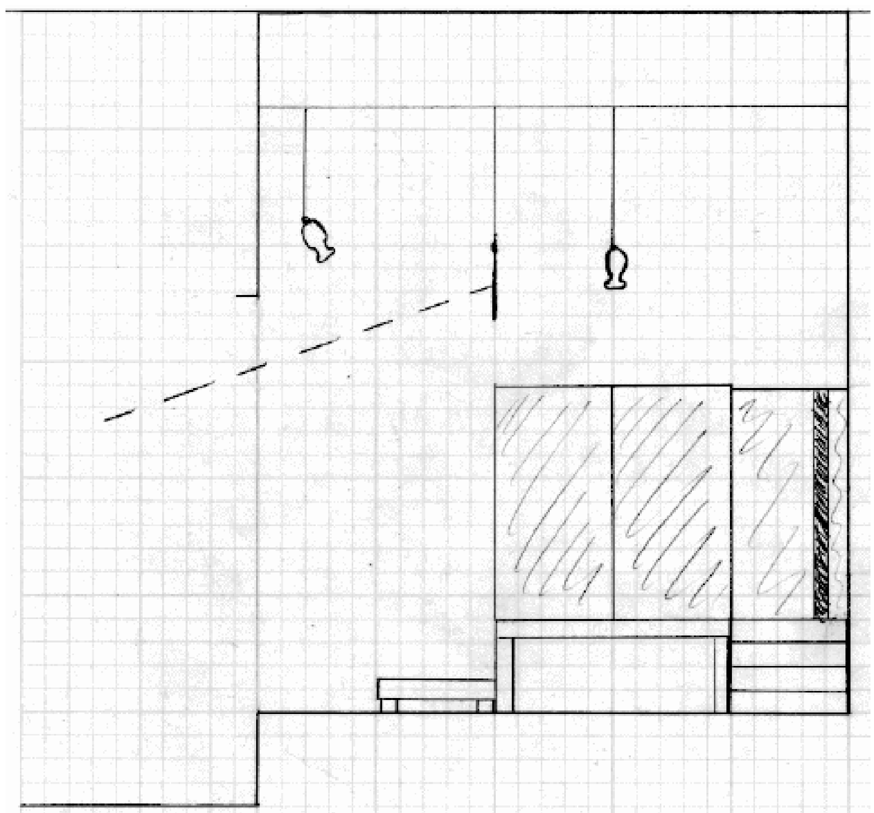

Figure 3.7: An example of a sectional drawing. The dashed line is an indication of an audience sight line. The lines at the top are battens, with a rough indication of lighting angle.

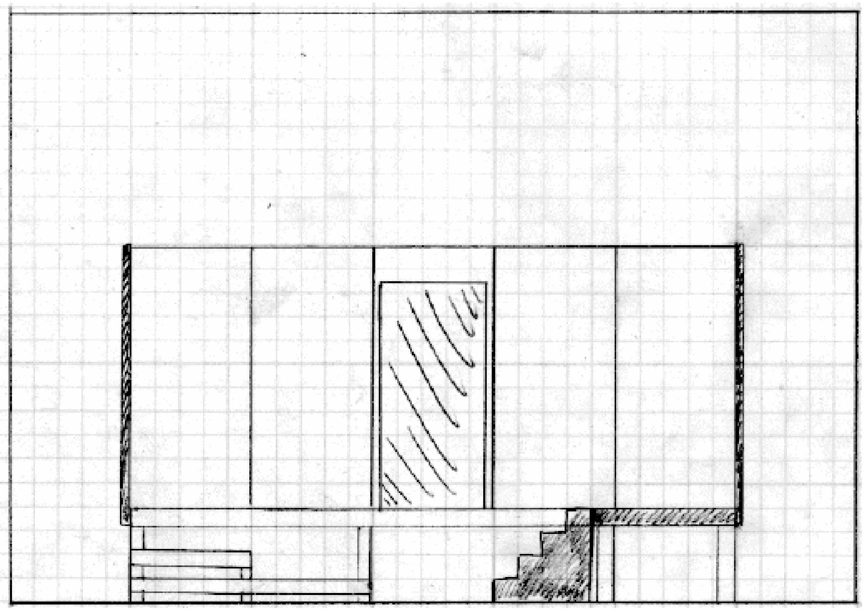

Figure 3.8: An example of a front elevation drawing. In general, these diagrams show measurements and give additional detail for each piece of the set.

allows easy design, layout, and editing of measured drawings. Advanced CAD packages can even generate 3D models from the data entered by the designer. These models can then be exported to other packages and *rendered*. Before rendering, material types are assigned to objects, virtual lights are positioned, and virtual camera angles and positions are assigned. Once this is done, the image is rendered, giving a somewhat lifelike pseudo-3D image of the model, as in figure 3.9.

These rendered images are suitable for showing to other members of the design staff. Changes can be discussed, and these changes can be made to the CAD drawings with relative ease. A new image can be rendered, shown to the staff, etc. This process allows the entire production staff to contribute ideas without driving the set designer insane by increasing their work load.

While CAD and rendering packages are excellent tools, they do not replace a well thought-out set design. The set designer still requires a knowledge of the materials and procedures of scenic design, not to mention an artistic vision to work towards.

3.7 A Typical Set Construction at WPI

This assumes proper knowledge of tool safety, and general carpentry knowledge. Note that there are many ways to build a set and that this is only one of the

Figure 3.9: A rendering of the set from WPI Masque's 1995 production of *King Henry V*. This rendering shows the various moving pieces of the set in their open positions.

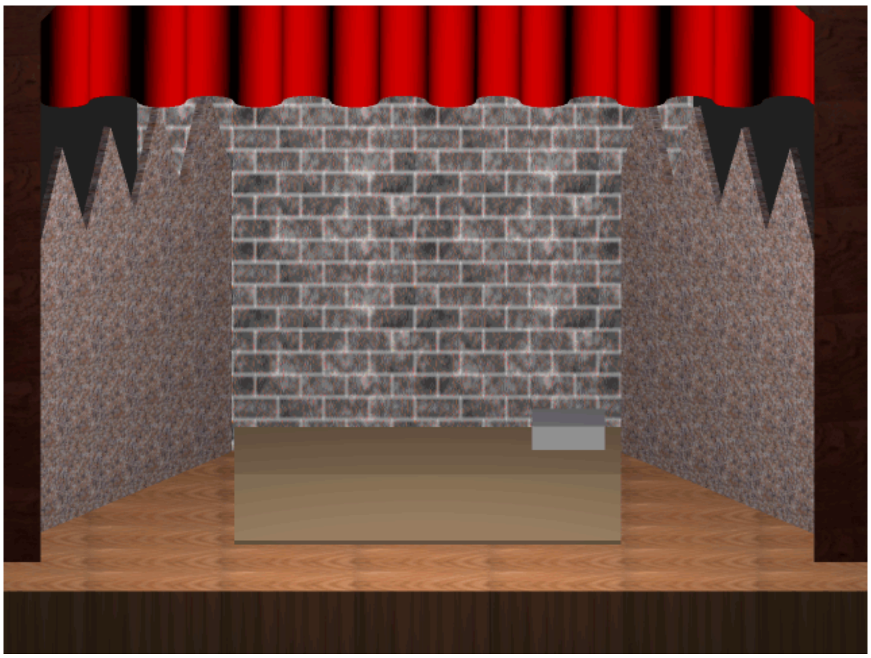

Figure 3.10: Another rendering of the *King Henry V* set from the 1995 WPI Masque production. This image shows the various moving pieces of the set in their closed positions.

many possible ways.

- Retrieve platforms, flats, stairs and other scenic elements from scene shop, as per set design.
- Purchase additional materials (lumber, screws, etc.)
- Assemble legs on to platforms, according to set design.
- Assemble all platforms, brace if necessary.
- Construct walls using flats. Use appropriate door or window flats where necessary.
- Construct any custom pieces that the set design calls for.
- Check final assembly and safety of entire set.
- Set gets first coat of paint (primer).
- Set gets texture and detail painting.
- Trim the set, using draperies and cloth.
- Perform final inspections and touch-ups.
- Check set before each performance, repair and touch up as necessary.

The set is disassembled (*struck*) in reverse order — scenic pieces, flats, then platforms.

Chapter 4

Rigging

"Argh! Tie it off, tie it off! I can't hold it much longer!" – Unnamed techie, expressing the joys of using the non-counterweight fly system in Alden Hall at WPI.

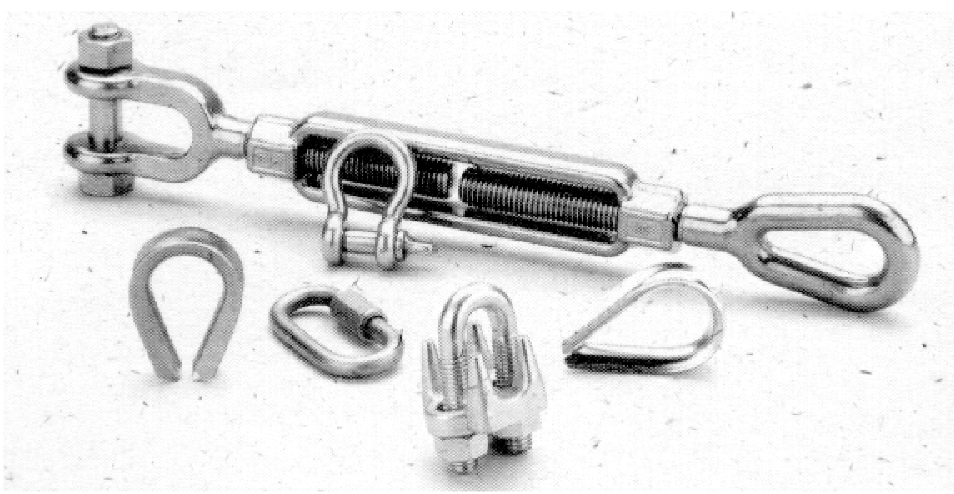

Figure 4.1: Pictured are some of the tools of the trade used to safely rig set pieces and the like. Pictured are (from rear to front, left to right): a turnbuckle, shackle, a thimble, a rapid link, another thimble, and a wire rope clip.

4.1 Introduction

In a typical theatre production, set pieces, lighting equipment and sound reinforcement speakers are flown over the heads of both actors and audience. To safely rig and fly equipment and set pieces, a knowledge of both rigging hardware and methodology are necessary. If items are improperly rigged and flown, people can be killed!

The intent of this chapter is to present a general overview of rigging techniques for a wide variety of tasks. Reading this chapter does not, however, make one an expert in rigging. There are many books dedicated to the specific topics discussed only briefly in this chapter. There really is no substitute for being trained by a professional rigger. It's highly recommended that at least an introductory course in rigging be taken before any rigging task be undertaken.

4.2 Common Rigging Hardware

There are several pieces of hardware that are used for many different tasks in theatrical rigging. It is this hardware that forms the toolbox of the stage rigger, and as with any work, knowledge of one's tools is of paramount importance for successful and safe job completion.

4.2.1 Rope

There are two main categories of rope available — natural fiber and synthetic fiber. It is not uncommon to work with both types of rope at a given theatre, so knowledge of how to properly care for and work with each rope type is important.

Manila rope, often called *hemp*, is made from manila hemp material, and is quite durable and strong. It is typically made up of three strands, and comes in many rope diameters. Most modern manila ropes are chemically treated to resist moisture and mildew. This treating only helps marginally, so keeping ropes dry is very important, as moisture and the resulting mildew are the largest enemies of manila rope. Manila rope is tough on the hands, so when working with it, it is always recommended that a pair of gloves be worn to avoid splinters.

Cotton braided rope does not have the appropriate structure for lifting loads, but it is a quite suited to drives and pulley systems for curtains and tie lines for soft goods. Cotton braided rope is typically soft and easy on the hands, thus gloves need not be worn when working with it.

Synthetic fiber ropes include ropes made of various man-made materials such as nylon, polypropylene, polyethylene and polyester. Synthetic fiber ropes have the advantage of being made out of continuous strands of material, as opposed to short overlapping fibers as in manila rope (Arnold, 278). These continuous fibers can not tear or separate as they can in manila rope. Other advantages such as near-complete immunity to water and mildew, chemical resistance, and a braided outer sheath make synthetic fiber ropes an attractive option for many rigging tasks.

While it's important to be familiar with the type of rope you are working with, there are some general guidelines that apply to all rope types. These are listed below:

- **Know the rope you're working with.** Before you use a rope for a rigging task, be aware of its type and associated working load limits.
- **Never exceed rope load limits.** In fact, always figure in for an 8 to 1 safety factor. This means use a rope that is rated for eight times the load you need to carry.
- **Avoid exposure of rope to heat, excessive light, chemicals, fumes, and ultraviolet light** This means keep rope out from under stage lighting, out of direct sunlight, and away from the set painting crew. Sometimes contact with fumes or light can not be avoided. In these cases, exposure should be minimized, and special attention should be paid to the rope being used.
- **Keep ropes clean and free from abrasives.** Don't drop rope into a pile of dust or dirt or drag it on the ground. If rope becomes dirty, it should be cleaned with cool water and air dried. *Never* put rope into a clothes dryer to dry it.
- **Coil and store rope properly.** Learn to coil rope properly from someone who knows how. A coil of rope should appear very relaxed and stay in its coil with no outside help. Rope should be stored in a dry, cool room, away from direct sunlight.
- **Never bend rope sharply.** This can *halve* the effective load bearing capability of rope.
- **When cutting rope, treat the ends appropriately.** It is common to use a hot knife to cut synthetic ropes. This both cuts the rope and treats each end properly such that it will not fray. In the absence of a hot knife, synthetics can be cut with a knife and the remaining ends can be melted with a lighter or small propane torch. Natural fiber ropes require binding or a vinyl whip treatment to avoid fraying and untwisting of the rope.

4.2.2 Wire Rope

Wire rope, often called cable, is a material made of a several strands of groups of thin steel wires. Different types of wire rope exist, the main differences being the arrangement of the wires, and the type of steel used.

One type of wire rope used frequently is called *hoisting cable*, and is typically 6 X 19 in construction. This means that there are 6 larger strands of 19 wires each. Hoisting cable is often used in fly systems, as it is strong and flexible.

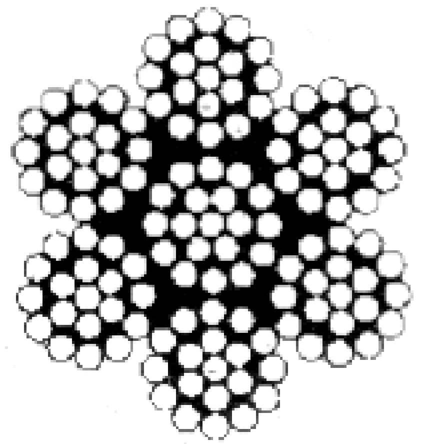

Figure 4.2: Cross sectional diagram of typical wire rope. Shown is standard 7 X 19 aircraft cable, a very flexible and strong type of wire rope.

Aircraft cable is another type of wire rope that is used often in theatre applications. It is usually 7 X 19 in construction, and is more flexible and stronger than hoisting cable. Aircraft cable is made out of specially processed steel that has a very high tensile strength. Aircraft cable can be purchased that has a thin coating of plastic on the outside. This coating can generally be painted, which makes it possible to mask visible pieces of aircraft cable on a set.

Wire rope is a very strong and effective means for rigging, however there are several things to note:

- **Be sure that you know the material you are working with.** Many hardware stores carry what may look like wire rope, but in reality is a material not rated for bearing load. When in doubt ask, and if they don't know, don't use it.
- **Never exceed wire rope load limits.** Keeping an 8-to-1 safety factor is necessary to be well assured that the wire rope will handle the load.
- **Never bend wire rope sharply.** Always use a thimble in any situation where the wire rope may get bent.
- **Be careful of the ends of cut wire rope.** Many sharp pieces of wire are exposed in the cutting process. Be sure to cover the cut ends with gaffer's tape or a vinyl coating.

4.2.3 Thimbles, Wire Rope Clips, and Swages

When working with wire rope, it is extremely important that several guidelines are followed with regards to termination. Any time the wire rope needs to be

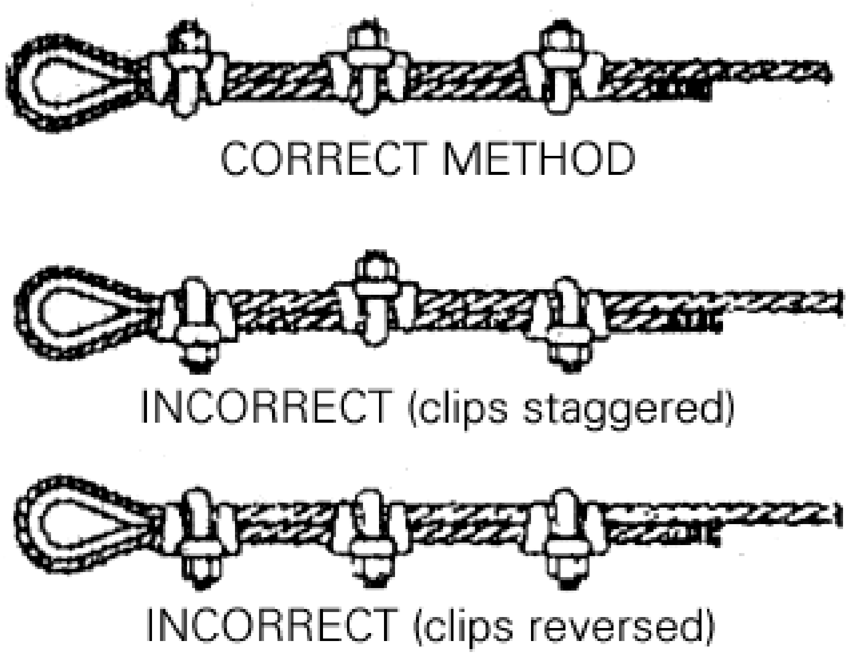

Figure 4.3: Correct and incorrect methods for using clips and thimbles on wire rope. The saddle of the clip rests against the "live" portion of the wire rope while the U-bolt rests on the short, "dead" portion of the wire rope. Using clips improperly severely weakens the connection, making it unsafe. Remember: **never saddle a dead horse**.

attached to a hang point that would cause the cable to sharply bend, a device called a *thimble* must be used. Thimbles simply guide the cable into a natural curve shape and offer a degree of protection to the cable in the loop. To secure the end of the rope, wire rope *U-clips* are used. These clips provide an effective means for terminating cables, but must be used properly to be fully effective. Figure 4.3 shows correct and incorrect methods for applying these clips.

The correct sequence for applying U-clips to a piece of wire rope are described below:

1. Turn back the appropriate amount of cable from the end of the piece being worked on. This amount varies with the diameter of the wire rope, but is typically from 12 to 18 inches.

2. Apply the first clip nearest the very end of the cable. Always leave a couple of inches of extra cable beyond the clip. Be sure to apply the clip properly — the U-bolt goes around the *dead end* of the cable, while the saddle goes around the *live end*. Tighten the nuts on the U-clip evenly, and to the torque recommended by the clip manufacturers.

3. If a thimble is being used, insert it into the loop, and then apply the second clip in the same fashion as the first, but only finger tighten the nuts.

4. Apply additional clips evenly between the first two clips. Two clips are usually sufficient for wire rope under 1/2 inch, but three are often used for safety. Wire rope of diameter 3/4 inch or greater requires four or more clips.

5. Tighten all clips to the recommended torque. Apply the load and re-tighten the clips. This re-tightening is important, as wire rope tends to shrink in diameter as load is applied.

Another method for securing the ends of wire rope is through the use of *swages*, or *nicopress sleeves*. Small metal sleeves are pressed on to the wire rope with a special tool. These sleeves are permanent, but act much in the same way that clips do. When properly applied, swages can hold the full rated working load of the cable they are attached to.

4.2.4 Shackles, Turnbuckles and Hooks

A wide variety of additional rigging hardware exists for various tasks. Turnbuckles are used in situations where small adjustments need to be made in the length of a cable. Usually turnbuckles are not used to bear load, but rather in tensioning guy wires, etc. Shackles are often used with locking hooks to connect between wire rope and nylon harnesses or rope.

Very close attention should be paid to the load capacity of the hardware being used. Often times, items purchased in a typical hardware store are not rated for load, and thus shouldn't be trusted for load-bearing applications.

4.2.5 Chain & Rapid Links

Often times chain is used to rig various pieces of the set, lighting, or audio equipment. It is important to note that only welded-link steel chain should be used to bear loads. Many types of chain are available with unwelded links, but these should be avoided when rigging. To connect pieces of chain together, it is common to use what are called *rapid links* (or *QuickLinks*, which is a trade name). Rapid links look like a link of chain with a threaded segment. A nut can be unscrewed, providing an opening for chain to be inserted into the link. Once the chain has been inserted, the nut can be tightened, providing a link capable of bearing weight. Rapid links carry load capacity ratings stamped on them. These capacities, as well as those of the chain being used should always be taken into consideration.

4.2.6 Slings

One of the most common ways to hang truss for flying is through the use of slings made of a synthetic material such as polyester. A modern sling consists of a synthetic fiber core encased in a woven synthetic casing. Slings of this nature tend to be very strong and quite durable, and by nature conform to the shape of the load they are carrying. This makes them suitable for many rigging tasks beyond that of hanging lighting truss.

There are many acceptible methods for attaching slings to the truss to fly it. The most common involves the use of four slings. When the truss is flown point-down, a choker scheme is used, whereby the sling wraps through itself and around the truss. Each end of the truss uses two slings arranged in this fashion. Other methods exist where two slings can be used, but the choker arrangement is difficult to achieve, thus truss stability tends to be sacrificed.

4.3 Fly Methods

Many methods exist for raising objects above a stage or audience. A variety of methods will be discussed, but by no means will all of the possible methods be covered. Presented here are the methods most commonly used in productions at WPI.

4.3.1 Non-Counterweighted Pulley Systems

Simple arrangements of rope and pulleys make up the simplest batten fly system. Three manila ropes, tied to a pipe batten, pass through pulleys (called *loft blocks*) mounted on the gridiron. These ropes then pass through another set of pulleys (called the *head block*), where they then are tied off to a heavy steel railing called the *pinrail*. The pinrail is in what is known as the *fly gallery*, which is a suspended platform generally at least twelve feet off the ground in over the wings of the stage. The front railing of the platform holds several steel *belay pins* that the ropes are tied off to. *Fly operators* (people operating

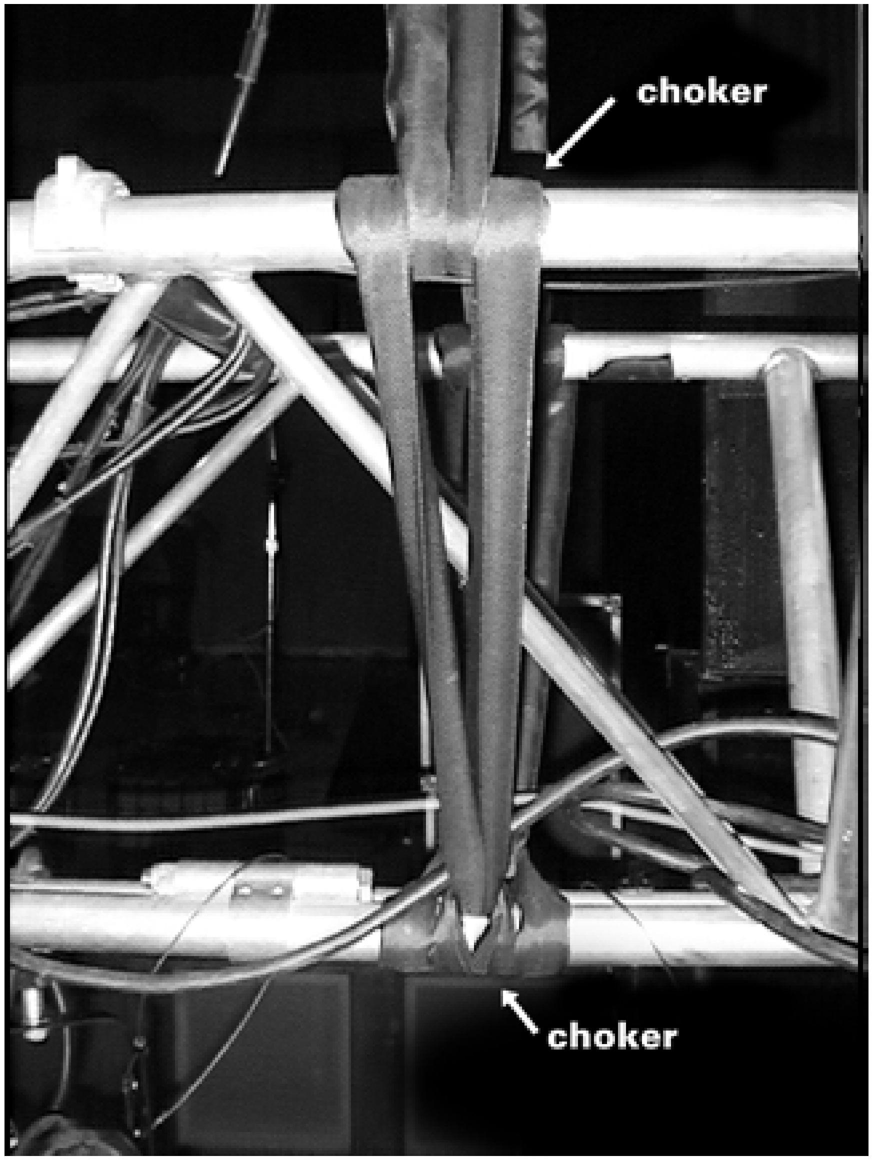

Figure 4.4: Slings used to rig a lighting truss to a set of chain motors. Note the choking scheme used to minimize movement of the truss.

the fly system) stand on the platform in the fly gallery to fly objects in and out. Typically it takes two to four people to safely use a non-counterweight fly system — one, two, or three to lift the load, the other to brake the rope and tie it off when the batten is moved into position. The rope is tied off to the belay pins using a figure-eight pattern.

Non-counterweighted fly systems are extremely difficult to use, not to mention dangerous. The main theatre venue at WPI, Alden Hall, still has several battens that are flown using such a system. Access to the fly gallery is obtained by climbing the ladder to the grid, crossing the grid and descending a second ladder. There is enough space for several people to work a set of lines, which is advantageous, because hoisting a batten full of lighting instruments is usually a three to four person job. Most designers try to avoid using these battens, but occasionally using the "hemp bars", as they are called at WPI, becomes a necessity. Training with an experienced fly operator is mandatory for safe use of these battens.

4.3.2 Counterweighted Fly Systems

The major disadvantages to non-counterweighted fly systems are that they require more than one person to operate, they require a lot of work to use, and they are unsafe. Most modern theatres are equipped with what is known as a counterweighted fly system. This type of fly system makes flying battens significantly easier and safer, and allows for one person operation in most cases.

Counterweight fly systems are rather complex, and there exist entire documents devoted to their design, construction, and operation. Only a basic introduction to the components and operating techniques will be given here. Anyone operating a fly system should have appropriate training from a competent fly person.

The basic principle behind counterweight fly systems is that a pulley system and counterweight mass are used to make the job of moving a heavily loaded batten easier on the fly operator. This mass may be adjusted for the amount of load on the batten, thus providing for a fairly consistent feel on the *operating lines*. Extremely heavy objects can be flown with relative ease, as long as the appropriate counterweights are used.

There are two key working positions to be aware of. Most operation for running a show occurs at the *locking rail*, which is at stage level. From this position, battens can be flown in and out in a safe fashion by a single fly operator. To raise or lower a properly weighted fly batten, the operator simply needs to release the rope lock and raise or lower the operating line. In addition to working at the locking rail, it is necessary to work from the *weight rail* to load or unload (or *strip*) counterweights onto the *arbor* when a batten is flown in and weight is being added or removed. Refer to figure 4.5 for a diagram that shows the components of a counterweight fly system.

Each empty pipe batten has weight, and therefore counterweights must be added to the arbor for that batten. Any additional objects flown from the batten will require that additional weights be placed on the arbor. To aid in

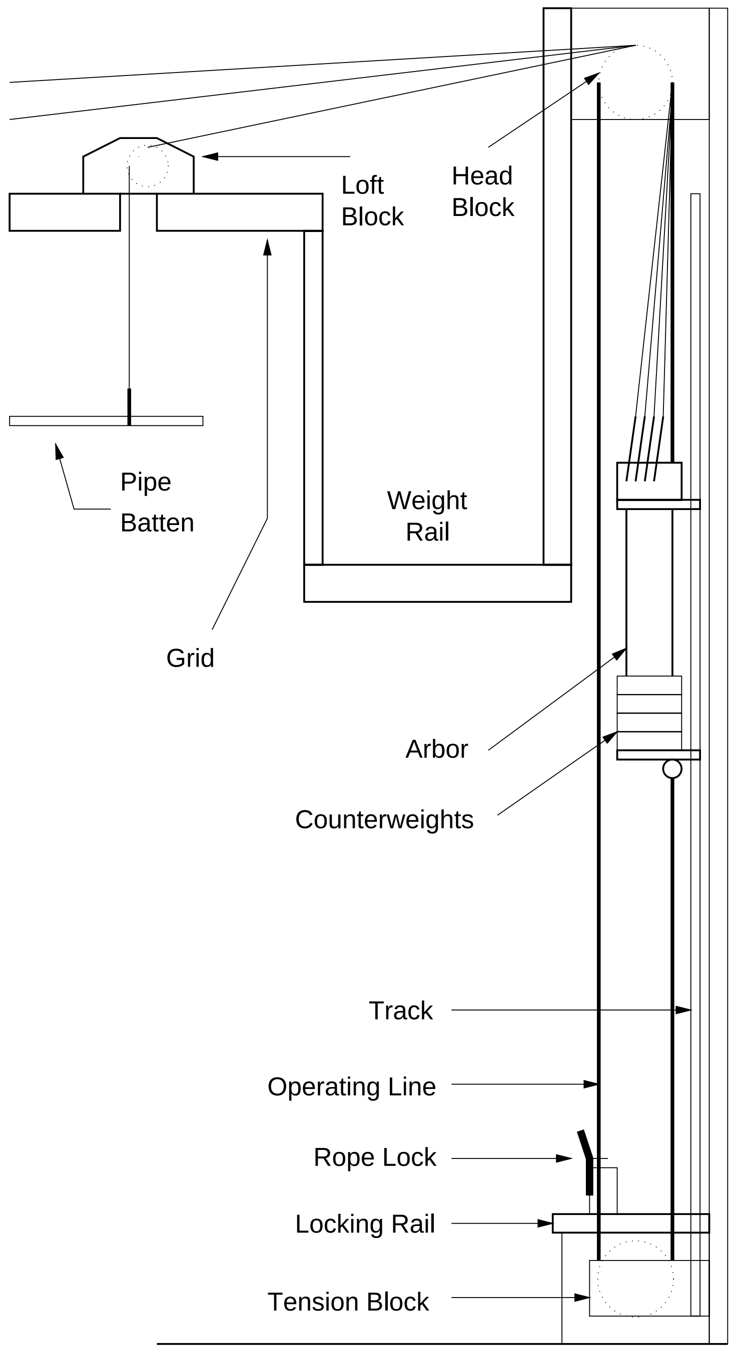

Figure 4.5: A diagram of the components of a counterweight rigging system.

distinguishing between the pipe weight and the additional weight on an arbor, two plates that rest on top of the weights are used. The first plate stays on top of the initial pipe weight load. The second plate rests on top of any additional weight that is added, directly below the locking collars that secure the weights. When stripping weights, it is customary to take off only the additional weight, leaving the pipe weights.

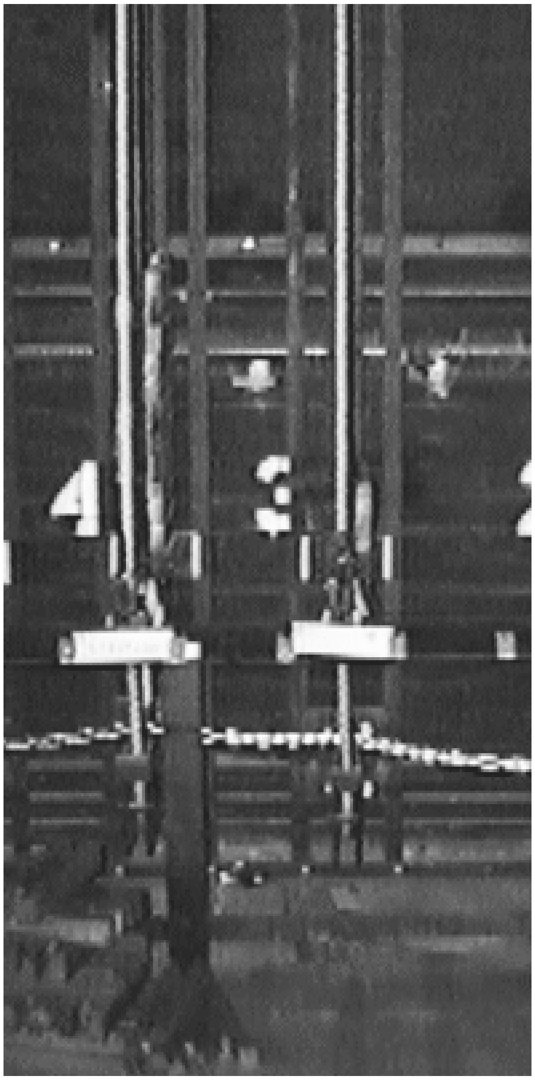

Figure 4.6: A portion of the counterweight fly system in Alden Hall at WPI.

It is sometimes necessary to work with an unbalanced line. This problem generally occurs when hard scenery is flown from a batten, or when a scrim, cyclorama, or other soft goods are flown. The problem occurs with hard scenery because the batten can not be flown into a convenient position for weight loading. There are two ways to handle this problem. One method involves muscling the scenery to the grid, and braking the operating lines with a piece of pipe. With the scenery gridded, the arbor for the batten is resting on the ground, thus the appropriate weights may be added. Another method involves laying the piece of scenery down on the ground so that the batten may be fully flown in. While the batten is flown in, counterweights may be added from the weight rail. Additional weight must be added to the batten for the duration of weight loading. Typically this is accomplished by having crew members hold on to the batten while weight is loaded. It should be made clear that in some cases this isn't always a safe option, especially when heavy scenery is being flown.

Another problem occurs when flying soft goods. While the batten may be fully flown in and weighted correctly, the nature of soft goods are such that an imbalanced load is placed on the batten as they are flown in and out. Their full weight is only distributed on the batten when they are fully flown out. In the intermediate time while they are being flown in or out, they are piled up on the ground, leaving an imbalanced batten. Typically this is handled by keeping the line counterweighted for the full weight of the piece being flown, and paying extra care when flying the batten in or out. The batten will have a tendency to come crashing to the ground as it is brought in, and will require some muscling to fly it out.

There are many issues to consider when working with counterweight fly systems. Some of these are listed below:

- **Always be sure the locking rail and immediate vicinity is clear of people when working on the weight rail.** There exists the potential for a weights to be dropped while they are being loaded or stripped from arbors, so clearing people away is a mandatory part of working from the weight rail. Often it helps to have a person on the ground keep people away from the area.

- **When adding weights, alternate the corner-cuts for easy stripping.** Stage weights are made with one flattened corner. These corners should be alternated so that the person stripping the weights at a later date can do so with relative ease.

- **Stripped weights must be stacked properly.** Weights should be stacked three wide in a criss-cross pattern. They should not be stacked more than three or four layers high so that the risk of a stack being knocked over is reduced.

- **Always be aware of the dangers when working with unbalanced lines.** If you don't know how to handle unbalanced lines, *don't use them*!

4.3.3 Lifts

Often times, a fly system is not available for use for flying lighting or audio equipment. Some venues, such as WPI's Alden Hall, do not have any permanent provisions for lighting equipment in the house. Thus, it becomes desirable to be able to fly a lighting truss in front of the proscenium by some portable means. Several companies produce portable lifts that can be raised and lowered by manual, pneumatic, hydraulic, or electric means. Lifts go by several names, such as *Genie Lifts* (a trade name) or *towers*. One such lift is shown in figure 4.7.

Lifts have a set of feet that are adjusted to give stability to the structure. These feet typically immobilize the lift, as well as increase the footprint to reduce the chances of tipping. Once the feet are in position, the lift is typically raised enough for the load to be placed on it. Once loaded, they can be raised to the appropriate height for the task.

Usually lifts have a set of forks, akin to a forklift, for bearing a load. When placing a load on these forks, the load should be placed as close to the lift end of the fork as possible, to minimize the amount of stress on the fork.

Often, two lifts are used in conjunction to raise a span of truss. When this is the case, it often helps to have a person stand back and keep watch over how level the truss is. Hand signals are typically used to tell the people raising the truss to stop or go.

At WPI, Genie Lifts are often used to fly lighting truss. There are several important things to consider when using these lifts, as listed below:

- **Make sure forks are placed on the lift properly.** There are two orientations for the removable forks. The appropriate one is with the offset from the fork to the mounting piece to be facing down, as in figure 4.8

- **Never dynamically load a lift.** This means don't bounce on it, and don't suddenly drop loads on to it. Most lifts have built-in braking schemes that will lock the extension arm in place if it is dynamically loaded. This means that the lift can not be raised or lowered without manually releasing the brake, which is a long and involved process.

- **Be sure to lock the lift crank after lowering.** The cranks on Genie lifts are ratcheting, but the ratchet releases when lowering the lift. This ratchet will not re-engage unless the crank is turned in the upwards direction. When a loud click is heard, the ratchet is re-engaged.

4.3.4 Chain Motors

While lifts provide a fairly effective means to fly equipment, they have several downfalls. For one, they are typically large and quite heavy. If used in pairs, two to three people are required to operate them safely. Safety issues aside, they are simply inconvenient in a lot of situations. Lastly, lifts take up a lot of

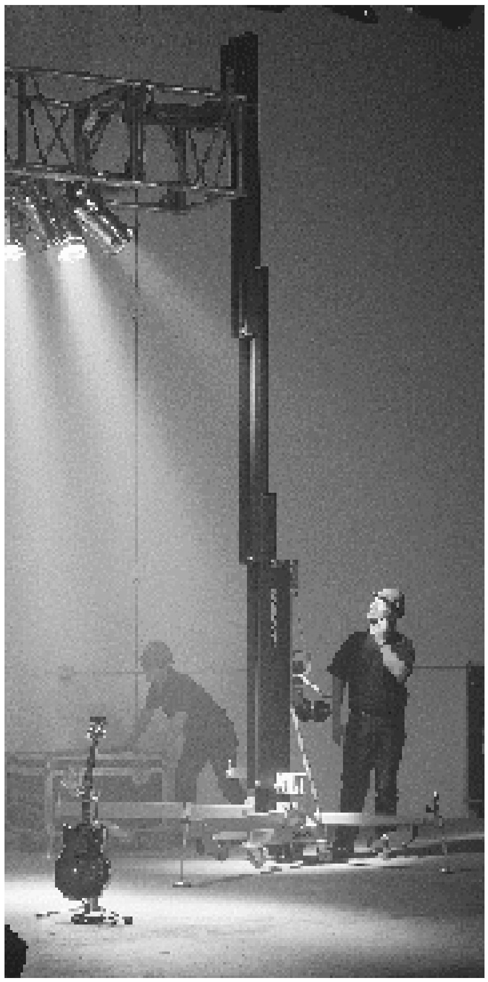

Figure 4.7: A **Genie Industries SuperTower** being used to hold lighting truss.

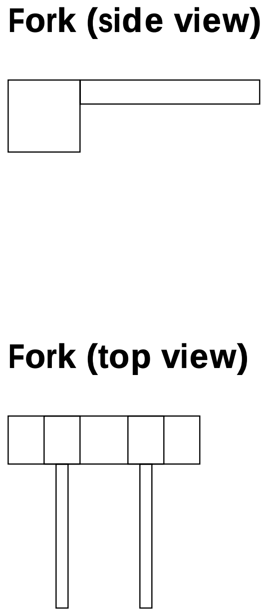

Figure 4.8: The forks of a lift. The top image shows the proper orientation of the forks.

floor space. In typical theatrical uses, the ideal placement of the lift conflicts with house seating. These are all areas that the chain motor excels in. If appropriate load-bearing hang points are available in a venue (as they are in WPI's Alden Hall), the simplicity and convenience of chain motors makes them an ideal solution for flying lighting trusses and other equipment.

A chain motor is simply a large electric motor with a gearbox and a chain drive mounted in one chassis. The chassis of the motor generally has a large hook mounted on its underside, to which loads are attached. An extremely heavy gauge chain with a hook at one end passes through the motor and into a chain bag. The hook of this chain is generally clipped to the shackle of a wire rope sling, which is attached to a load-bearing overhead beam. Once the attachment has been made to an overhead hang point, the motors can have loads attached for flying.

Several methods exist for the control of the chain motors. The simplest method uses handheld controls (sometimes called *pickles*) to raise and lower the motors. Complex computer-controlled systems exist for automatic flying of equipment. These systems can control dozens of motors simultaneously. Systems this complex are not generally necessary for a small number of chain motors.

At WPI, a pair of chain motors with handheld controls are often used to fly lighting truss. The most common venue for this is Alden Hall, where several sets of hang points exist for such a purpose. The following list of instructions

Figure 4.9: A **CM Lodestar** chain motor with slings and lighting truss, flown from the ceiling in Alden Hall at WPI.

should be followed for proper use of the chain motors:

1. Choose a set of hangpoints to use. Three sets exist at varying distances from the stage.
2. Place one chain motor roadcase under each hang point. Exact alignment isn't necessary at this point.
3. Obtain access to the Alden Hall attic. Find the drop ropes stored in the attic. Tie them off with a figure eight knot to a beam nearest the hangpoints being used. Drop them through the hangpoint holes.
4. In the hall, tie the drop ropes to the wire rope slings. The wire rope slings should be attached to the chain of the chain motor by use of a shackle.
5. Locate two lengths of 2 inch iron pipe. These are stored near the drop ropes in the attic. Making sure people are clear of the chain area in the hall, raise one drop rope. When the wire rope sling is through the hole, slip the iron pipe through the sling, as in the figure 4.10. Repeat for the other rope.
6. Locate the backup safety cables and attach them to each wire rope sling. These safety cables are attached to the metal ceiling beams, and are of appropriate length to attach to the slings and provide for a backup if the main hang points should fail for any reason. They should be attached to the wire rope slings using 1-ton rapid links or heavy duty steel carabiners. This is the last of the work that needs to be done in the attic.
7. In the hall, attach power and control cabling to the chain motors. Raise each motor out of its roadcase until it is at a convenient working height. Slings may be attached to the hook of the motor, either directly, or by the use of a large shackle.

While working with chain motors are fairly straightforward, there are several points one should be concerned with when working with them:

- **Pay close attention to the chain when raising and lowering the motors.** Note any binding, noises, or other problems. Discontinue use of the motors if the problem appears to be serious.
- **Inspect attic rigging frequently.** If the motors are to be flown for long periods of time, inspect daily for any signs of impending failure in any piece of the rigging.
- **Don't fool around with the motors.** It's very tempting, but it should be avoided due to excess wear and tear on the motors.
- **Keep the handheld controls out of public access.** Don't leave them lying around so anyone can wander in and use the motors.
- **Turn off the power breaker when motors are not in use.** This is to prevent unintentional movement of the motors.

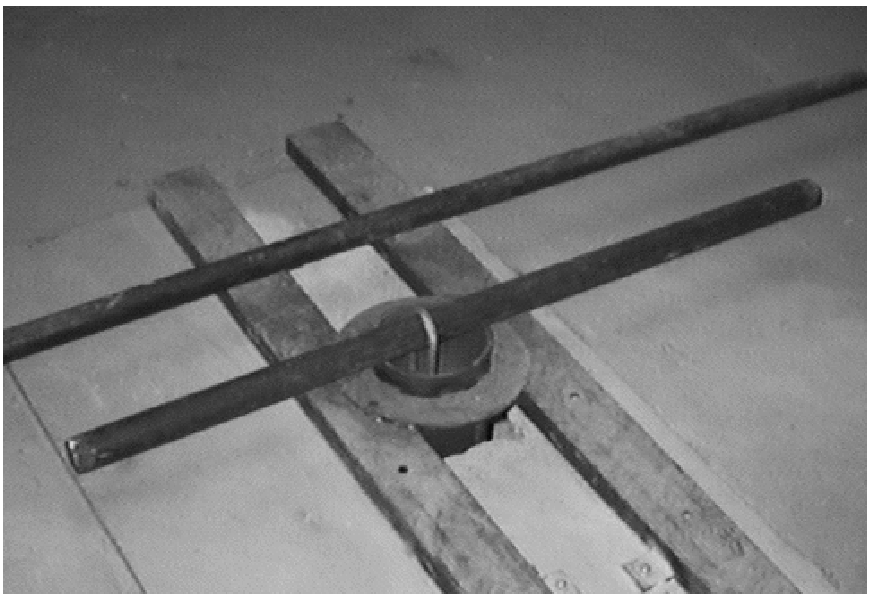

Figure 4.10: View of a hang point in the Alden Hall attic. The 2 inch iron pipe passes through the wire rope sling, which comes through the hole from below. The pipe at the top of the image is not related to the rigging. *Note that the required safety cable is not shown in this image.*

4.4 Flying Set Pieces

Safe flying of set pieces requires careful application of both set design and rigging techniques. Appropriate hardware needs to be applied at structurally sound points on the scenery and attached to battens in the proper fashion. Special attention needs to be paid to adjacent line sets so that flown scenery will not interfere with lighting or audio equipment that may be occupying nearby fly space.

Rigging hard scenery is reasonably straightforward. Often, threaded eye bolts are used to provide a means of connecting wire rope to the set piece. These eye bolts are mounted in pre-drilled holes using washers. In many cases, this point is reinforced using additional wood to make it more structurally sound.

When rigging walls, it is vastly preferable to tie in to the bottom of the wall rather than the top. In practice this may be impossible, as the set piece may contain many door and window cutouts. Good judgement must be exercised on the parts of both the set construction crew and the rigging crew in order to safely rig and fly set pieces.

Chapter 5

Lighting

"Stage lighting is often surrounded by a thick and impenetrable veil of mystery, which is due, undoubtedly, to lack of knowledge of both the limits and potentialities of the problem." – Stanley McCandless.

Figure 5.1: WPI Masque's November 1992 production of Shakespeare's *The Tempest*, in which some stunning lighting effects were used to enhance the appearance of the set.

5.1 Introduction

Lighting provides a tool for setting moods and tones of scenes on stage. In order to effectively utilize this tool, one must have a fairly in-depth understanding of the physics of light as well as the mechanical and electrical considerations of the lighting equipment.

This chapter is an attempt to cover most aspects of a typical theatre lighting setup, including exposure to a wide variety of lighting instruments, dimmers, lighting boards, and other associated hardware. Additionally, basic lighting theory will be discussed, including important techniques necessary for successful lighting design.

Having knowledge of how to use the equipmenta allows one to act as the *Master Electrician* for a production. The responsibilities of the Master Electrician (*M.E.*) are to hang, patch and focus the lights as per the lighting plot provided by the lighting designer. Often times the M.E. will also operate the lighting console for the production.

While a knowledge of basic lighting theory is helpful to anyone working in the theatre, it is especially important to the *Lighting Designer*. The Lighting Designer (*L.D.*) must have a firm grasp on the theories of light, optics, and color, as well as a fair degree of artistic vision. The lighting designer has to use lighting to reinforce the moods of the play, as established by the work being performed as well as the production staff. In keeping with the the theme of this book, the artistic aspects of lighting design will not be stressed, as they are extremely difficult, if not impossible, to convey in written form. The easiest way to get a feel for what works and what doesn't is to work with an experienced L.D. on a few performances.

5.2 Lighting Instruments

There are many different types of lighting instruments used in theatre. Each type of instrument plays an important role in the overall lighting scheme.

5.2.1 Scoops

The simplest type of instrument used in theatre is known as the *scoop*. It consists of simply an incandescent lamp mounted inside of a large, parabolic metal reflector. The main use of a scoop is to provide a very bright flood from a single source. Their application to lighting the stage tends to be limited, but they can be very useful for some types of effects lighting as well as cyclorama washes. Many scoops have no provisions for color filters, but a sheet of color can be affixed to the front of the instrument with gaffer's tape. This works as long as the instrument doesn't need to be on for long periods of time, as the tape tends to lose its grip when heated. A scoop is shown in figure 5.2.

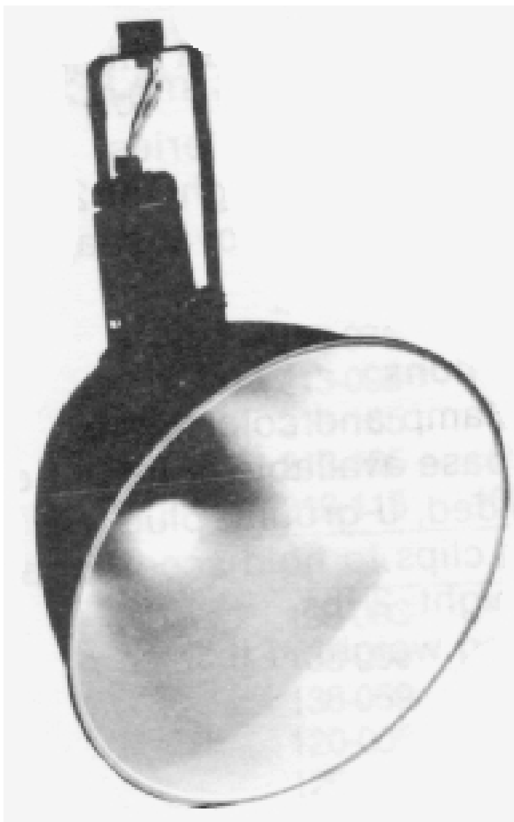

Figure 5.2: Typical scoop, with no lamp installed.

5.2.2 Cyclorama Lights

Another simple instrument, called the *cyclorama light* (or less formally, a *cyc light*), is mainly used for providing color washes on a flown cyclorama. Cyc lights are available with anywhere from one to four individual elements, consisting of quartz lamps and reflectors. Large color frames can be slid into the face of each of the individual sections of the instrument. Cyc lights provide a uniform wash, which makes them especially suited to cyc and backdrop lighting. An example of a cyc light is shown in figure 5.3.

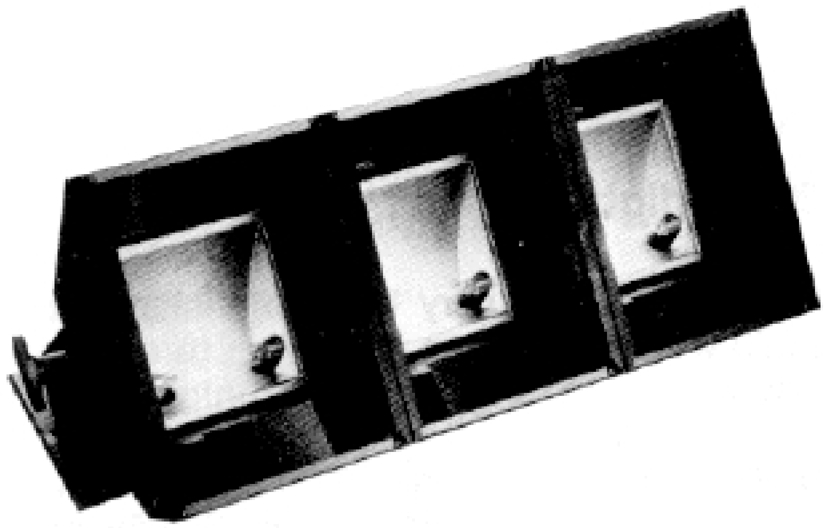

Figure 5.3: Three-element cyclorama light.

5.2.3 Parabolic Reflector Cans

Parabolic reflector cans (most commonly called *PAR cans*, or simply *cans*) are non-focusable instruments. PAR cans consist mainly of a metal cylinder with a sealed-beam parabolic reflector lamp at one end. These lamps are very similar to those used in many automobiles as headlights. The instrument throws an unfocused beam, the shape of which depends on what type of lamp is in the instrument. The most common types of lamps are: very narrow spot (*VNSP - "vee-nisp"*), narrow spot (*NSP - "nisp"*), medium flood (*MFL - "miffle"*), and wide flood (*WFL - "wiffle"*). In addition to the type of lamp, PARs come in several sizes, denoted by a number (typically one of 16, 38, 46, 56 or 64). The instrument size and throw increase as this number increases. Theatrical applications of cans typically include washes and effects lighting. Color frames can be used with most cans by using the clips present on the front of the instrument. Refer to figure 5.4 for an example of a PAR can.

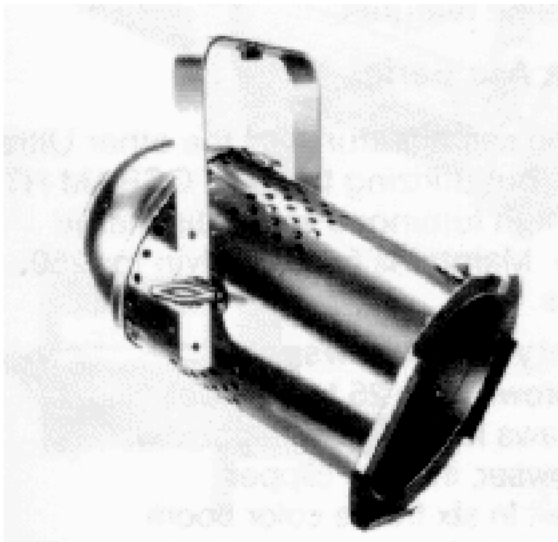

Figure 5.4: Typical PAR can.

5.2.4 Fresnel Spotlights

Fresnel spotlights (pronounced **freh**-nell) produce a soft-edged beam that is well-suited to washes and specials. Fresnels consist of an incandescent lamp, a mirrored parabolic reflector, and a round fresnel lens. It is this lens that lends the instrument both its name and its characteristic of having a soft focus. Fresnel spotlights come in a few sizes, the most common of which are three, six and eight inch. This figure refers to the diameter of the lens used on the instrument. Adjustments allow the focusing of the beam from spot to flood. Provisions for color frames are generally present on the front of fresnels. Figure 5.5 depicts a typical fresnel spotlight.

5.2.5 Ellipsoidal Reflector Spotlights

Ellipsoidal reflector spotlights (often called ERSs, or *Lekos*, after a company's ellipsoidal instrument) are among the most complex non-automated lights found in a theatrical lighting setup. Ellipsoidals consist of an incandescent lamp, an elliptical reflector, and one or two plano-convex lenses. There are many types of ellipsoidal instruments, but they all share the common trait of producing a sharp beam that can be focused and shaped. Most employ four shutters that allow the spill of light to be controlled. Ellipsoidals typically have provisions for color frames and *gobo* projection. Typical uses of ellipsoidals are: acting

Figure 5.5: Typical fresnel spotlight.

area lighting, specials, back or side lighting, and pattern projection (discussed a little later in this chapter). Figures 5.6 and 5.7 show typical ERS instruments.

5.2.6 Automated Instruments

Self-contained automated lighting instruments that provide such features as color changing, pattern changing, panning and tilting, and strobing are available. These are the most complicated instruments available, and involve a considerable number of technologies. There are literally dozens of different designs of automated lights from as many companies. Much competition exists between these companies, making copyright infringement lawsuits commonplace.

One of the most common designs involves aiming a focused light at mirror that pans and tilts. The optics involved in focusing the light are similar to those in an ellipsoidal instrument, but can vary greatly. Often wheels are inserted at the focal point of the optical system, allowing for color or pattern changes. A computer control system coordinates all of the functions of the instrument, allowing the instrument to be run by remote control.

A pair of **High End Systems TrackSpots (tm)** are used at WPI on a regular basis. These instruments are of the type described above, offering remote control of the position of the spotlight as well as color, pattern, strobe, and dimming. Figure 5.8 shows a **TrackSpot**, and Appendix Q provides specific

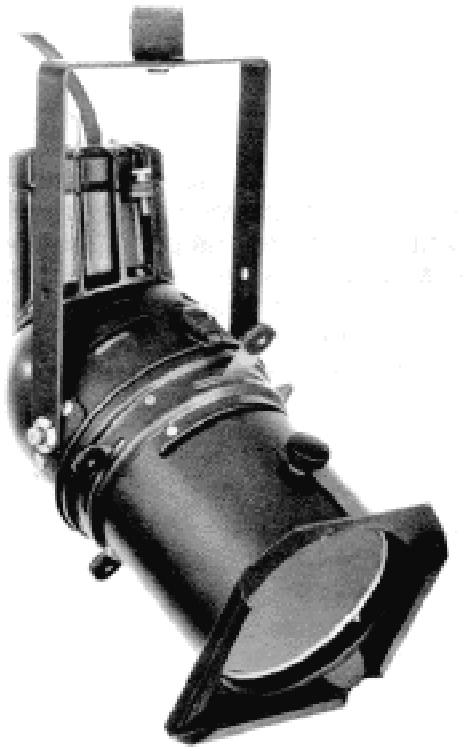

Figure 5.6: Typical non-axial ellipsoidal reflector spotlight.

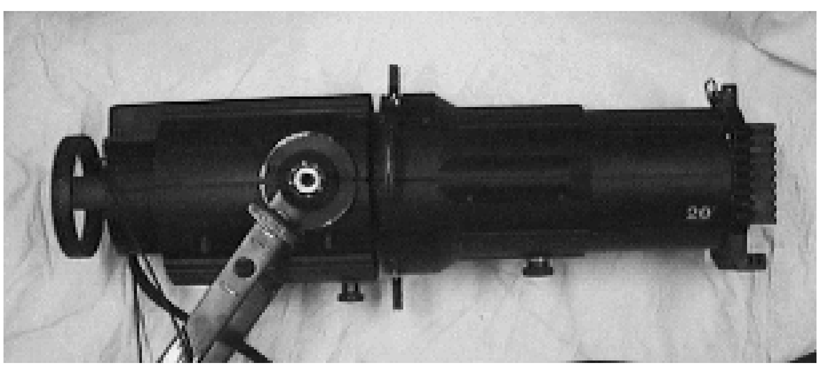

Figure 5.7: An **Altman Shakespeare**, a modern ellipsoidal reflector spotlight.

information about setting up these instruments.

It should be noted that, though automated instruments have been available for quite some time, some trepidation exists among lighting designers. Many do not trust the technologies and prefer to stick with traditional lighting. Others claim that the effects produced with automated instruments are tacky and lacking in professionalism. However, many shows have taken advantage of the convenience and wide array of effects that automated instruments offer with a great deal of success. It is left to the discretion of the reader as to what conclusions to draw about automated instruments.

Figure 5.8: The *TrackSpot*, produced by **High End Systems**, an example of an automated lighting instrument.

5.3 Color

5.3.1 Color Theory

Plain white light tends to be bland and harsh when used to light actors on a stage. Because of this, techniques for providing colored light have been developed and refined over the years. These techniques rely mostly upon the physical properties of light.

5.3.2 Primary, Secondary and Complementary Colors of Light

Almost everyone understands the concepts of the primary colors as they pertain to pigments. Red, yellow and blue are the primary pigment colors. Mixing yellow and blue yields green, blue and red yields magenta, etc. Light behaves in a similar fashion, though it has a different set of primary colors. Red, green and blue are the primary colors of light. Figure n depicts the primary and secondary colors of light. This figure also shows what are known as *complementary colors* — colors that are opposite from one another in their makeup. For example, pure blue is the complement of pure amber. Pure blue is made up of just blue, while amber is made up of only the opposite colors, red and green. Figure 5.9 depicts the primary and secondary colors as well as indicating those which are complementary.

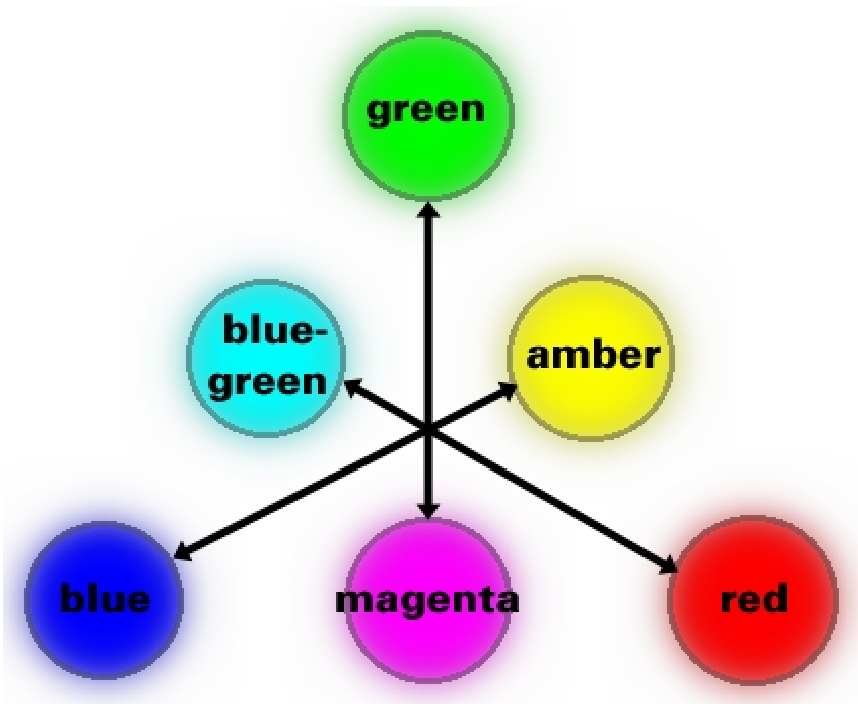

Figure 5.9: Primary and secondary colors of light. Red, green and blue make up the primaries, while the other colors depicted are secondary. Colors on opposite ends of arrows are complementary.

5.3.3 Light Mixing

With pigments, if you mix equal amounts of pure red, yellow and blue, you end up with black. Light can be mixed in a similar fashion, with the primary difference being that light mixes towards white rather than black. That is to say, with equal amounts of pure red, green and blue, white is the final result. This type of mixing of light is called *additive mixing*. It should be noted that complementary colors mix together to form white. Figure 5.10 provides an effective way to visualize additive color mixing.

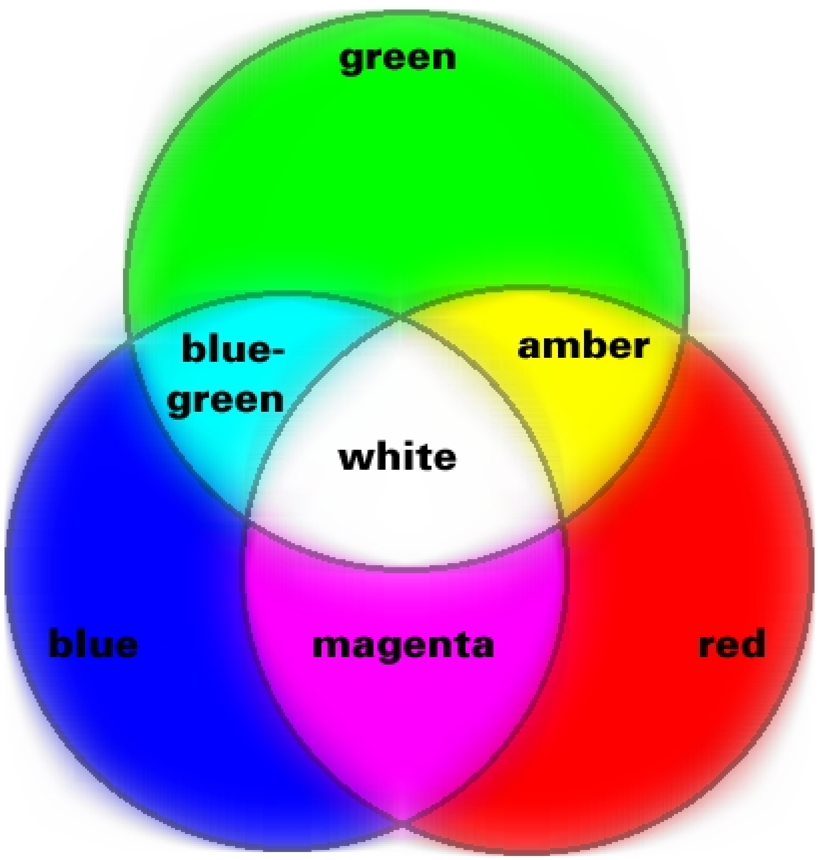

Figure 5.10: Additive mixing of the primary colors. Assuming equal color purity and intensity of the three primaries, they will mix to form white (center).

5.3.4 Practical Use of Color

Glass, Gelatine and Plastics

Several methods exist for changing the color of light that lighting instruments project. Most of these methods involve the placement of color media in front of the instrument. The most familiar of these methods involves the use of tinted glass. This is a reasonably functional method, but doesn't prove cost-effective or practical when a large variety of colors are desired.

!sX The next most common method involves a material known as *gelatine*, or less formally, *gel*. Gel is made from synthetic dyes mixed with animal or plant jelly, and because of its makeup has many negative side-effects. The main problem with gel is that it fades rapidly under high-intensity, high-heat lighting instruments. Also, gel becomes brittle over time and is destroyed when it comes in contact with water. This is the primary reason that plastics are used to accomplish the same task. Acetate or polyester, in combination with synthetic dyes, make up what most modern lighting designers and technicians refer to when speaking of "gel" in the noun form. Plastic works reasonably well as a color media, but still suffers from fading, and tends to warp or burn out after a period of time. Dark colors such as blues tend to be more susceptible to these problems than lighter colors.

Several companies sell color media, the most common of which are **Rosco** (under the trade names **Roscolene** and **Roscolux**), GAM, and Lee. Swatchbooks that contain samples of color media are generally available free of charge from the companies or their distributors. Each company has their own scheme for numbering their colors. For example, GAM 250, Lee 106, Roscolene 823, and Roscolux 27 are all approximately the same pure red color.

Plastic color gel typically is purchased in large sheets (approximately 2 feet by 2 feet), and usually need to be cut down to fit into the *color frame* for an instrument (see figure 5.11). At WPI, most gels are kept for later use, so it is very important that they be marked with a grease pencil after they have been cut. Typically the marking includes an abbreviation of the manufacturer name and the color number.

Dichroic Color Filters

A fairly recent development in color filter technology has given the industry the *dichroic filter*. Dichroic filters (*dichros - pronounced "dye-crows"*) are glass filters with thin layers of metallic oxides deposited on them. Dichros transmit certain frequencies of light while reflecting others. Due to their nature, the color of the transmitted light is different from the color of the reflected light, which are both different from the color of the dichro when viewed at a 45 degree angle. While this is an interesting characteristic of the filters that has its own set of applications, the most important thing to remember about dichroic filters is that they will produce a saturated, pure, single wavelength of light when used on an instrument. Dichroic filters can be obtained that produce near-ultraviolet light, which can be used to produce an interesting night-time effect, similar to

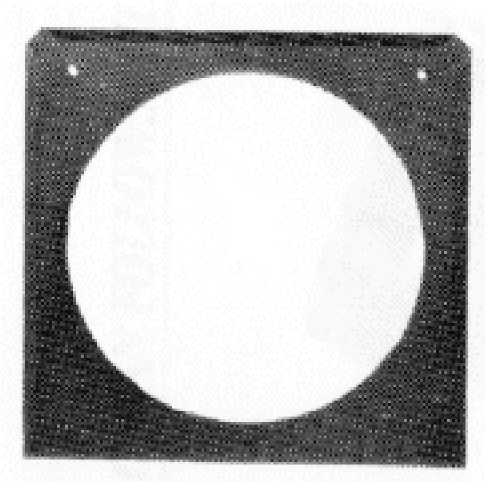

Figure 5.11: A typical color frame, used to support a cut piece of color media on the front a lighting instrument.

that produced by a black light. The primary reason for using dichroic filters is for the purity and permanence of color. Plastic gel tends to burn up, especially dark colors. Dichroic filters are expensive, but will not burn up with use, thus making them good investments.

5.4 Patterns

Often times it is desirable to project a pattern on to the scene being lit. This can be a very striking effect, and is usually inexpensive to achieve. The basic concept is fairly simple; a pattern is cut into a small piece of metal and placed into the focal point inside of an ellipsoidal reflector spotlight. With appropriate focusing, the pattern will be enlarged and projected by the instrument. The sheet of metal with the pattern cut in it is typically referred to as a *gobo* in the industry, and figure 5.12 shows some of the available patterns.

More complex (and consequently expensive) gobos are available that are made using glass and a photo-etching technique. This can yield photographic quality shaded projections with an extremely high resolution. Some theatre supply houses can even custom-etch patterns from photographs or negatives, though this tends to be expensive.

Generally, gobos are placed in metal gobo holders and inserted into the instrument via a special slot. Sometimes old ellipsoidals do not have provisions for a gobo holder, therefore the gobo must be wedged into the instrument's aperture. This tends not to be optimal, because the lack of an externally accessible holder makes it very difficult to move and adjust the image.

Several companies produce gobos, often times the same companies that sell

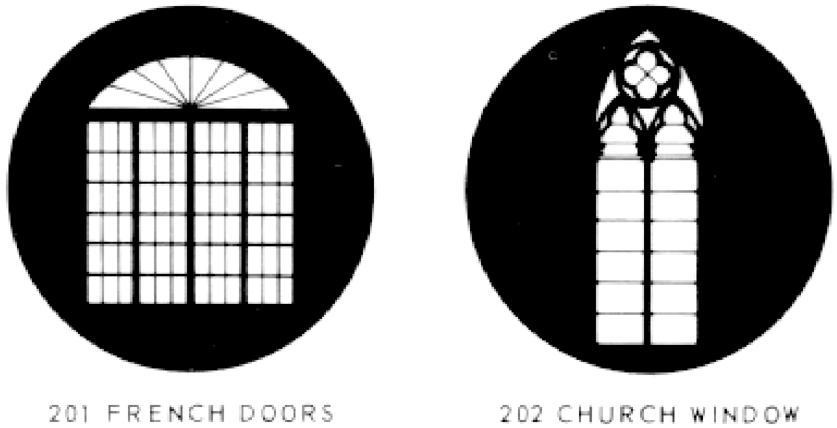

Figure 5.12: Examples of available gobo patterns. Patterns such as these can be used very effectively to enhance the appearance of a production.

color media. Catalogs of patterns are available, usually free of charge, from these companies or their distributors.

Interesting effects can be obtained by combining gobos and multi-colored color gels. Pieces of different color gels can be cut up and taped together to form a single, multi-colored sheet of gel. When combined with a window gobo, an interesting stained glass effect can be had. A similar effect on a larger scale can be had by using multiple instruments, each with their own gobo and gel. Each gobo projection makes up part of a larger pattern. This requires careful focusing, but the end result can be quite impressive. Creative use of gobos and gels can yield some surprisingly good effects, and are among the least expensive things that can be done to improve the look of a production.

In a pinch, custom gobos can be cut out of several layers of black aluminum foil (often known by **Rosco**'s trade name of **Cinefoil**) using a sharp razor blade. This typically only works for pattern outlines, but some surprisingly good effects can be had with this technique.

5.5 Dimmers

5.5.1 Dimmer History

The earliest electrical lighting used in theatres was not dimmable; it was either on or off. Precise control of light levels is a recent addition to the theatre. The technology for dimming instruments has improved markedly since dimming schemes were invented in the early part of the 20th century. Bulky, inefficient methods for dimming have been replaced with small, efficient solid state circuitry.

Figure 5.13: A striking scene from the 1995 WPI Masque production of Ray Bradbury's *Fahrenheit 451*. The effect was created by projecting a foliage pattern onto a *scrim* (a large mesh cloth).

It is not uncommon to find small rack-mount units that contain eight or more dimmable channels such as those shown in in figure 5.14. Often several of these units are mounted in a permanent installation or portable roadcase, along with power connectors, lighting instrument connectors, and a hard-patch area. Hard patching is the process of connecting individual lighting instruments to dimmer channels. Each dimmer channel allows for independent control of whatever is connected to it, be it one or many instruments. The means for hard patching vary from theatre to theatre, but the concept is the same.

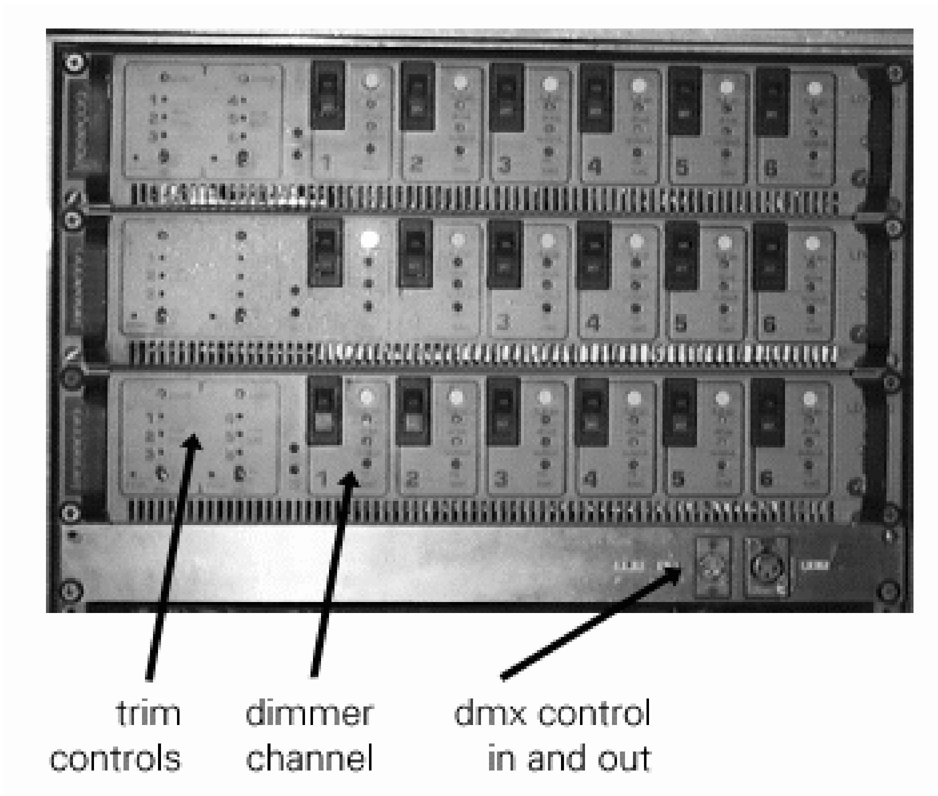

Figure 5.14: A rack of dimmers, providing eighteen discrete dimmable channels. The individual dimmers are manufactured by **Leprecon/CAE, Inc.** Productions at WPI typically use anywhere from one to three of these dimmer racks.

Dimmer units that can run multiple channels of lighting in a single box generally have a front panel with some controls and indicators for each channel. It is quite common to find a *circuit breaker*, a *bump switch*, and a variety of LED indicators for each channel. The circuit breaker is a means for automatic shutdown of the circuit should it be overloaded. The bump switch allows the individual channel to be turned on at the dimmer, which is convenient for testing and hard patching. Common types of indicators are those that show whether a channel is active and whether it has anything connected to it. Figure 5.15 shows a closeup of the controls of an typical individual dimmer channel.

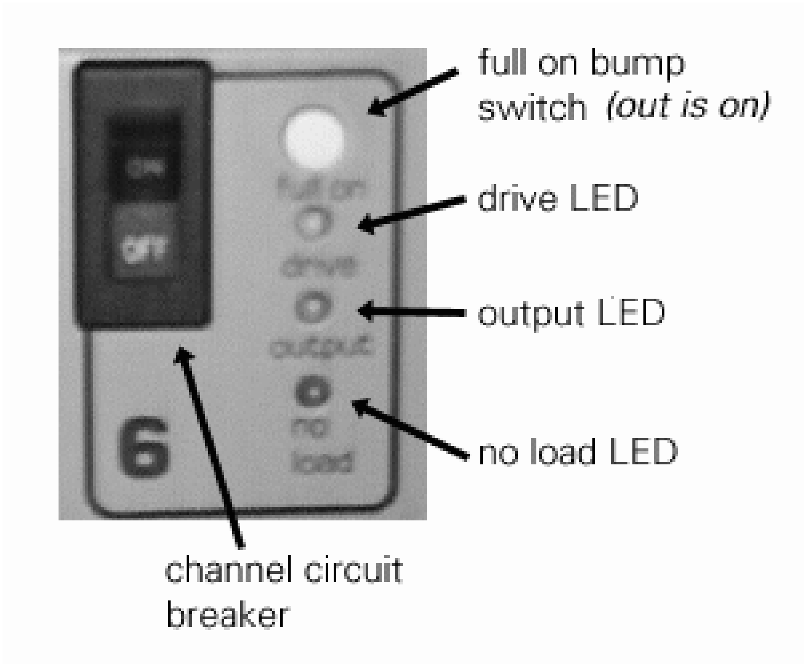

Figure 5.15: Closeup of an individual channel on a Leprecon dimmer.

Many different schemes are used for hard patching dimmers. At WPI, the dimmers used for most productions are portable, so a wall-mounted hard-patch area is not present, as in some theatres. Instead, each rack of dimmers has a panel on the rear with special breakouts for lighting cable connectors. Individual *twist-lock* and multiple conductor *Socapex* connectors are available for breakouts. These connectors are discussed in more detail in section 5.6.

Lighting instruments are connected to the breakouts, and the individual wires of the breakouts are then connected to the channel outputs on the rear of the dimmers. When hard patching, it is important to pay close attention to the power requirements of the lighting instruments and the power capabilities of the individual dimmer channels. While it is often desirable to put several instruments on a single dimmer channel, some instruments use too much power to make this possible. The racks of **Leprecon** dimmers that are used at WPI can provide 2400 watts per channel while the **NSI** digital dimmers provide 1200 watts per channel.

Some dimmers, such as the **NSI** digital dimmers shown in figure 5.17, have no provisions for hard patching, per se. Some models have *edison* style connectors on the rear, for direct connection of common consumer-style lighting

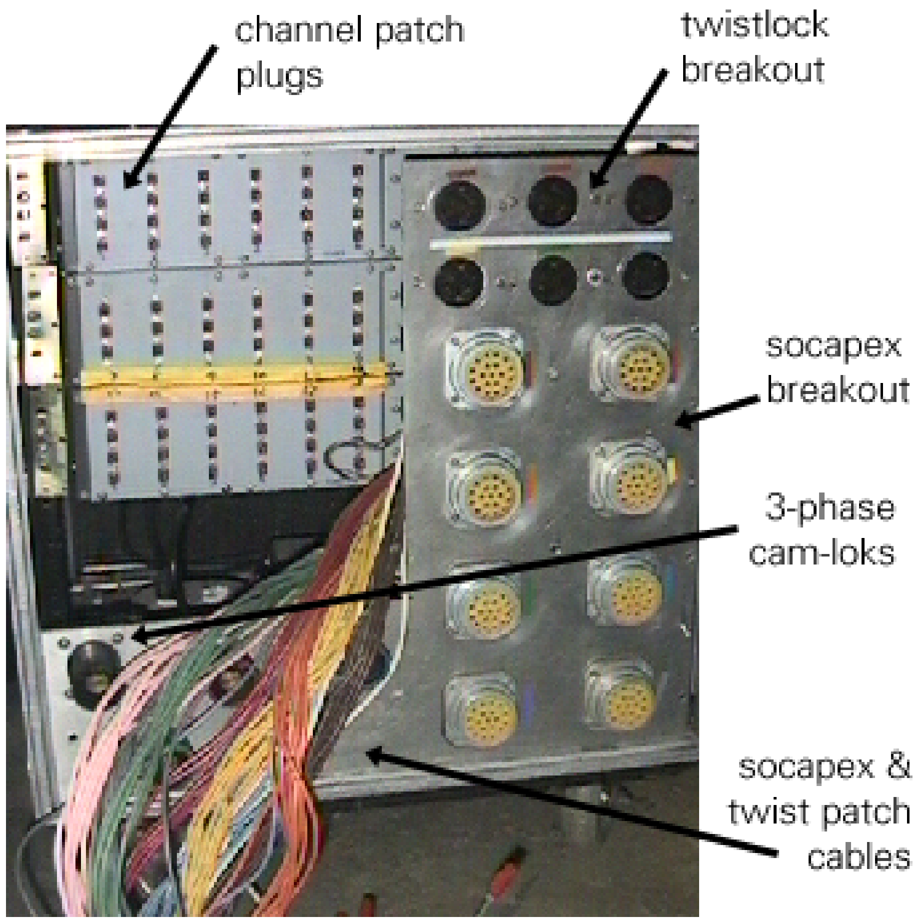

Figure 5.16: The rear of a typical dimmer rack used at WPI. The channel patch plugs combined with the patch cables allow lighting instruments to be hard patched to dimmer channels.

equipment. Others have multi-conductor Socapex connectors, wired such that one dimmer channel powers a single channel of the Socapex cable.

Figure 5.17: The front panel of a digitally controlled dimmer, manufactured by **NSI, Inc.** Dimmers such as these are often used at WPI to control a variety of small lighting instruments such as PAR 16's, practicals, etc.

5.6 Cables and Connectors

Various types of cabling and connectors are used to connect lighting instruments to dimmers. Most theatres use what is known as *stage pin* cabling, however instruments at WPI are wired with *twist-lock* connectors. In each case, a hot, neutral and ground are carried to the lighting instrument. Most of the time, rented lighting equipment is outfitted with stage pin connectors. WPI Lens and Lights stocks several twist-lock to stage pin adapters in its inventory so that rental equipment may be used.

Often times, permanent theatre installations will have special outlet strips along the lighting battens to connect the instruments. In the case of WPI, very little is permanent, so movable breakouts are used. These breakouts connect up to eight twist-lock connectors to a multi-conductor cable terminated with a *Socapex* connector, as shown in figure 5.18. Socapex connectors are present on the back of many dimmer racks, and allow for the breakouts to be plugged in for later hard patching.

An important consideration when wiring lighting equipment is *cable dressing*. Neat and orderly wiring is very important because it makes finding problems easier, and makes the overall setup much safer. Large coils of live cables should be avoided, especially around metal objects, as this creates an inductor and electromagnet. If a big enough coil is made, it is possible to cause dimmer damage, and cause problems with other equipment in the vicinity of the coil.

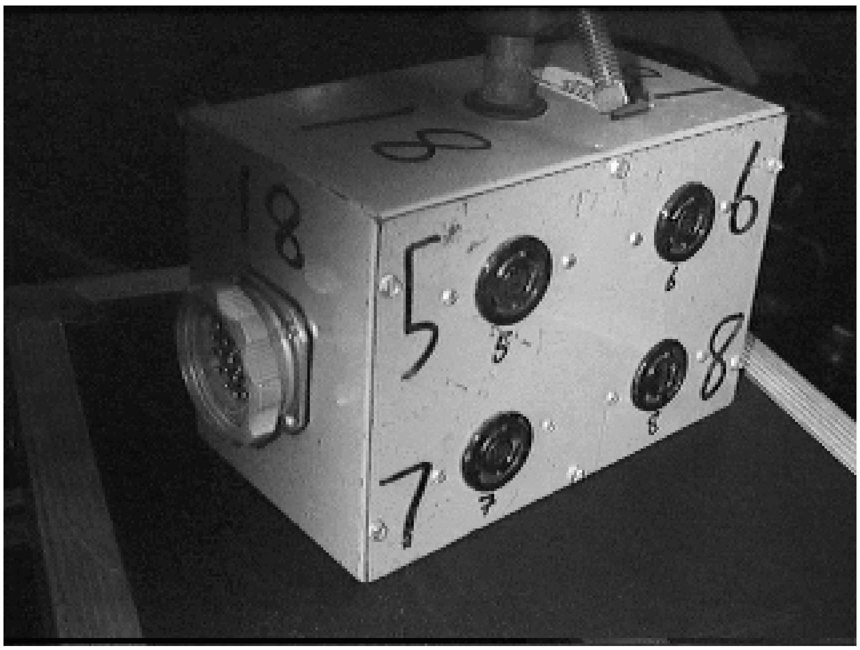

Figure 5.18: Socapex breakout box. Eight twist-lock connectors terminate the eight discrete channels of the Socapex cable. The Socapex connector is the large connector on the left and the remaining are twist-lock style.

5.7 Lighting Boards

The lighting board is what the M.E. or L.D. uses to run the lights for a production. Many different styles of boards exist, with a wide range of capabilities and features. Portable lighting boards are actually a fairly recent concept. Early systems required the controls for dimming the instruments to be part of the dimmers due to mechanical limitations. Within the past twenty years or so, schemes for running the dimmers remotely have been developed, some of which are discussed in detail in the next section. These innovations have helped to bring about the creation of separate lighting boards.

The simplest lighting board one is likely to find today allows the operator to set up two *scenes* and *cross-fade* between them. These are commonly referred to as *X-Y boards*. An X-Y board has a number of channels associated with it, where each channel can control one or more dimmer channels. For example, twelve channels may be controlled with a small board. Levels can be set for each of these individual channels on two scenes (the X and Y scenes). A cross-fader allows switching between scenes — as one scene comes up, the other goes down, and vice versa. One scene is generally in use at a time. While the other scene is inactive, it can be *pre-set* for the next scene, which is generally done from a sheet of paper with the appropriate levels written on it.

Figure 5.19: Small but powerful lighting board, manufactured by **Leprecon/CAE, Inc.** This board is used to run the lights in many of the small productions at WPI.

Most boards also allow some form of *soft patching*, meaning assigning more than one individual dimmer channel to a board channel. This is advantageous because each dimmer channel is rated for a maximum power handling capability. Soft patching allows more instruments to be controlled as a logical unit than a single dimmer channel allows. Older lighting boards use a matrix of diode pins to electrically connect board channels to dimmer channels. Modern boards tend to accomplish the same task through the use of software.

Advanced lighting boards usually provide all of the same features as an X-Y board, but add the ability to store scenes, record a sequence of scenes in a *cue stack*, and record light *chases*. Scene storage is an especially handy feature because it becomes increasingly difficult to set an entire scene when the number of channels on a board is high. With a standard X-Y board, every fader in a scene has to be set to a level recorded on a piece of paper. Scene storage boards remove this hassle by allowing the operator to record a scene and assign it to a single fader. More advanced boards allow these recorded scenes to be strung together into what is commonly known as a cue stack. This enables the operator to simply push a "go" button to advance to the next lighting cue. Lastly, some boards allow repeating sequences of scenes to be run. Most are outfitted with a speed control that allows the operator to adjust how quickly the sequence progresses. Some boards even provide an input for an audio synchronization signal, such that lighting chases may be synchronized with an audio track. See figures 5.19 and 5.20 for examples of advanced lighting boards.

5.8 Control

Since modern lighting setups have separate dimmers and boards which are often located a hundred or more feet apart, a method of control must be used so that the board may control the dimmers.

One of the first methods used to accomplish this task was a purely analog scheme. Individual wires for each channel are used, with each carrying a small (typically zero to ten volt) analog signal representative of the position of the fader on the board. This method works reasonably well, and is in fact still used in many theatre installations. However, the multi-conductor cabling is expensive, difficult to maintain, and quite bulky. The amount of cabling required to run a large number of dimmer channels can become difficult to manage after a time.

To combat these problems, several different schemes have been developed over the years. Most rely on some form of *multiplexing*, the combining of several discrete signals into one by dividing time up into several slices and devoting a slice to each signal. This allows all of the multiconductor cabling to be replaced with a single piece of cable, using typically only three conductors.

Several schemes for multiplexing lighting information have been developed. Two of the most common ones AMX192 (analog multiplex, 192 channels) and DMX512 (digital multiplex, 512 channels). DMX512 is what is used at WPI for lighting control.

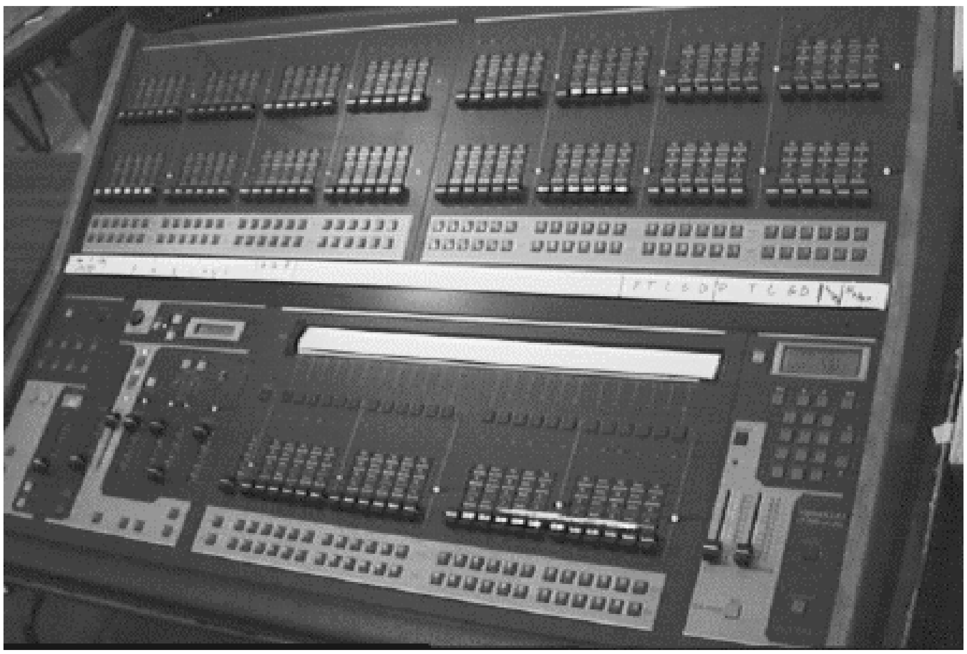

Figure 5.20: Large lighting board, manufactured by **Leprecon/CAE, Inc.** It features 48 channels, 96 scene presets, cue stack, programmable chase, and a floppy disk drive for storage and retrieval of board programs.

DMX512 can be run using regular 3-pin microphone cable over long distances. This affords much flexibility in the placement of the lighting board and dimmer racks, as they can be spaced quite far apart. Most new dimmers decode DMX512 internally. The **NSI** dimmers that WPI owns are prime examples of this. However, the majority of the dimmers used at WPI are older analog models that have been retrofitted through the use of DMX512 demultiplexers. These devices decode the digital signals used on a DMX line and convert them to analog signals used by the dimmers. Devices such as this give older devices an extended life, as they can be controlled by the latest computer lighting boards. Figure 5.21 shows one such demultiplexer.

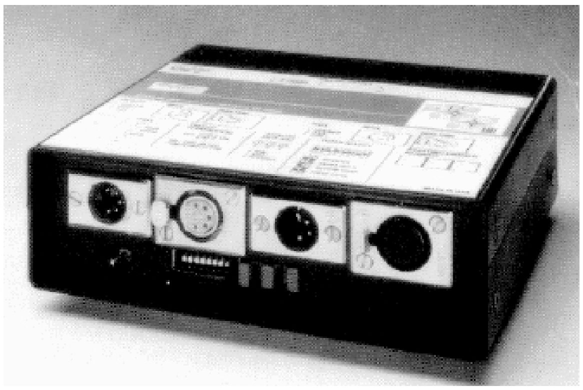

Figure 5.21: DMX512/AMX192 demultiplexer, used to convert DMX or AMX signals to 0-10V analog signals used on older dimmers. The three main dimmer racks used at WPI employ DMX demultiplexers manufactured by **Electronic Theatre Controls, Inc.**

DMX512 is also used for the control of many automated lights. The **High End TrackSpots** used at WPI are controlled over DMX. Individual channels of DMX are assigned to functions such as pan, tilt and color. Appendix Q has more information about the DMX channel mapping used on the TrackSpots.

5.9 Design

There are many factors to consider when designing the lighting for a production. Lighting is a powerful tool for enhancing the moods and tones of a play if used properly. Much of this power comes from the fact that its effects are largely subliminal. It is the duty of the lighting designer to understand these effects, and produce a lighting design that is both attractive and enhancing to the overall production.

Lighting design is very much an art, and in keeping with the theme of this book, only the most technical aspects of lighting design will be stressed.

5.9.1 Washes

For general purposes, it is desirable to provide what are called *washes* of light. Washes are general, unfocused light designed to evenly light a certain area of the stage. Typically several different washes are used to give each scene a different feel. Often several instruments are used that can be used for general purpose filling of *dark spots* and other effects.

Obtaining a usable dim wash is a task many lighting designers face. Many novice lighting designers think that a satisfactory dim wash can be obtained with only a few instruments. The truth of the matter is that it typically takes more instruments running at lower levels to produce a usable dim wash.

Fresnels and PAR cans are most frequently used for washes. Ellipsoidal instruments may also be used if they are shot from far enough away or defocused.

5.9.2 Specials

Many times it is desirable to accentuate certain portions of the stage with light. This can have a very dramatic effect, but also can be used very subtly. A dramatic use of a special would be having a single instrument light an actor. A more subtle use of a special would be to highlight an actor during an important speech without reducing the existing lighting.

Ellipsoidal instruments are usually used for specials, due to their focusing and shuttering capabilities.

5.9.3 Cyclorama Lighting

Many productions use cycloramas behind the acting space on stage to represent a sky or other expansive background. The placement of the cyclorama lights can have a dramatic effect on how the cyc appears. Often the lights are mounted on the floor behind scenery, but they can also be flown from a batten. The differences are purely artistic, and will be left to the discretion of the reader.

5.9.4 Color

Different colors can bring about many different feelings in people. Many people associate colors with moods and feelings in their lives. Fortunately, many of these associations are common, and can be drawn upon by the lighting designer to set a mood for a scene. Much of the effect is subliminal, and somewhat subjective, but it is still an effective technique. Table 5.22 lists several common color associations. This makes a good starting point for determining what colors to use in a lighting design, based upon the tones of the piece being performed.

5.9.5 Lighting Angle

Another variable that lighting designers have control over is lighting angle. Depending on how a person is lit, different features of the person's body and face are accentuated. This can be used effectively to make a character look sinister,

black	depressing, solemn, dead, evil
white	stimulating, purifying, living, truthful
red	warm, passionate, sexual, angry
blue	cool, tranquil, solemn, expansive
magenta	rich, royal, soothing
green	peaceful, alive, growing, hopeful

Figure 5.22: Table of common colors and common associations. It should be noted that many of these have a bias towards Western culture.

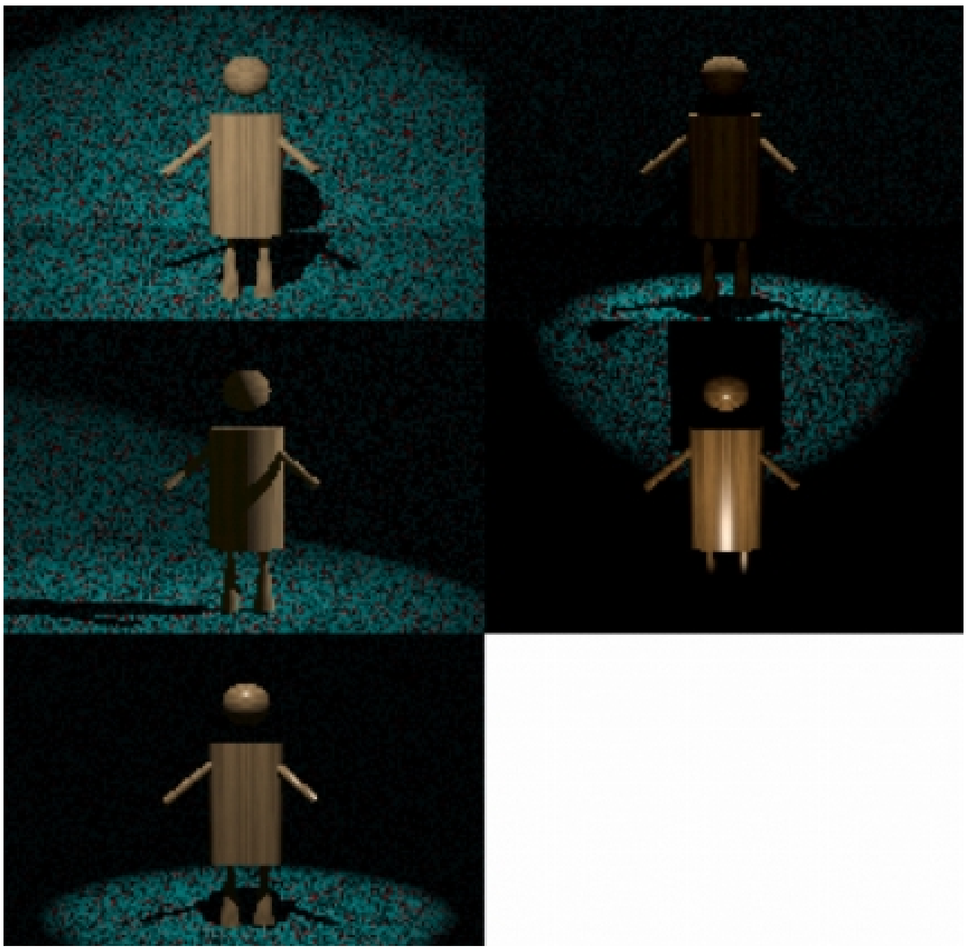

Figure 5.23: Computer rendering showing the effect of lighting an actor from several different angles. From left to right, top to bottom: from front overhead (low angle), from rear overhead (high angle), from side, from front below actor, from directly overhead.

mysterious, or larger than life. Lighting that hides the face (back lighting) tends to make people more nervous and less trusting of a character. Floor lighting and downlighting can both make a character look larger than life, while side lighting can make a character look mysterious. These techniques are effective only if used sparingly. If overused, they become the norm to the audience, and thus lose their effectiveness.

5.9.6 Simulating Exteriors

It is important to consider that, when attempting to reproduce day or night scenes, making a realistic representation of either with lighting instruments is near impossible. What needs to be done, rather, is to attempt to catch the essence of sunlight or moonlight. A bright shaft of light from an instrument can be used to supplement a wash to give the feeling of daylight. Generally, bright, warm colors are used in the wash to provide the essence of a bright day. Very light blue is often used to represent moonlight, with faint dark blue washes being used to supplement the scene. Star gobos can be projected to enhance the appearance of the night scene.

A rainy or overcast daytime scene is harder to produce, as there are few effects such as the beam of sunlight that can be used. In this case, cool colors are generally used, with a fairly even balance of light from all directions.

5.9.7 Lighting Design Paperwork

Shop Order

When a lighting hang is begun, the first task for the Master Electrician and crew is to gather the appropriate materials from the lighting shop. This is where the *shop order* comes in. It is the lighting designer's duty to assemble a list of all materials required from the shop. This list includes control elements such as lighting boards, dimmers, lighting instruments, effects devices, etc.

Each lighting designer has a favorite method for preparing shop orders. The specific format is not important, as long as it accurately lists all materials required for a production.

Instrument Plots

In order for the lighting designer to communicate to the electrician's crew the placement and electrical connection of the lighting instruments, an *instrument plot* is created. This plot shows the type, location, circuit, color, and focus area for each instrument used. The most common type of plot is a top-down view, as shown in figure 5.25.

The symbols used for lighting instrument plots have been standardized by the **USITT** (United States Institute of Theatre Technology). Symbols exist for almost every type of lighting instrument used in a theatre setting. Templates are available to aid lighting designers in creating pencil-and-paper instrument plots. Additionally, computer-based templates are available for LDs who use

EXAMPLE PRODUCTION - SHOP ORDER

CONTROL

- (1) Leprecon LP2000 lighting board with cue stack option
- (1) Leprecon LP1512 lighting board

DIMMERS

- (3) Lens and Lights standard dimmer racks: 3X Leprecon analog dimmers plus ETC DMX demux
- (1) NSI digital dimmer with edison plugs, for practicals

INSTRUMENTS

- (4) Altman Shakespeare 20 degree
- (10) 6x9 1kw axial Lekos
- (10) PAR-64 MFL
- (4) PAR-64 NSP
- (2) High-End TrackSpots

Figure 5.24: A portion of an example shop order.

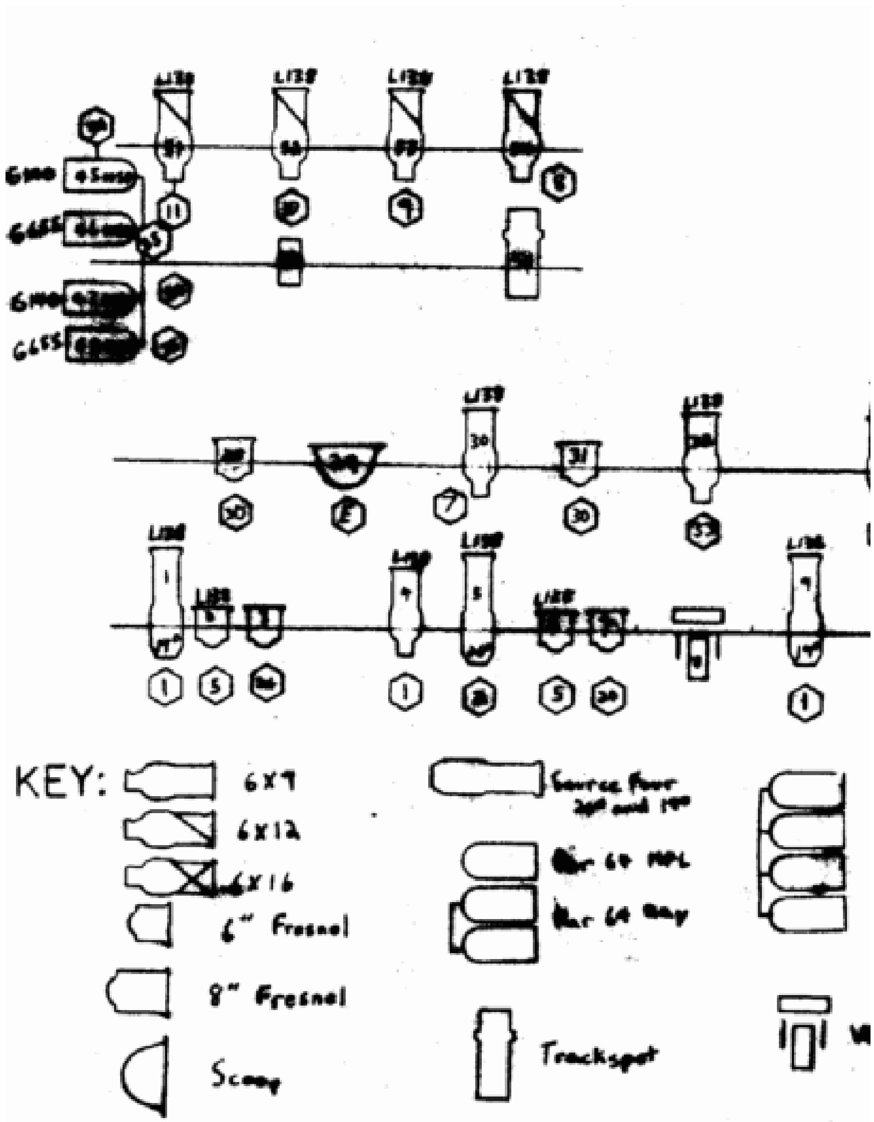

Figure 5.25: An portion of a lighting plot, showing the key and some of the instruments. This is the instrument plot from the 1994 WPI Masque production of Shakespeare's *A Midsummer Night's Dream.*

CAD packages to create their lighting designs. Figures 5.26 through 5.30 show most of the USITT standard instrument plot graphics.

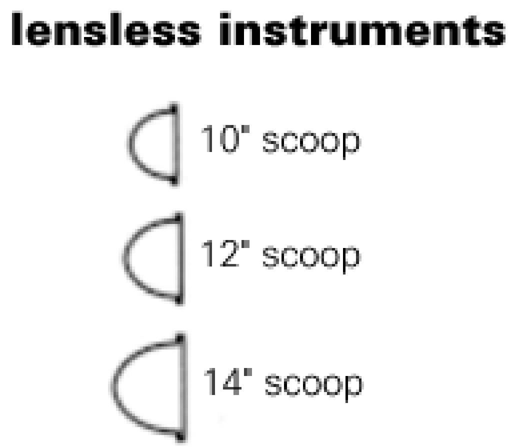

Figure 5.26: The USITT lighting graphic standards for lensless instruments.

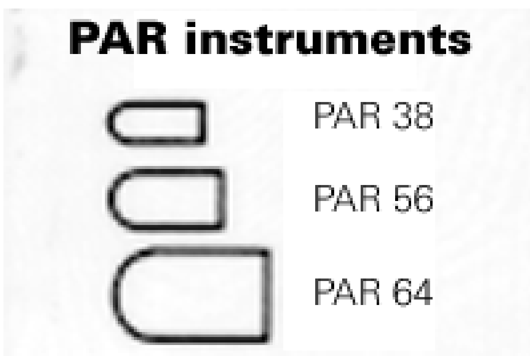

Figure 5.27: The USITT lighting graphic standards for PAR cans.

Focus Sheets

While the instrument plot shows the position of the instruments, it provides no information about where the instruments should be focused. Instead, a *focus sheet* is consulted. Focus sheets can differ greatly, but in general most provide dimmer channel, focus area and color for each instrument used in the plot. Focus sheets are important so that the electrician's crew can focus the lighting instruments without the presence of the lighting designer. Often, fine adjustments must be made in the presence of the LD, but much can be done from the focus sheet.

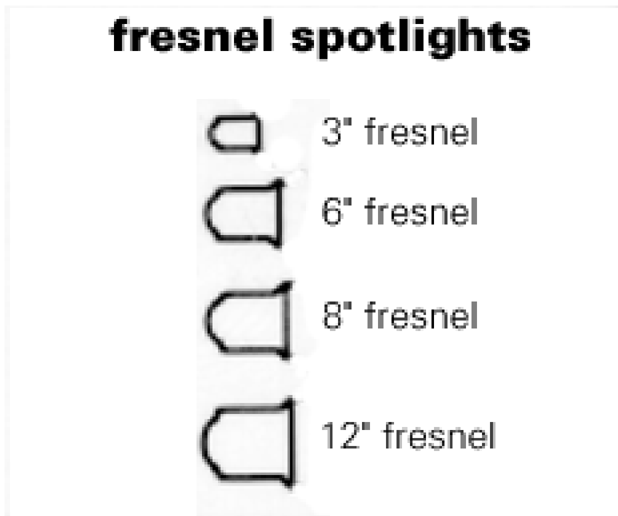

Figure 5.28: The USITT lighting graphic standards for fresnel spotlights.

5.9.8 Computer-Aided Lighting Design

Several computer programs exist for aiding in the layout of lighting instrument plots. Some of these programs even have advanced features for rendering images of what scenes will look like when lit by certain instruments. These packages can be a great aid to the lighting designer by removing a lot of the tedium involved in producing the necessary documents. They can also be of great aid to the producer and production staff, by providing images of what the lighting will look like long before a single instrument is hung. This can be of enormous help to everyone working on the production staff, as it helps bring everyone's vision closer together of what the production will look like in the end.

This is especially useful in cases where automated fixtures are used. A few companies produce powerful software that allow entire shows to be laid out, programmed, and simulated ahead of time. Figures 5.32 and 5.33 show example screen shots from such programs.

5.10 A Typical Lighting Hang at WPI

This assumes knowledge of how to properly rig the lighting truss and fly system. It also assumes knowledge of how to properly connect the dimmer racks to the power feed in a venue. Other chapters in this book cover these topics in some detail, and should be read before attempting these tasks. As always, when in doubt, ask a knowledgable person.

- Retrieve instruments, dimmers, board from shop, as per shop order.
- Set up dimmer racks, connect power to racks.

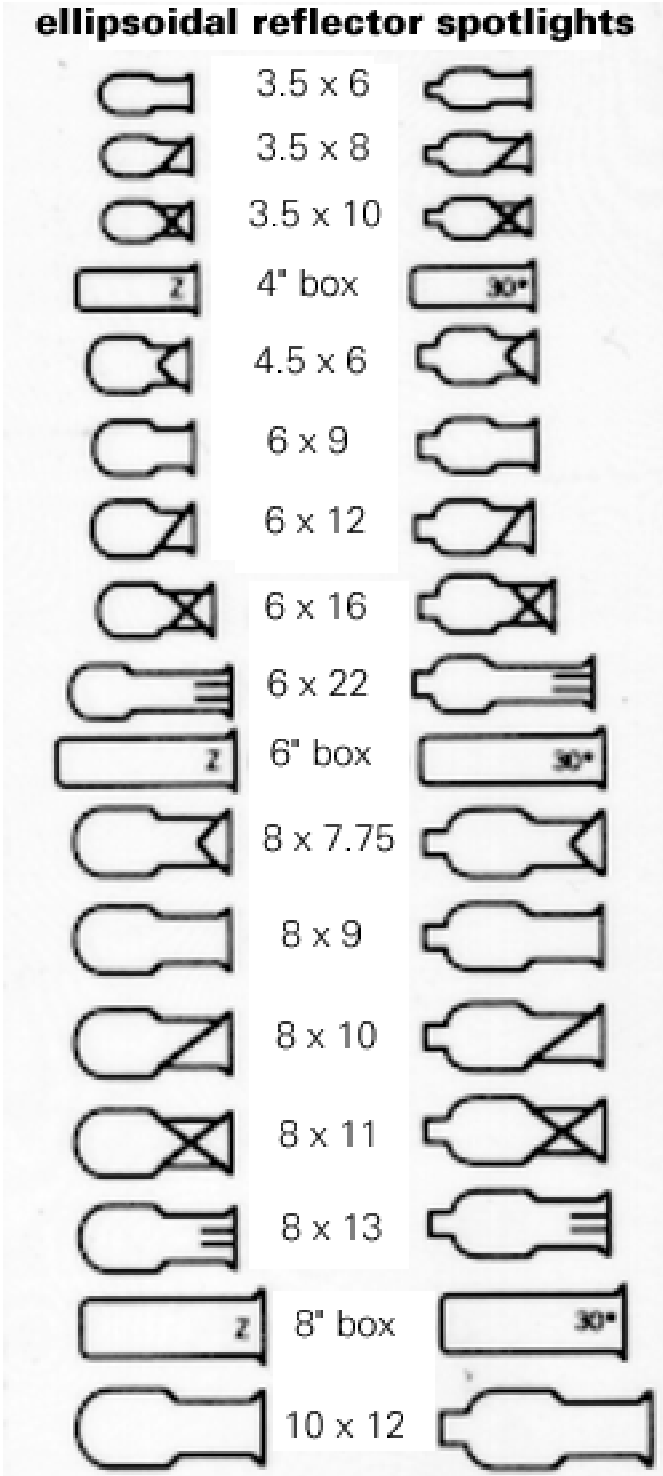

Figure 5.29: The USITT lighting graphic standards for ellipsoidals.

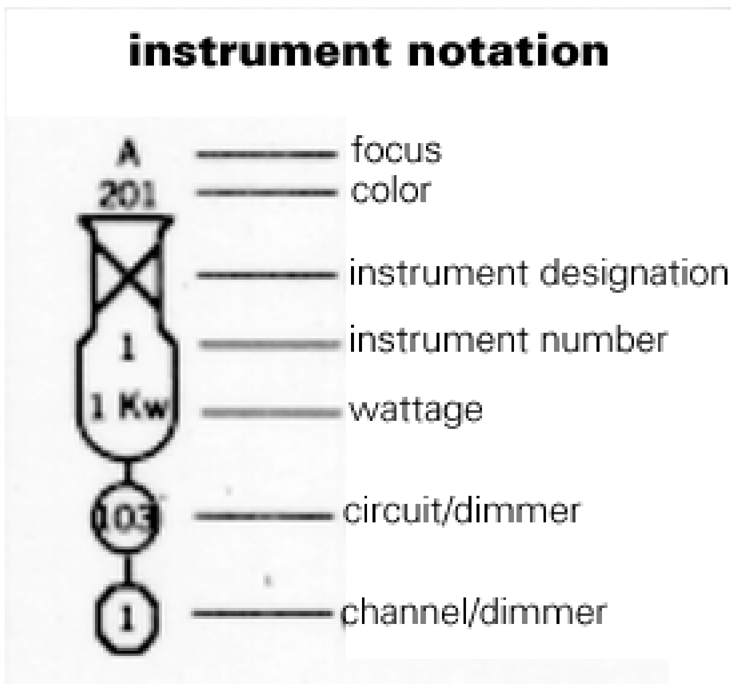

Figure 5.30: The USITT lighting graphic standard for instrument notation on a lighting plot.

```
EXAMPLE PRODUCTION - FOCUS SHEET


Inst    DimCh   Focus                          Color
======================================================
 32      23     downstage right, soft focus    R02
                shutter off-stage spill

 33      18     downstage left, soft focus     R02
                shutter off-stage spill

 34      19     downstage center, hard focus   none
                (blinds gobo)

                                .

                                .

                                .
```

Figure 5.31: A portion of an example focus sheet.

- Lay out instruments in front of truss, battens, as per lighting plot.
- Hang instruments as per plot.
- Install Socapex breakouts on the truss or battens.
- Connect Socapex cable to breakouts, run cable to dimmer racks.
- Connect Socapex cable to dimmer racks.
- Hard patch instruments to dimmer channels, as per plot.
- Test instruments. Replace or repair any bad instruments, cable, etc.
- Connect DMX cabling from dimmer racks to lighting board.
- Soft patch lighting board, as per plot.
- Focus instruments, following appropriate safety precautions.
- Program scenes and, if applicable, cue stack, on the lighting board.
- Refocus instruments and reprogram board as dictated by the director of the production.

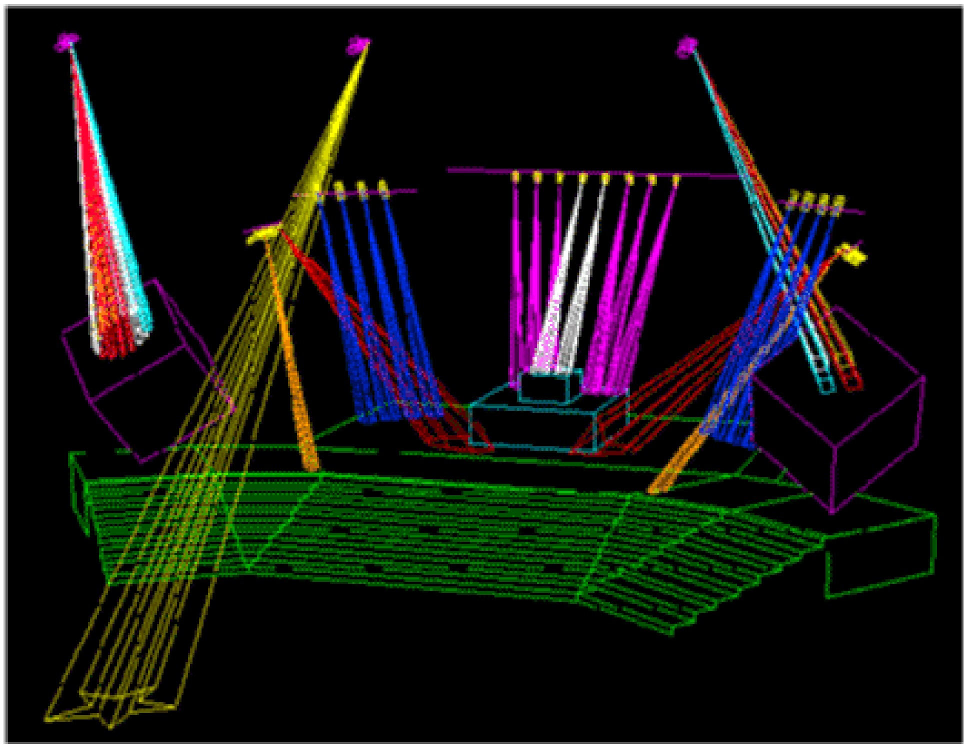

Figure 5.32: A screen rendering from **CAST Lighting's WYSIWYG** automated lighting fixture design program. Programs such as this allow CAD drawings of the venue to be imported, over which lighting instruments can be placed.

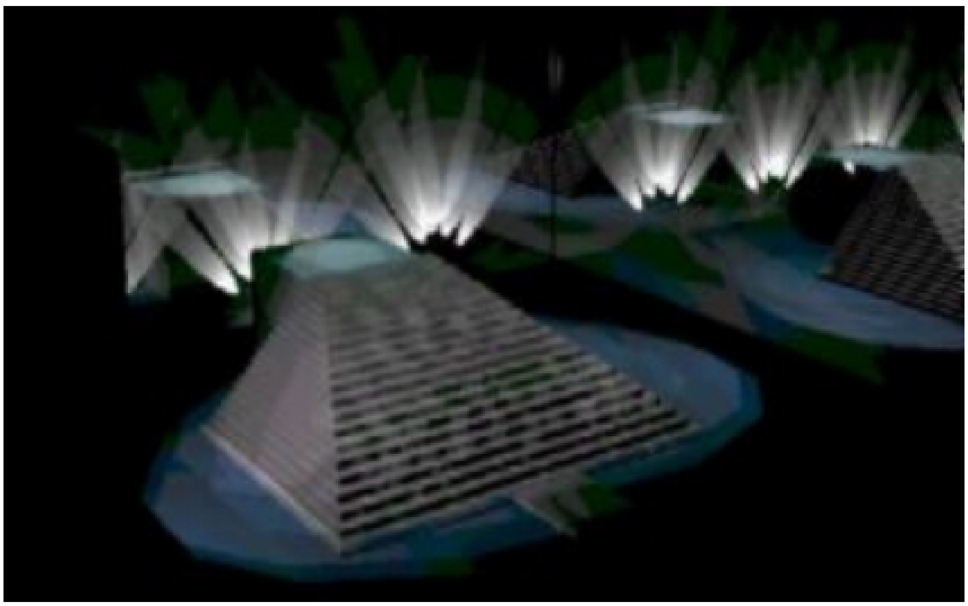

Figure 5.33: Another screen shot from **CAST Lighting's WYSIWYG** software.

Chapter 6

Audio

"Was that rifle shot **supposed** *to sound like a bazooka?"* – Dan Afonso, WPI technical theatre personality, commenting on one of the author's sound effects for a production.

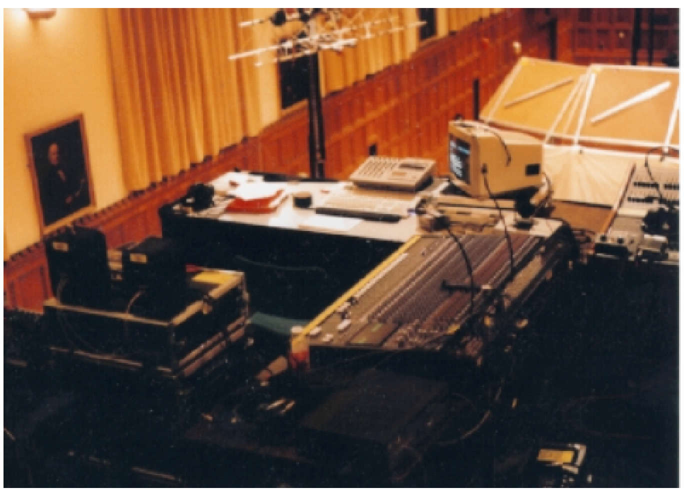

Figure 6.1: The audio equipment used to produce the sound for the 1995 WPI Masque production of Shakespeare's *King Henry V*. A 32-channel mixing board, a multi-track cassette deck, a computer-automated mixer/matrix, a digital sampler, and outboard effects gear were among the many pieces of equipment used for the production. Most of the audio cues were automated using a custom computer software and hardware solution designed in part by the author.

6.1 Introduction

Audio can be used as a tool to set moods and evoke feelings. It can add realism to a production, which can help to further immerse an audience member in the theatre experience. A sound system can also be used solely to reinforce the voices of actors on stage so that they can be heard in a large hall. Often times, a combination of music, sound effects and voice reinforcement is used in a theatre production.

There are generally a few possible production positions that pertain to audio. Not all productions will have all of these positions, but it is certainly possible. Most common is the *audio designer*, who is responsible for determining what types of sound to use for the play, creating the effects, and designing the sound system. Sometimes the audio designer only determines what effects should be used, and an *audio engineer* creates and gathers the sounds and designs the sound system. On occasion, an *audio operator* is present to run the equipment during performances. It is not uncommon for one person to do all of these things under the guise of *audio designer* or *audio engineer*. The distinction between the positions is not clear cut, and there is a lot of crossover.

In order to successfully design a sound system and audio effects for a show, a working knowledge of the equipment is necessary. Many diverse components are used to form a complete audio system, many of which are complex devices in their own rights. The intent of this chapter is to provide a reasonably broad exposure to the equipment and techniques used to create, edit, and reproduce audio effects in a theatre setting.

6.2 Input

A variety of devices exist for input into a sound system. Some are used to capture live sounds while others play back recorded sound. A given theatre production may take advantage of either or both of these.

6.2.1 Microphones

Microphones (*mics*) are among the simplest input devices used in an audio system. Generally speaking, microphones convert sound energy into electrical energy. In this regard, they are the exact opposite of the familiar audio *speaker*. Microphones are available with a wide variety of sizes, shapes, and operating characteristics. Some types of microphones even include very small *amplifiers* inside of them to boost the tiny electrical signal created within the microphone to a more useful level.

Converting Sound to Electricity

Dynamic microphones are among the simplest types of microphones. They consist of a diaphragm that is attached to a small coil of wire. This coil of wire is mounted such that it is surrounded by a magnet. The diaphragm is arranged such that it will move when it is exposed to sound pressure. This, in turn, moves the coil, creating an electric current in it, due to the magnet. The current produced is an electrical representation of the sound that moved the diaphragm. Dynamic microphones are durable, reasonably inexpensive, and usually have good sonic characteristics. Their applications in theatre are numerous; everything from wireless mic transmitters to intercom systems can use dynamic microphones. They are also especially useful in situations where a production calls for an actor's "disembodied" voice to play a role, as dynamic mics are an excellent choice for speech and singing. Two common, favorable types of dynamic microphones are **Shure** models **SM-57** and **SM-58**. These durable mics are suited to a wide variety of tasks, and are quite affordable. The microphone resting on top of the case in figure 6.2 is a **Shure SM-58**, while the microphone directly below that is an **SM-57**.

Figure 6.2: A variety of microphones in a microphone road case.

Condenser microphones and *electret condenser microphones* vary in design considerably from dynamic microphones. A full dissertation on the operating characteristics of condenser mics will not be given here; suffice it to say that they use properties of capacitance to produce a very small signal proportional to the sound wave entering the microphone. This signal is amplified with a small transistor amplifier mounted inside of the mic. Because of this, condenser microphones require some sort of power, either from a battery or what is known as *phantom power* (the powering of microphones remotely from the sound board). Condensers are very sensitive, and offer excellent sonic capabilities. For this reason, they can be useful in theatre applications where a sound needs to be picked up from some distance away from its source. A favorite condenser microphone for many applications is the **Shure** model **SM-81**.

There are many other methods for converting sound energy to electrical engergy. Carbon, piezoelectric and ribbon are also common types of microphones, though less so than dynamic and condenser types. It is not within the scope of this book to provide an in-depth description of all types of microphones, so further reading elsewhere is recommended for those with an interest in the subject.

Directionality

Different types of microphones pick up sound from different directions. So-called *omnidirectional* microphones pick up sound from all directions roughly equally. Directional microphones such as those with *cardioid* and *supercardioid* pickup patterns pick up sound from one direction while rejecting most other sound. Lastly, there are microphones with a *figure-8* pattern that pick up sounds from two sides along the same axis, but reject sound along the perpendicular axis.

It is important to choose the appropriate type of microphone for a task. If there is a lot of ambient noise, a directional microphone can help to capture only the desired sound. If it is desirable to capture ambient sound, an omnidirectional may be the best choice. The **Shure SM-57** and **SM-58** are both directional microphones. The **Shure SM-81** has interchangeable heads that allow it to act as a directional or omnidirectional microphone.

6.2.2 Analog Tape

Most everyone is familiar with standard cassette tapes such as those used in consumer hi-fi gear. Analog tape works by magnetically encoding a representation of an audio signal on a long strip of metallized plastic. This strip of plastic moves past what is known as a *head* inside of the tape deck. Heads are responsible for converting the magnetic energy into electricity for playback, and vice-versa for recording. Other components inside of the deck help to keep the tape moving past the heads at precisely the correct speed. It should be noted that practically every component in a tape deck physically touches the tape, thus causing wear and tear on the tape itself.

While it can be argued that cassette tapes reproduce sound accurately, they are plagued by several other problems that reduce audio quality. Tape suffers from *hiss* (high-pitched sound that sounds like steam spraying from a pipe), *dropouts* (periodic loss in audio level), and *wow* and *flutter* (periodic changes in pitch due to the mechanics of the tape deck or the stretching of the tape itself). Expensive tape decks get around many of these problems with special electronics and high quality mechanisms.

Tape is not an especially robust medium. Inexpensive consumer-grade cassette tapes start to lose sound quality after they have been played even a few times. The most expensive cassettes last a few hundred plays before noticable degradation occurs, providing the deck they are played in is in proper working order. These are problems that significantly affect a theatrical performance, where shows are often run nightly for weeks on end. This makes tape an undesirable medium for the playback of sound effects or music for a production.

In addition to the lack of robustness of tape, it is not a medium that affords easy *cueing*. Accurate cueing (positioning the tape so that playback starts at the desired point) is something of an art, and is yet another unreliable aspect of cassette tapes. This makes tape difficult to use to play back sound effects accurately and on cue.

This does not, however, mean that tape is completely useless in a theatre setting. Multi-track tape decks are available that allow sound to be recorded in *layers*. This allows a convenient way to create complex sound effects when a computer is not available. Portable cassette decks with recording capability exist, thus they become prime candidates when recording sound effects at a remote location. Also, when working on a production that has music being composed for it, it may recorded ahead of time and presented to the audio engineer on a cassette. Cassettes tend to be the lowest common denominator as a medium that people can record and play back at their convenience. This offers some advantages, but they must be weighed carefully against the disadvantages of tape.

It should be noted that a lot of professional theatres still use analog tape in *reel-to-reel* format. Reel-to-reel allows reasonably easy cueing, and is a lot more robust than standard consumer cassette tapes.

6.2.3 Digital Audio Tape (DAT)

A significant advance in tape technology has given the industry the *DAT* (*Digital Audio Tape*). DAT addresses many of the problems associated with standard tape, but does not solve all of them.

Standard tape employs an analog method of recording. That is to say, at any given time, the voltage coming off of the playback head in a tape deck may be any voltage within a certain range. This voltage directly represents the sound recorded on the tape. With DAT, what is stored on tape is a digital representation of the sound. All that is being read off of the tape are binary data — ones and zeroes.

Digital recording schemes work by *sampling* (reading) an analog signal many times a second. Each sample is a representation of what the continuous analog wave (the sound) is “doing” at a particular time. However, it is not an entirely accurate representation of the sound, as there are a discrete number of representations for each sample. That is to say, where an analog signal can be *any* value in between two end points, a digital sample can only be one of several values in between those points.

DATs sample at either 44.1KHz (44,100 times a second) or 48KHz (48,000 times a second)[1]. DAT decks sample with a 16-bit resolution, meaning 16 individual ones or zeroes are used to represent one sample. This translates to each sample being any of 65,536 values. The faster the sampling rate and more bits of resolution yield a more accurate representation of what's being recorded. It should be noted that *no* digital recording method is as accurate as analog methods, because digital methods are only approximations of the analog signal.

Several advantages make DAT more appealing than standard tape. A scheme of indexing and cueing is included, thus it is fairly easy to cue with DAT. However, seeking between cues is not instantaneous, as the tape must still be physically moved to the proper position. DAT is also relatively free from the noise problems associated with analog tape.

Even with DATs advantages, it is still a tape, and thus isn't exceptionally robust. Quality DATs can last a considerable period of time, but when they start to degrade the effects are quite noticable. As the magnetic oxide flakes off of the tape, the DAT deck becomes incapable of reading the data, and produces a noise somewhere in between an explosion and someone scraping their fingernails on a chalkboard. Needless to say, this is less than desirable. This and the problems with cueing make DAT more suited to recording effects and music for a production for playback in some other digital format such as compact disc.

6.2.4 Compact Disc (CD)

Another format familiar to most people is the *compact disc*. Until recently, this media was for all intents and purposes play-only. No consumer equipment existed to record CDs, so recording was an option only for the wealthy. Other folks were forced to use pre-recorded material, which wasn't a total loss, as several good sound effects libraries are available on compact disc.

A CD is a circular plastic disc just under 5 inches in diameter. Encased in the plastic is a thin layer of aluminum or gold. This aluminum has a series of pits and bumps that represent digitally encoded data. These pits and bumps are read by shining a low-powered laser at the disc and detecting the reflection. Compact discs, like DATs, store information digitally. They offer 16-bit resolution at a 44.1KHz sampling rate.

Compact discs and their associated players offer many advantages over any form of tape. First, CDs have no moving parts, and reading data off of a CD is

[1] An interesting side tangent from an Electrical Engineering giant named *Nyquist*: With digital sampling schemes, the maximum audio frequency that can be reproduced is half of the sampling rate. Thus, with a 48KHz sampling rate, a 24KHz audio signal may be represented. The range of human hearing is approximately 20Hz to 20KHz, so as you can see the range is well-covered. Audio purists argue that even 48KHz isn't a high enough sampling rate because sampling can't capture harmonics (multiples of frequencies) above the range of hearing, which may not be audible but still perceivable to humans. Most other people just shake their heads and don't really notice the difference.

largely a non-contact operation. This means that CDs have an *extremely* long life. Playing a CD does not appreciably affect the media, which is an incredible advantage over tape. Secondly, CDs have an effective indexing scheme so that up to 99 individual audio tracks may be called up almost instantly. The seek speed is a function of the actual CD player being used.

Recent advances in technology have made affordable, personal CD recording equipment possible. Recordable CDs are made of a metal alloy and a special organic dye. The recording process involves the use of a laser to heat the dye, and consequently deform the metal alloy layer. This creates pits and the bumps, just like those on mass-produced CDs, which are manufactured in an entirely different manner using a press. Recordable CDs can hold up to 74 minutes of audio, and as of this writing cost about $5 each. Recordable audio CDs can only be written once, they are not erasable.

For well under $1000, a *CD burner* can be purchased for a personal computer. With appropriate software, audio CDs can be created with relative ease. Several facilities on the WPI campus offer the capability to burn CDs, generally for only the cost of the blank CD.

6.2.5 Mini-Disc (MD)

Another fairly recent advance in digital recording and playback technology is the *mini-disc*. An MD is an encased 2.5 inch disc, similar in appearance to a computer floppy disk. A scheme called *magneto-optical encoding* is used, whereby a laser is used to heat the disc and a magnet is used to alter its structure. Digital data is encoded on the disc using this scheme.

In order to fit a relatively large amount of data on a mini-disc, a *compression scheme* is used. This scheme squeezes the digital audio data down so that they take up less space on the disc. The compression scheme used on mini-discs is a *lossy* scheme — that is to say, some audio quality is lost in the compression process. The proponents of mini-disc claim that the loss in quality is very small, and that most people won't notice it.

Mini-disc offers many of the same features as CD with regards to track indexing and cueing. A major advantage of MD is that audio can be recorded using a portable or home machine. Consumer MD players and recorders have been available for some time, and are quite affordable. Mini-discs are reasonably robust, and are erasable. All of these traits make MD an ideal candidate for playback of sound effects in a theatre production.

6.2.6 Digital Samplers

Digital samplers are standalone devices capable of recording and playing back small clips of audio on demand. Samplers are typically used by musicians to simulate musical instruments or produce interesting effects, but they have a lot of features that make them ideal for theatre audio.

Samplers are essentially computers with a chunk of RAM (Random Access Memory), and a mass storage device such as a floppy or hard disk drive. Ad-

Figure 6.3: An advanced digital audio sampler, manufactured by **Akai**. Samplers such as this can store many minutes of audio on an internal hard disk and play it back from a MIDI keyboard or by computer control.

ditionally, they have the circuitry necessary to digitally sample and play back sound. Typically they are used in conjunction with a MIDI (Musical Instrument Digital Interface) keyboard or controller.

MIDI is a scheme that musical instruments (keyboards, synthesizers, drum machines, etc.) can use to communicate with each other. It allows for many different types of messages to be sent, the simplest of which are called *note on/note off* messages. These messages simply say to a musical instrument *"start or stop playing this note now."* Samplers can be configured to assign individual sounds to notes, thus playing "C" on a keyboard could produce a gunshot, while playing "A" could produce a phone ring sound.

Samplers offer some advantages over more conventional types of media. Most samplers allow for *polyphony*, the playing of several notes at once. This makes it easy to layer sound effects on demand. Also, with samplers, the cue time for sounds is typically next to nothing, allowing for cueing that rivals even the fastest CD player.

6.2.7 Computer Sound Cards

A standard personal computer outfitted with a *sound card* and appropriate software can function much like a digital audio sampler. The setup is much like that of a sampler, though generally much more functionality can be obtained due to the unconstrained user interface. Sound files can be edited graphically and played back at will. Sounds can be recorded at the touch of a key, and played back just as easily.

A significant disadvantage to most sound cards is that they are typically of low quality. Large amounts of hiss, hum, and background noise can be extremely detrimental to the overall quality of sound. More costly sound cards yield much better sound, but the very best cost close to $1000 at the time of this writing.

Even inexpensive PC sound cards can still serve as useful tools. With the right software, a PC and a sound card can form a powerful audio editing station. Sounds can be captured, manipulated in many ways, and processed for burning on to CD or playback on a digital sampler.

6.3 Mixing Boards

Complex productions often will combine several different audio inputs – microphones, CD players, tape decks, etc. A way to manage all of these inputs and combine them so they can be played out of a single sound system is clearly necessary. This is where the *mixing board* (also called a *sound board*, *mixer*, or *mixing console*) comes in.

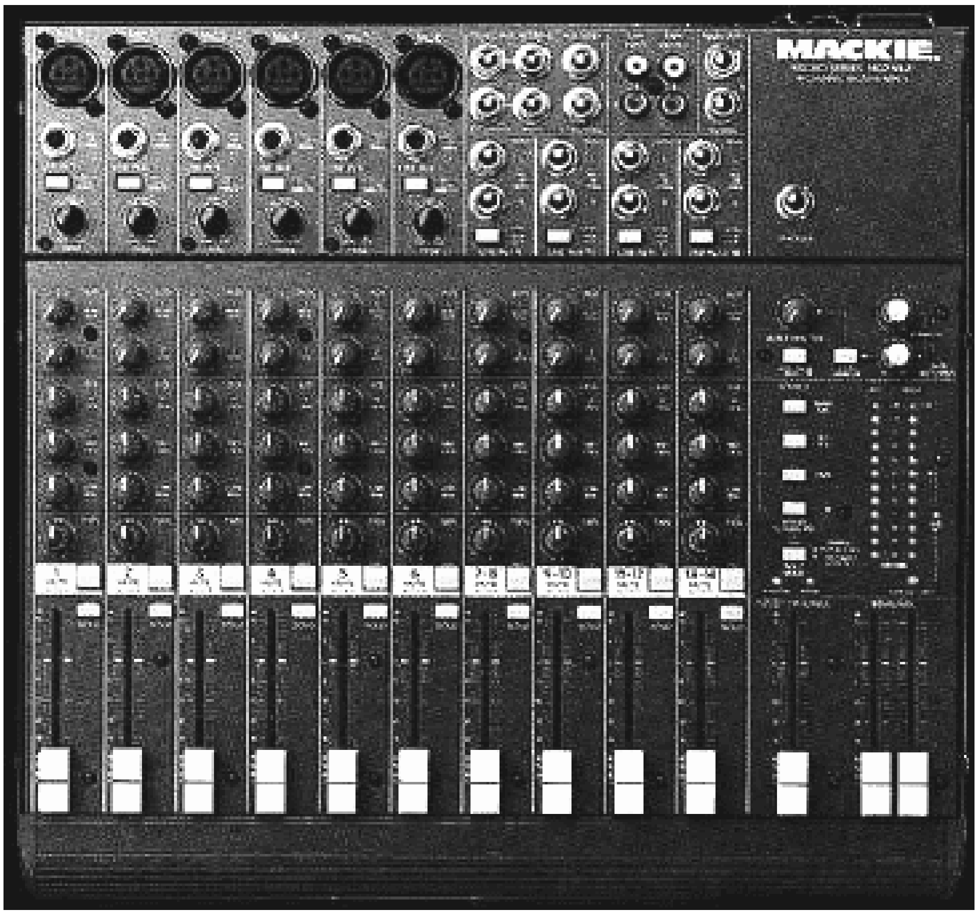

Figure 6.4: A 14-input mixing board, manufactured by **Mackie Designs, Inc.** Small boards such as this are offer plenty of capability for most theatre shows, and should be used in place of large boards where possible.

The overall job of a mixer is to take several inputs and combine them into a small number of outputs. Generally many features are offered, such as adjustable *equalization* (the changing of the tone of a sound), volume level adjustment, and *muting*. Mixing boards can be quite complex, and there are many differences in operation between models.

Mixers are generally referred to by the number of *input channels* and *output channels* they have. An input channel is a place where a single audio signal can be connected into the sound board. An output channel is a path of exit from a sound board for an audio signal. Mixers with four, eight, twelve, sixteen, twenty-four or thirty-two input channels and two to eight output channels are not uncommon. On these boards, each input can be assigned to an output, with the options of assigning several inputs to one output, and one input to several outputs.

Input channels typically allow for the connection of a *microphone-level* signal or a *line-level* signal such as that from a CD player or tape deck. Microphone-level signals are very low-level, on the order of millionths of a volt. Line level signals are in the range of a tenth of a volt to two volts. This discrepancy in levels is one of the reasons that most mixers have two types of inputs. Typically these inputs are chosen with a small pushbutton or toggle switch, as only one may be used at any given time. Most mixers allow for some sort of trim adjustment, to *normal* the level of the signal as it enters the board. This is necessary because different microphones and pieces of equipment have slightly different output levels. The trim adjustment allows the board operator to make each input appear to be at about the same level so that the differences can be ignored once the board is set up properly.

Each channel on a mixer typically has what are referred to as *auxiliary sends* (*aux sends*). It is common to find one to eight aux sends on a sound board. Each send typically has a knob associated with it on each vertical channel strip. The knob controls the level sent to that particular aux send. Aux sends can be thought of as board outputs with individually adjustable levels. Typically aux sends are used to send some of the input signal to an effect such as reverb, but they can be used creatively for other purposes.

Generally, each channel has some form of *equalization* (*EQ*) — that is, controls to adjust the tonal quality of the sound. Small mixers may only have adjustments for bass and treble, while larger boards may provide bass, treble, mid-range, and adjustable range controls. These adjustable range controls are called *parametric equalizers*, and allows the user to choose not only to boost or cut a frequency range, but to choose which range to work with. Equalizer controls function much like the familiar bass and treble knobs found on stereos. It is common to use an equalizer to improve or alter the sound of an input. For instance, removing bass from wireless body microphone inputs can reduce annoying "clunking" sounds that may be picked up from the mic.

Most mixers are capable of handling *stereo* signals. A system is considered stereo if it has two discrete signal paths in the final output stage (i.e. the left and right speakers). Since each input strip is mono (on most mixers, anyway), the board provides a *pan* control to adjust the "position" of the mono sound between the left and right channels. The signal can be panned anywhere from full left, to center (both channels), to full right. This is an extremely useful

Figure 6.5: The typical elements of an input channel on a mixer. This is representative of a relatively small mixer. Larger boards usually have a larger equalization section, more aux sends, and output channel assignment switches.

feature, as it can make for more realistic effects. For example, if a sound is supposed to be coming from one side of the stage, the pan control can be used so only the speaker on that side is used. It should be noted that on boards that have multiple outputs, the control is usually set up to pan between even and odd sets of outputs. For example, hard left really means output channels 1, 3, 5, etc. The manual for a sound board should always be consulted to see how this feature is implemented to avoid any unpleasant last-minute surprises.

The most prominent part of a mixer is probably the set of channel *faders*, generally located at the bottom of the board. Most mixers use linear style faders (also called sliders), but some use rotary knobs. Regardless of the style of control, they all perform the same function, which is controlling the level of the signal sent to the outputs of the mixer. On large boards, the output select switches are usually positioned near each channel fader. These switches allow the board operator to set which output channels each input gets routed to.

Lastly, two buttons commonly found on mixers are the *mute* and *solo* buttons. Mute, as its name implies, silences the input signal. This is very useful in situations where there is noise on an input (such as someone chatting near a microphone) that is not desired at the outputs (or "in the mix", as it is called). The mute switch allows the faders, which may be set at an important level, to be left alone when silencing an input. The solo switch, found in many different forms on different boards, allows a signal to be listened to by itself. Often this can be routed to a pair of headphones, which is an extremely useful feature for cueing tapes, etc.

Figure 6.6: A 32-input mixing board with eight discrete output buses, manufactured by **Mackie Designs, Inc.** This particular model of mixer is owned by WPI, and is often used for large theatre shows.

The mixing board is a key element in the sound system, and knowing how to use it properly can go a long way towards making the sound effects and music of a production sound good. While most mixers function similarly, there are always small differences between boards. These differences sometimes are very obvious, but sometimes they require reading the manual before they become apparent.

6.4 Signal Processing Equipment

There is a class of equipment which typically is used in between the sound sources (microphones, CD players, etc.) and the output section (amplifiers and speakers). This equipment is known as *signal processing* gear. Included in this category are equalizers, compressers, limiters, noise gates and effects processors.

Signal processing gear is typically used with the auxiliary sends mentioned above in the sound board section, or is *inserted* on each channel. Most sound boards allow for a special cable called an *insert cable* to be plugged in to an input or output channel. Plugging this cable in interrupts the signal and allows it to pass through an external piece of equipment before entering the rest of the sound board.

When using an aux send to run signal processors, the signal is passed to both the effect and the main outputs. This allows mixing of the *dry* (uneffected) and *wet* (effected) signals. Multiple input channels can send to the same aux send, and thus share an effect such as reverb or echo. When a piece of signal processing gear is inserted, the signal is completely wet, as it passes entirely out of the sound board, through the effect, and back in. Inserted gear only works on the individual channel it was inserted on, and thus can not be shared. Figure 6.7 shows a diagram of aux send and inserted signal paths.

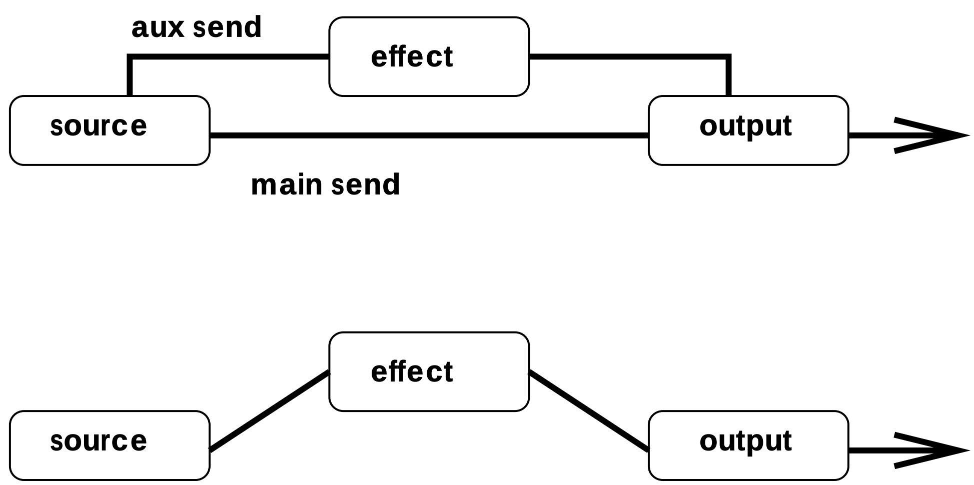

Figure 6.7: The difference in signal path between using signal processing equipment with an aux send (top) and as an insert (bottom).

6.4.1 Equalizers

As discussed in the sound board section, equalizers are used to shape the tone of a sound. Outboard equalizers are rarely (if ever) used with aux sends on a sound board. Instead, they are usually inserted on an input channel to equalize an input signal, or on output channels to equalize the output of the system before sending the signal to amplifiers and speakers. In applications where microphones are used (especially body mics), equalizers can be an extremely helpful tool in eliminating *feedback* problems. In addition to eliminating feedback, overall sound system equalization is used to adjust the system such that it sounds pleasing. Equalizers are also often used to overcome deficiencies in the speakers used, or in the venue that they are being used in.

Two main types of outboard equalizers exist. The most common is the *graphic equalizer*. Graphic equalizers consist of a set of slider controls and circuitry that allow boosting or cutting of a range of frequencies. Each slider is set to control a small range of frequencies, and can usually boost or cut this range fairly substantially. Graphic equalizers with ten to thirty bands are quite common. Graphic EQs with more bands afford the audio engineer much more control over what frequencies to boost or cut. This is a boon when eliminating feedback, as it allows the offending frequencies to be removed without disturbing other frequencies.

While graphic EQs work well for removing feedback, *paragraphic* EQs are often used instead. Like the parametric EQs mentioned in the sound board section, paragraphics allow the setting of the frequency to be boosted or cut. The only difference is that the control to boost or cut the signal is a slider rather than a knob. As a point of interest, the *graphic* portion of graphic and paragraphic equalizers comes from the fact that an idea of the signal shaping can be had by simply looking at the sliders on the front of the equipment. That is to say, it is a graphical representation of the equalization curve.

Many people often wonder how one goes about setting all of the sliders on an equalizer. To some, it seems to be black magic, and in some ways it is. There are two main approaches to setting equalizers, and both will not always apply in a given situation.

In cases where microphones are being used, there exists the potential for the system to feed back. This is a case where *ringing out* the system is often used. An equalizer is set up on the outputs of the sound board. The level of the microphones are brought up one by one, until feedback is heard. The frequency of the feedback is determined (either by experience or guessing), and removed using the equalizer. This process is repeated until all microphones are working at an acceptible level. Often, especially when wireless body microphones are used, actors will move around. Sometimes they move into a position that makes feedback extremely likely. This should be taken into account when ringing out a system by having someone walk around to all locations that the actor will be in and performing the above procedure at these locations.

In cases where no microphones are used, ringing out the system makes no sense, as the potential for feedback does not exist. It is this case (as well as the case when microphones *are* used) that equalizing to make the system sound pleasurable is used. This is a *highly* subjective topic, and is practically impossible to explain to someone. Since everyone has different tastes, it is difficult to agree upon one set of criteria that define what makes a sound system sound good. However, here are some general guidelines that can be useful:

- There should be no noticable peaks in the sound. For example, booming bass or "honking" speech are not desirable. In the first case, the bass frequencies (100Hz and below) should be cut. In the second case, the low-mid frequencies (200-500Hz) should be cut. In general, the sound sytem should sound natural and smooth. Many people have never really heard a smooth and natural sounding sound system. This makes it difficult to know one when you hear one. When starting out, it helps to find someone who is experienced to expose you to a good sounding system. When you hear one, remember what it sounds like, and try to achieve that sound.
- It is a common temptation to boost the low bass frequencies. Generally this just wastes amplifier power and reduces the overall *headroom* (ability to get louder) of a system. A large portion of the speakers used for sound reinforcement do not respond below 40Hz, thus boosting these frequencies on the equalizer does no good.
- Equalize to a sound source you know, and that is similar to what the final sound system will be reproducing. If the system is just going to be reproducing voice, equalize to voices. Make them sound as understandable and clear as possible. If the system is going to be playing loud techno music, by all means, EQ to the latest *Prodigy* CD.
- If you've got the time, put some music in that you know well, and *play* with the equalizer. Get to know what the different frequency bands on the equalizer do to the sound. This will help immensely when trying to make a system sound good.

6.4.2 Compressors and Limiters

Quite frequently, microphones will be used in a theatre application. These mics may be on the actors, or elsewhere. One frustrating aspect of running sound for a show in cases like this is that often the volume level will not be loud enough at times and too loud at other times. This can be due to many factors, most of which involve the actors. This problem can be practically eliminated through the use of a device called a *compressor/limiter*.

A compressor/limiter reduces the *dynamic range* of an audio signal. Simply put, it makes quieter things louder, and louder things quieter. Several controls are available, such as attack and release times, threshold levels, and compression ratios. There are two main schools of setting compressor controls; one dictates that some calculations be made, while the other follows the "fiddle with it until it sounds good" methodology.

The calculation scheme is rarely used when the compressor is being used on an input such as a microphone. Since compressors/limiters can be placed on the output stages of sound boards, they are often used to protect the speakers and amplifiers from excessive peaks. Setting the compressor such that the sound may not rise above a certain level is fairly easy, and in this sense the compressor is merely acting as a limiter. However, finding the level that won't destroy the speakers isn't necessarily easy, as there are many factors to consider. This is where the calculations can come in. Needless to say, they are beyond the scope of this book. Consult the *Yamaha Sound Reinforcement Handbook* or a competent audio engineer for more details.

The best way to get a feel for how a compressor works is to hook one up and insert it on a microphone input on a sound board. Adjust the attack, release, threshold and ratio until the sound seems fairly natural. Try moving the microphone closer and farther away while speaking into it. With appropriate settings, the ill-effects of an person speaking quietly at one moment and yelling the next, or moving closer and farther away from the microphone can be reduced.

6.4.3 Noise Gates

Often equipment produces undesirable noise, or microphones pick up unwanted background noise. For instance, inexpensive computer sound cards emit a lot of hiss that is very noticable when the sound system is otherwise quiet. Also, microphones may pick up background noise that could prove to be distracting when played through a large sound system. These problems can be mostly eliminated by using devices known as *noise gates*.

A noise gate will not pass an audio signal through it unless it is above the *threshold level*, set by a knob on the front of the unit. Once the sound level rises above the level set by the threshold knob, the gate opens, allowing the input signal to pass through it. Additional controls adjust how quickly the gate opens and closes. Some gates do not actually shut off the sound, but they reduce it by some amount. These gates have an additional control to adjust how much reduction is used when the gate is closed.

Generally, a noise gate is inserted into a problem channel and adjusted such that the threshold level is set to be above the background noise. The end result is silence from the channel when there is just background noise from the input, and the normal signal when a level higher than the threshold is present.

6.4.4 Effects Processors

Special audio effects such as pitch shifting, reverberation, and delay are often desirable in a theatre application. Discrete reverb and delay units are common, but are often replaced with *effects processors* or *multi-effects units*, which can provide a number of audio effects in one box.

There is no standard type of effects processor. Each offer a different number of effects, different sound quality, and a different user interface. Some common effects are listed below:

- **Delay.** The audio signal is delayed by a certain period of time before it is played. Times from a few milliseconds to several seconds are common. Echo effects are commonly done with delays.
- **Reverb.** Reverb effects simulate room characteristics, and are often adjustable to simulate different sizes and types of rooms. Reverb is often confused with echo, but rest assured, it's different.
- **Flanging and Phasing.** Two effects that are difficult to describe, but most everyone has heard both. Both can be said to make a sound appear to "swish".
- **Pitch Shifting.** Pitch shifters increase or decrease the pitch of the sound. This effect, combined with others, is what gives *Darth Vader* his characteristic voice.

Effects processors can be used as inserts on channels or with aux sends. Aux sends are more commonly used because more than one channel can "share" an effect. Also it allows mixing of the wet and dry signals, which is very desirable in most cases.

Figure 6.8: A roadcase with several pieces of signal processing equipment, including a **dbx** compresser/limiter, a **Yamaha** effects processor, and a **Klark-Technic** graphic equalizer.

6.5 Output

The final and perhaps most important part of a sound system is the output section. Choosing the right components and using them properly is of paramount importance to the convincing reproduction of sound effects.

Most everyone is familiar with amplifiers and loudspeakers, as they are present in the consumer audio market. The equipment used for large sound reinforcement applications is similar to consumer gear in function, but is usually more durable and capable of producing much louder sound.

6.5.1 Power Amplifiers

The outputs of a sound board are typically line level signals which can not directly drive speakers. Thus, a *power amplifier* must be used between the outputs of a mixer and the speakers. Power amplifiers come in a variety of sizes, each with different capabilities and features.

Power amplifiers are functionally simple units. All amplifiers have a set of line-level inputs and a set of speaker-level outputs. Most have a power switch and volume controls as well. The outputs of a sound board are typically connected to the inputs on the amplifier, and speakers are connected to the speaker outputs. The job of the amplifier is to take the small line-level signal and boost it to the levels required to drive speakers. One characteristic of better amplifiers is that they more faithfully reproduce the small signal at the speaker outputs. Inexpensive amplifiers tend to *color* the sound by inaccurately reproducing the line-level signal at the speaker outputs.

One important rating for amplifiers is the amount of power they can supply, specified in *watts*. Given sufficiently capable speakers, the more power an amplifier can supply the louder the overall sound system can be before it begins to *distort*[2]. System distortion is not desirable as it sounds bad and can damage speakers. It is important to note that some low-end professional equipment, and quite a bit of consumer gear is improperly rated. Knowing that the general public tends to buy amplifiers based solely on the number of watts they can produce, some companies go out of their way to artificially bloat these figures. *Caveat emptor.*

The power rating for an amplifier is usually specified in terms of driving a certain *load*. The load (in most cases a speaker) has a characteristic *impedance*. Most speakers have an impedance of four or eight ohms, and not by accident, most amplifiers specify their ratings for four or eight ohm loads. It is important to pay attention to loading because it's possible to blow up an amplifier if it is not rated to handle the load being driven.

6.5.2 Speakers

The final element in a sound system is the loudspeaker. The purpose of the speaker is to convert an electrical representation of sound into mechanical vi-

[2]This is a gross oversimplification, but it is, for the most part, true.

brations. Many different types of speakers exist, making choosing the right one for the job a difficult task. Making the right choice involves balancing several factors including size, sound quality, efficiency and power handling.

A typical speaker is made up of several components. One or more *drivers* are mounted in a *cabinet*, generally made out of wood or plastic. There are many kinds of drivers, each suited to reproducing a particular range of sound. Bass drivers (often called *woofers*) reproduce low sounds. Midrange drivers reproduce the sound in the middle of the audible frequency spectrum. High-frequency drivers (usually called *tweeters*) reproduce the top end of the audible frequency spectrum. Some speakers contain two or three drivers that can respond over much of the audible frequency spectrum. These speakers are often called *full-range* speakers. Other designs exist in which indivual cabinets house drivers, but the whole speaker is not capable of reproducing the entire audible frequency range. For example, it is common to find two-cabinet speaker setups. One cabinet houses a tweeter and a mid-range driver, while a second cabinet houses a woofer.

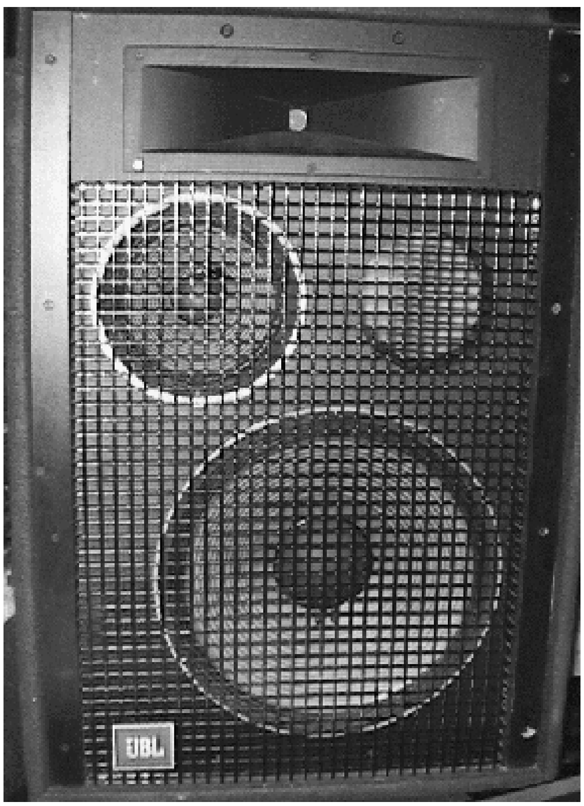

Figure 6.9: A 3-way full-range speaker, manufactured by **JBL**.

Speakers can range in size from a boxes a few inches a side to boxes and other shapes several feet per side. Generally cabinets that handle bass are larger than those that handle mid-range or high frequencies. High-powered mid-range and high drivers can be built into fairly small packages separate from bass units. Units such as this are becoming common in consumer audio, and have some application to theatre audio. These so-called *subwoofer/satellite systems* are ideal in some cases because they allow the relatively large bass cabinets to be hidden, as bass frequencies tend to be non-directional. The remaining satellite speakers are usually small enough to be mounted in convenient, inconspicuous locations. Schemes such as this are often preferred in theatre applications because having large unsightly speakers flanking a proscenium stage is typically not desirable. However, systems of this nature tend not to be able to produce incredible amounts of volume, and they often do not sound as good as other designs.

6.5.3 Crossovers

Most consumer speakers, and some low-end professional speakers have *passive crossovers* built in to them. These crossovers are responsible for taking the single full-spectrum signal from the amplifiers and sending the appropriate portion to each driver within a speaker. This assures that the woofer is only reproducing bass frequencies, the mid-range driver is reproducing only mids, and the tweeter is reproducing highs. However, passive crossovers aren't the most efficient devices in the world, and most high-end professional systems do not use them. Instead, they use devices called *active crossovers*, which do much of the same thing, but they do it on line-level signals, before the amplifier stage of a sound system.

With active crossovers, each amplifier is responsible for driving speakers only within a specific range of frequencies. This division of power, so to speak, makes for a more efficient system. The system can be driven to much higher volume levels, and will generally sound much clearer and more defined. Also, the levels sent to each of the drivers can be adjusted, which makes balancing the system easier than with systems with passive crossovers.

The practice of using an active crossover scheme in a system is known by several names, which depend on how many splits are being made in the audible frequency range. If the system is simply being broken into lows and highs, it is said to be *bi-amped*. If it is broken into low, mid and high, it is said to be *tri-amped*. Logically enough, if a system is broken into low, low-mid, high-mid and high, it is a *quad-amped* system. If a system with a passive crossover is used, the speakers are generally referred to as *two-way*, *three-way*, or *four-way*, respectively. The distinction is important. A tri-amped system requires an active crossover unit, three separate amplifiers, and speakers capable of having their drivers driven by separate inputs. A three-way system only requires one amplifier and speakers with built-in passive crossovers.

Active crossovers have several controls for adjusting their operating parameters. They provide a means to adjust the *crossover frequencies* – the frequency at which the sound will stop being reproduced by one driver and start being

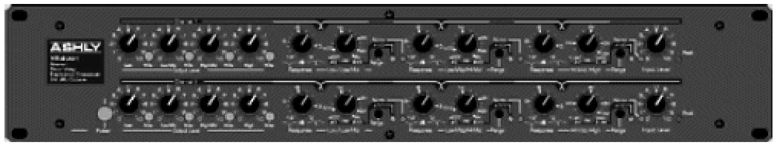

Figure 6.10: An active crossover unit, manufactured by *Ashly Audio, Inc.* Note the large number of controls on the unit, for controlling crossover frequency, slope, and volume levels.

reproduced by the next. This transition is not instantaneous. In fact, it is modeled as two intersecting slopes. These slopes are adjustable on most active crossovers, allowing a very gradual change between two drivers to a farly steep change. Setting a crossover requires knowledge of where the individual drivers of a speaker system are designed to cross over. This information is usually contained in the manuals for the speakers, and is sometimes printed on the back of the speakers themselves. Improperly set crossovers can, at best, make a sound system sound terrible, and at worst, destroy drivers.

6.6 Cabling and Connectors

Many different types of cables and connectors are used to connect the various components of an audio system together. Knowing the function of different types of cabling and connectors is important to successfully setting up a sound system.

6.6.1 Line-Level

Many different connectors and cables are used for line-level signals. All good line-level cabling is what is known as *shielded* cable. A braid or wrap of wire around a center conductor in a cable serves to help stop electrostatic and electromagnetic noise from entering the cable. Electromagnetic noise is emitted from several devices commonly found in a theatre situation, such as fluorescent lighting, lighting dimmers, and electric motors.

There are two types of line-level cables used in audio systems — *balanced* and *unbalanced*. Most consumer hi-fi equipment is unbalanced, meaning the signal is carried on only one wire of a cable. In an unbalanced cable, the shield is used as a return path for the signal, while the center conductor carries the signal. Most professional sound equipment offers balanced connections, which are carried on two wires of a cable. Each wire carries a copy of the audio signal, but one is at the opposite polarity than the other. Balanced cables are far less prone to picking up interference, thus their appearance on professional gear, where cable runs may exceed hundreds of feet.

A few types of connectors are used on cables to connect equipment together. The most common types are the *XLR cable* and the *1/4 inch phone plug*. Each can be used to carry balanced or unbalanced signals. Another type of connector sometimes used is the *RCA phono connector*. This connector is the standard used to interconnect consumer hi-fi gear, but is rarely found on professional equipment. RCA connectors can only carry unbalanced signals. Figure 6.11 shows the different types of audio connectors.

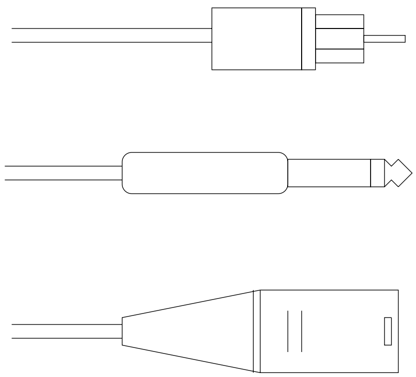

Figure 6.11: Various line-level audio connectors.

Cable that has a male XLR connector at one end and a female XLR at the other is most commonly referred to as *mic cable*, simply because that's what it's most often used for. Other variations exist, such as male XLR to male phone plug, female phone plug to male phono plug, etc. These types of cables are referred to as *adapters*, *converters*, or at WPI, *funnies*. Finding all of the appropriate cables to hook the line-level components of a system together can sometimes be a challenge, and one should feel some sense of accomplishment after doing so. Often finding the required cables is more of a challenge than actually hooking up the system!

Often times it is necessary to carry a large number of separate audio signals a substantial distance. While it is possible to run several lengths of individual cables, this is less than convenient. For this reason, *multicore snakes* have been developed that carry anywhere from a few to forty or more signals. These cables are essentially several individually shielded cables bundled together. Most snakes have one end that is a box with panel-mounted connectors, such as the one shown in figure 6.12. The other end is generally a mass of wires and connectors, and is called the *tail* end of the snake. The tails of a typical snake are shown in figure 6.13. Snakes are extremely useful for carrying signals from several microphones and other equipment located on a stage or remote location to a sound console.

6.6.2 Speaker-Level

There are many means for connecting speakers to amplifiers, some straightforward and others somewhat complex. Speaker cables are fairly heavy gauge

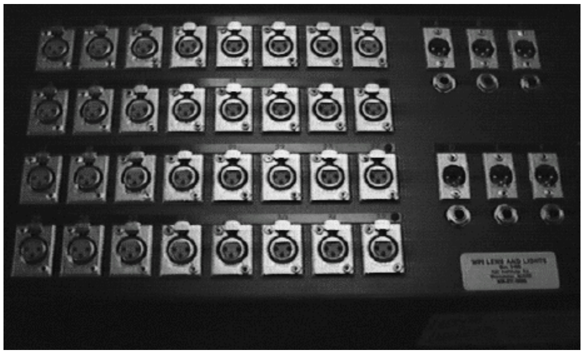

Figure 6.12: The box end of an audio snake. Thirty two XLR channels (typically used as inputs to a sound board) are available, as are six XLR/phone plug channels (often used as sends from the sound board). Typically this is the end placed on or near the stage.

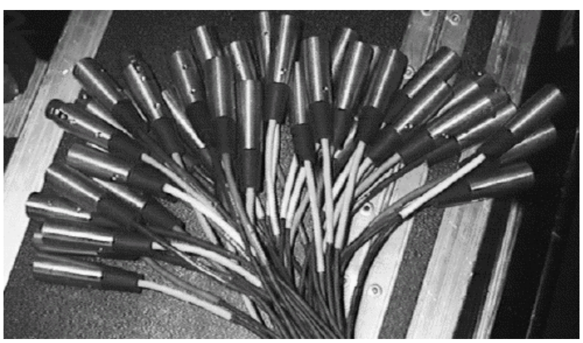

Figure 6.13: The tails of an audio snake. These connectors are typically connected to the inputs and outputs of a sound board.

unshielded cables. Eighteen gauge wire (commonly referred to as *lamp cord* or *zip cord*) is about the smallest speaker cable found in professional audio systems, while twelve or ten gauge is about the largest. Large cable is needed because of the high currents necessary to drive the speakers. Small cable can not adequately carry the signal to drive large speakers, and will significantly degrade performance if it is used.

Many types of connectors are used to hook speakers to amplifiers. Sometimes bare wire is used with *5-way binding posts* on the speakers and amplifiers. This scheme works reasonably well for permanent installations, but is impractical for portable systems that must be taken apart frequently. Phone plugs, often used for line-level signals, are also frequently found on speakers. Companies such as **Neutrik, Inc.** produce advanced locking multi-conductor speaker connectors. These types of connectors are ideal in bi-amped or tri-amped systems, where several individual speaker connections have to be made. Often racks of amplifiers and the speaker cabinets are outfitted with multi-conductor connectors such as **Neutrik Speak-On**s. A special multi-conductor speaker cable with mating **Speak-On** connectors is used to connect the speaker to the amplifier, making the process of connecting up a tri-amped system incredibly simple. These types of connectors are used at WPI on the school's largest sound reinforcement speakers. Other non-standard connectors such as *twist-locks* are used at WPI, because of availability and because of their locking characteristics. Figure 6.14 depicts the speaker connectors most commonly used at WPI.

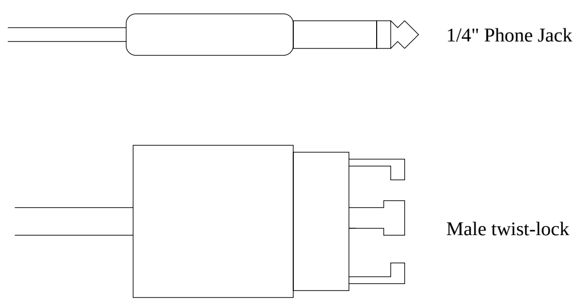

Figure 6.14: Commonly used speaker connectors. Twist-lock is rarely seen for audio use outside of WPI.

6.7 Automation

Large sound systems can become incredibly complex fairly quickly. A large number of input devices, effects gear, and other equipment can make running a large show difficult. In situations where multiple cues have to be run in rapid succession or simultaneously, it can become nearly impossible for a single operator to run the system. These types of situations are where some form of automation can help immensely.

Simple automation can be had by use of *MIDI* (Musical Instrument Digital Interface) to control effects. Most multi-effects units can be run via MIDI, allowing a simple way to control these units from a single control pad or a computer. Rather than having to set controls on a number of front panels, computer software can automatically send out the necessary commands to control the units.

Many productions require sound effects to be played back precisely on cue. In complex setups, sounds may be made to come out of any of a number of speakers independently, so as to add realism to the effect. Cueing the sound and controlling the mixing console to position the sound in sound-space becomes a formidable task. Integrated systems for cueing and mixing sound help incredibly in this area. Unfortunately, most systems are well out of the price range of most college theatres. However, a system the author has co-developed, called *SMsurround*, has brought forth an affordable and powerful automated sound system. Automated playback of digital sound effects from computer and digital sampler, cueing and playback of compact discs, automatic fades and fader "chases", and MIDI control of equipment are all possible with the system. The system was developed at WPI as an independent study project in the spring of 1995 and was used for two productions thus far. Unfortunately, the prototype of the system has several shortcomings which will be addressed in a complete revamping of the system, to take place in late 1996 and early 1997.

6.8 Design

While it is important to know how to use the individual components of a sound system, it is very important to know how to design an entire sound system for a particular show. When working in a theatre environment, it is also very important to know how to create sound effects that complement the production.

The nature of the effects dictate the type of sound system needed. For example, if mostly quiet, ambient effects are needed, a huge concert-sized sound reinforcement system is not needed. Conversely, if explosions are supposed to shake the seats of the audience, a tiny pair of speakers will not do the job well. Ideally, one designs and creates the sounds to fit the play, and the sound system to fit the nature of the sound effects.

6.8.1 Creating and Obtaining Effects

One of the first things an audio designer does is to sit down with the production design staff and determines what effects the production needs. Many plays and musicals include lists of suggested sounds. This usually provides a good starting point for the audio designer.

Once the type of effects have been determined, it is generally up to the audio designer to acquire or create these effects. Many commercial sources of sound effects are available, generally in compact disc or computer CD-ROM format. Additionally the Internet and the World Wide Web are excellent resources for sounds. In all cases, attention should be paid to copyright information, as some sound effects sources do not provide rights for public performance.

In cases where effects can not be found in pre-recorded format, they generally have to be created. Often a natural effect can simply be recorded from the source using a microphone and recording device. Sometimes effects require a scene to be staged and recorded, such as a rally. It is very important to remain creative when creating effects, as it is often something out-of-the-ordinary that will produce the desired effect.

6.8.2 Editing and Processing Effects

Once the basic sound effects have been acquired, they often need to be edited to suit the particular production. For example, some effects may be too long and need to be shortened, while others may need to be processed to have different tonal qualities than the original. Computer-based digital audio editing software and sound cards provide a set of extremely powerful tools for the audio designer. Commonly available digital audio editing tools are only now becoming mainstream, and are still not being used to their full potential in many settings.

Unless the original sound effects are already in digital format on a computer, they need to be *digitized* (sometimes called *sampled*) into the computer. Most sound cards have audio inputs, and can sample sound at CD-quality or better. Once the sounds are sampled, they are usually saved on the computer's hard disk. The most common format for saving digital audio on computers is the *Microsoft .WAV* format. Because of this, sampled files are often called WAV (pronounced 'wave') files.

Most sound cards come with simple software for editing audio files. Third-party companies such as **Sonic Foundry, Inc.** produce comprehensive packages that provide many more features than the software shipped with cards. Packages such as **Sound Forge** provide features such as equalization, fading, panning, reversing, slowing down or speeding up, pitch changing, delay, reverb, flanging, etc. They also allow the content of the sound to be edited, allowing for words to be rearranged in a speech or sounds to be strung together, such as an explosion following a gunshot. Learning to use audio editing software is one of the most useful things an audio designer can do, as it affords flexibility and power that were not possible until recently.

Once the sound effects have been edited and are to the satisfaction of both the audio designer and director of the production, they can be cued directly off of computer or burned onto a compact disc. Consolidating the effects to a single media is desired, as it makes the audio operator's job much easier when running the sound for a production. It is much easier to cue all of the sound effects off of a CD than it is to cue some off of CD, some off of tape, and still more off of a computer.

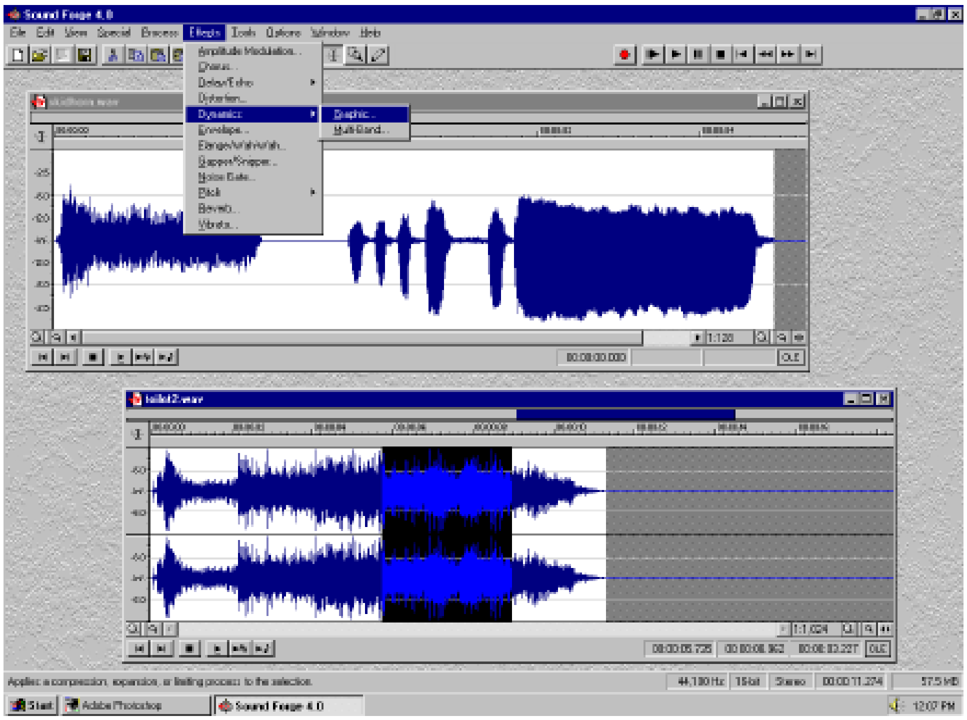

Figure 6.15: **Sound Forge 4.0**, digital audio editing software by **Sonic Foundry, Inc.** Software such as this allows quick and easy editing of digitally-stored sound effects.

6.8.3 Designing the Sound System

As previously mentioned, designing the sound system is usually part of the audio designer's job. The goal of designing the sound system is to choose components that will aid in reproducing the sound at acceptible volume and quality levels, while affording all of the control needed to run the show in real-time.

The Input Section

The inputs to a sound system will vary from production to production. Productions can demand a wide variety of components such as wireless body microphones for key actors, offstage microphones for "disembodied voice" effects, CD players for music, a computer or digital sampler for effects playback, etc. Once all of the sounds have been gathered and discussions have been had with the production design team, the audio designer should have a reasonably good idea about what types of inputs are needed.

The choice of CD player generally matters little, as even the cheapest produce reasonably good sound. Better models allow programming and auto-cue features, which make running a show manually off of a CD player much easier. Try to choose a model with so-called "direct access" features that allow any track to be called up by typing its number, rather than having to skip through all tracks to reach a later track. Standard consumer CD players generally have these features and will do the job nicely. In cases where computer automation is being used, computer-based CD-ROM drives are often used in place of discrete CD players. Some automation packages, such as *SMsurround*, can support an unlimited number of individual and multi-disc CD-ROM drives, making the audio operator's job very easy if many CDs need to be dealt with.

The choice of standard microphones for vocals is largely a subjective matter. Different microphones have different characteristics and will make people sound different. When in doubt, the old standby, the **Shure SM-58** will usually do the job well. Smoother response can be had when working with female voices if a microphone such as the **Beyerdynamic M-88** is used, but this is quite subjective. If wireless microphones are to be used, they should be the *true-diversity* type as they are much less susceptible to interference. The design should place the wireless receivers as close to where they will be used as possible, and as far away from other electrical equipment as possible.

In situations where a computer or sampler are to be used, there are numerous choices to be made. Often what is used is simply what is available. It should be noted that inexpensive computer sound cards will yield less-than-satisfactory results, as they have a tendency to produce a lot of hiss and distorted sound. Generally, as the cost of a sound card increases, it can generally be expected that the sound quality will increase as well. Digital samplers are available with many different features and sound qualities. If a sampler is going to be used for a show, the audio design should specify what type of sampler, or at the very least what sorts of features are needed.

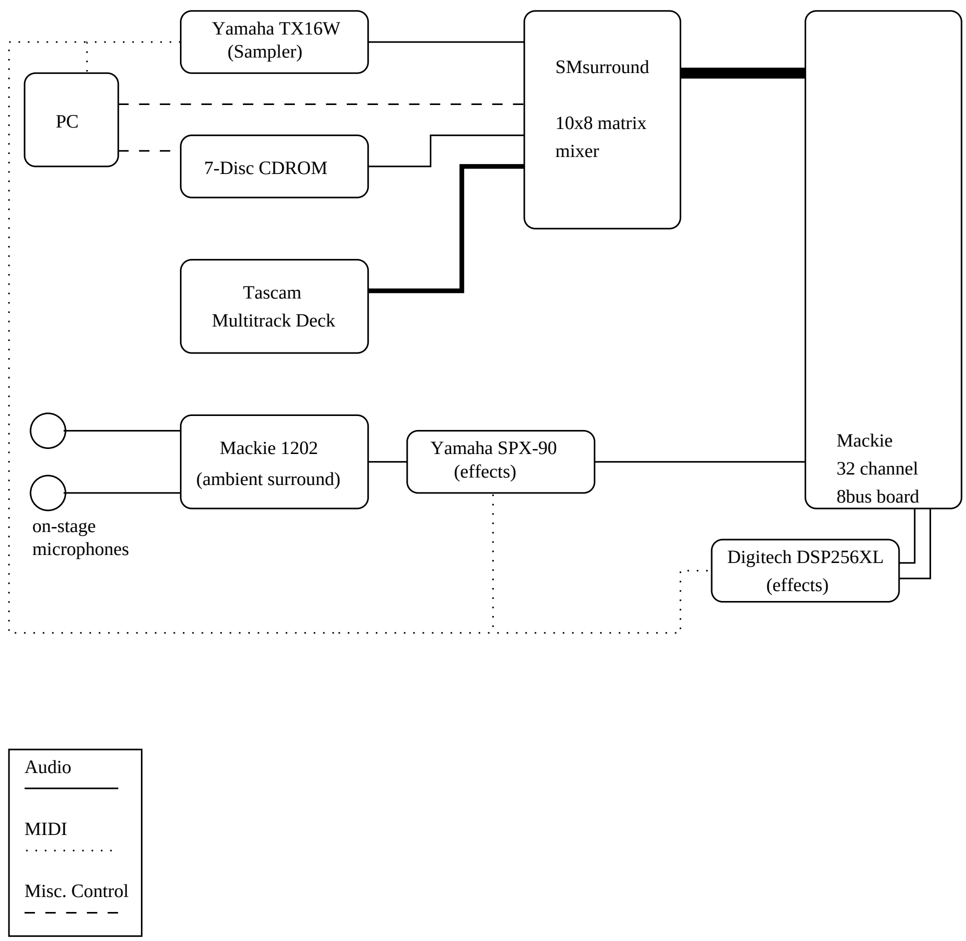

Figure 6.16: A diagram of the input section of the audio system for the 1995 WPI Masque production of *King Henry V*, designed by the author.

Signal Processing

Many productions have been run using very little signal processing equipment. Often all that is used is an equalizer to EQ for the speakers and the room. However, other pieces of processing gear can be used to improve the overall quality of sound or to produce interesting effects.

As mentioned earlier, compressor/limiters are very useful for microphone inputs. They can help provide a more consistent volume level without making the job of the audio operator any more difficult. They can also be used to help protect the sound system from any transients, such as from the sound of someone dropping a microphone.

Multi-effects units can be used to deepen, echo or reverb an actor's voice. This can be useful for certain productions that call for such effects. Also, reverbs and room simulators can be used with general pickup microphones on a stage to provide a room ambience sound[3]. It is important, though, to not over-use effects — unless, of course, that is the desired effect.

The Output Section

Choosing the speakers and amplifiers for a production can be a daunting task. However, some general guidelines can make the job a lot easier. Firstly, don't over-design the system. If the system is only going to be playing crickets chirping for two hours, the largest most incredible bass drivers are not going to help one bit. However, if very loud effects that are intented to scare the audience and shake their seats are needed, a single pair of studio monitors isn't going to do the job.

A good place to start is determining the nature of the sound to be reproduced. Determine if they're to be reproduced very loudly or if they're quiet and more in the background. Next, determine if any sort of multi-channel scheme is going to be used. Many successful systems have been run in *mono* (single channel), but don't discount the interesting possibilities of a multi-channel system. Systems with up to eight discrete channels have been used at WPI with relative success. Having discrete channels means that speakers can be located at various positions in the hall or on stage, with the ability to have sound effects come only out of individual speakers or combinations of speakers. This can make sound appear to come from different locations.

Once these decisions have been made, speakers should be chosen. If mostly quiet effects need to be reproduced, small speakers such as the **Bose 101** or the **JBL Control-1** can be used. These speakers are small and easy to mount in various locations. They sound decent for their size, but don't reproduce bass frequencies particularly well because they are small. If very loud sound effects are desired, larger speakers should be used. Two-way and three-way speakers by **JBL** and other companies work reasonably well for a medium to large sound system, while large concert stacks manufactured by **EAW** and several other

[3]As described in a project by R. Rubinstein and T. Guyette, and implemented in the 1995 WPI Masque production of Shakespeare's *King Henry V*.

companies work well for very large sound systems. Often components can be mixed and matched with good results, especially in a multi-channel system. For example, a set of medium-sized 3-way speakers can be used as the main sources of sound, supplemented with a couple pairs of small speakers for *surround* channels. Additionally, the bass units from a large concert rig may be used as modules to enhance the bass response of the entire system.

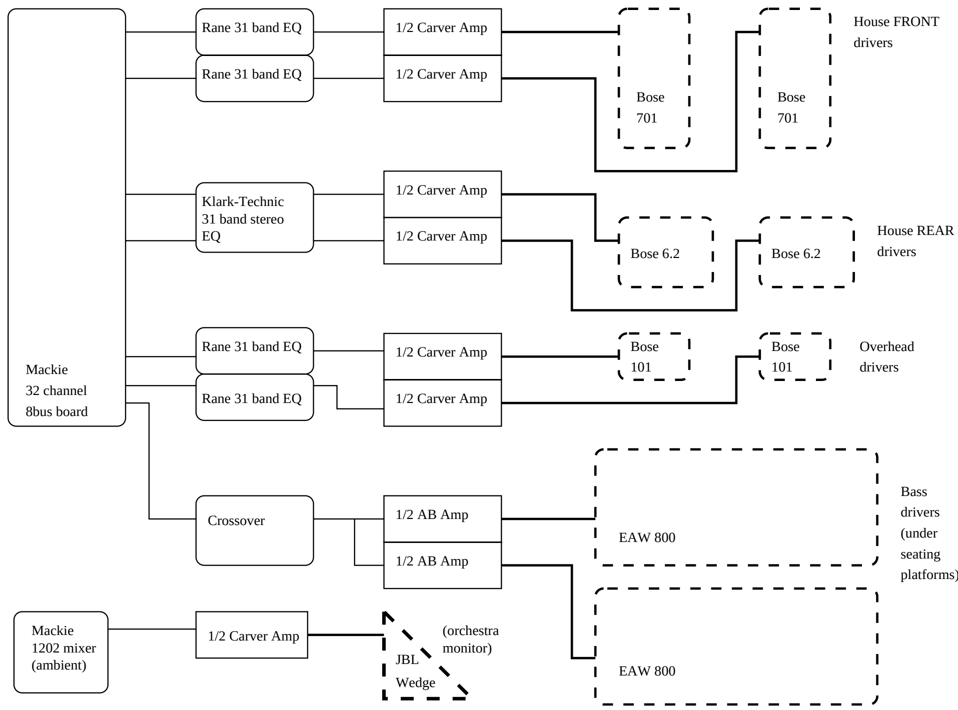

Figure 6.17: A diagram of the output section of the audio system, designed by the author for the 1995 WPI Masque production of *King Henry V*.

Once the particular types of speakers have been chosen, their locations need to be specified. Speaker placement is largely dependent on several factors such as speaker design, how the audience seating is arranged, etc. Factors such as *directionality* and *dispersion* of the speakers should be taken into account. The physics of speaker placement are fairly complex, and will not be discussed in detail here. In general, though, the overall goal is to make everyone sitting in the audience hear the sound effects and/or music and not lose the voices of the actors on the stage.

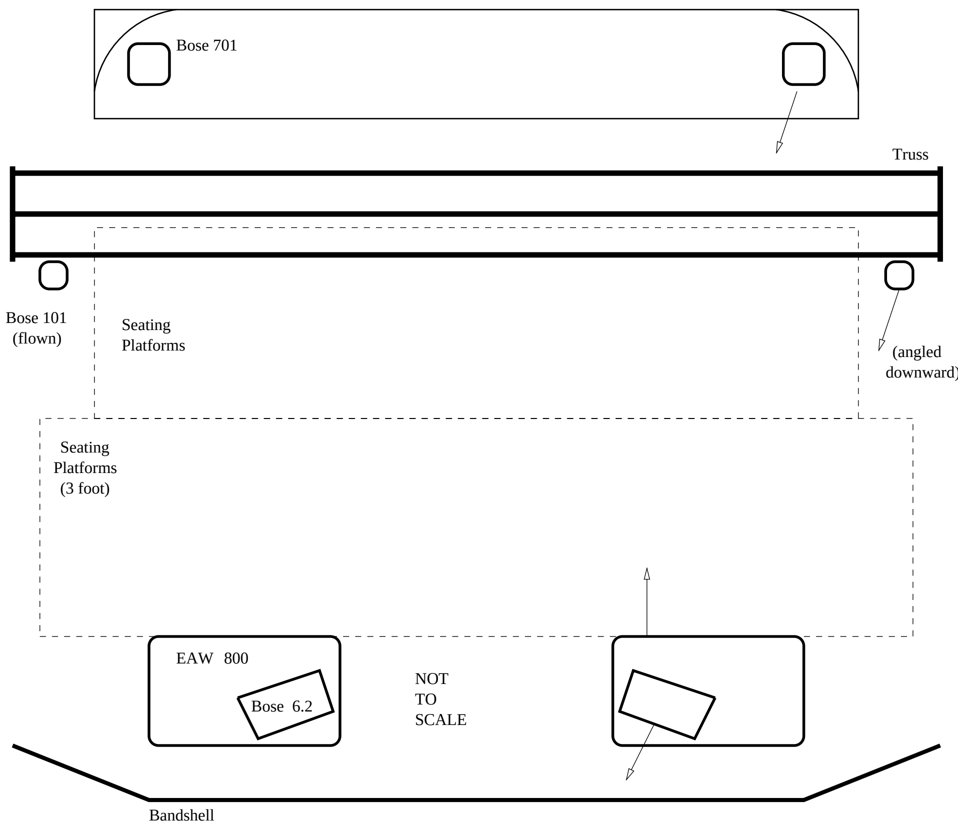

Figure 6.18: A plot of the speaker setup for the 1995 WPI Masque production of *King Henry V*, designed by the author.

6.9 A Typical Audio Setup at WPI

This assumes knowledge of how to properly use much of the audio equipment discussed in this chapter. This is not the *only* way this can be done, it is just a suggested setup method.

- Retrieve speakers, amplifiers, cables, mixing boards, and other equipment from storage, as per the audio design.
- Set up the mixing board and other equipment in a temporary location. Wire everything as per audio design.
- Run snakes and other cabling as necessary.
- Connect audio amplifiers to source (mixing board and EQs, typically).
- Arrange speakers as per the audio design.
- Connect speaker cabling to speakers and amplifiers. Test every element of the speaker/amplifier system to be sure it is working properly.
- Connect any microphones that are to be used for the performance. If wireless mics are being used, have assistants wear them and walk around the acting space with them.
- Begin equalization processs. Reposition speakers if necessary. Repeat until feedback problems are eliminated, and sound is satisfactory.
- Move mixing board and other equipment to permanent location.
- Re-connect equipment, test.
- As the house fills up, slight changes in equalization will be necessary or desired. It helps to have a qualified assistant sit in the house to make judgements, especially if the equalizers and mixing board are located in a remote location, such as in the balcony of the hall.

Chapter 7

Power

"I've got my priorities straight. Coffee before power, muffins before DMX." – Nathan Towne-Smith, WPI Theatre Tech major.

Figure 7.1: Safe and adequate sources of electrical power are necessary in the modern theatre. There are dozens of electrical devices used for a typical theatre production, each of which requires an appropriate source of power for proper operation.

7.1 Introduction

Dozens of electrical devices are used in the modern theatre. Everything from lighting and sound equipment to the tools required to build a set require a reliable, safe source of power to operate. Knowing how to appropriately connect to a venue's power source is important to ensure that the equipment operates properly, and to see that nobody gets a lethal electrical shock during the course of a production.

7.2 Basic Theory

While it is well beyond the scope of this book to provide a full description of electrical engineering theory, there are several basic facts that should be understood by anyone working with electrical power. Note that this is an *extremely* simplified coverage of the topic, and that there are hundreds of books written about each of the topics discussed.

First, the most common *voltages* worked with are 110 and 220 volts, *alternating current*. *Currents* anywhere from a few milliamperes to hundreds of amps are used. Additionally, one, two and three *phase* power is used to run a variety of devices.

Alternating current is sinusoidal in nature, unlike the "flat" direct current provided by batteries. The current changes direction a given number of times a second, which, in the case of standard U.S. power , is 60 times a second.

Multiple phases of power are made up of several sinusoids, each "aligned" slightly differently with respect to time. That is to say, they are out of phase with respect to each other. This difference in phase can be used by efficient electrical motors, or ignored, as is the case much of the time when used for lighting or audio.

7.3 Power Feeds

Different theatres provide different means for connecting equipment to be powered. Some simply provide a large number of standard *edison* style connectors, the same type used in homes. Others provide high-current (200 amps or greater) hookups, such as *Cam-Lok* type connectors, as shown in figure 7.2. Often some medium-capacity feeds are available, such as the *MDS* style feed. These medium-capacity hookups usually supply less than 100 amps, and are generally one or two phase. The type of hookup available in a venue dictates what type of equipment can be connected. Venues with high-current hookups can support portable lighting dimmers, large audio systems, and more. Venues with less capable hookups generally can not support large racks of dimmers or large audio systems.

Many venues provide some sort of combination of high-current and low-current hookups. WPI's Alden Hall is a prime example of this. The power panel in Alden Hall, shown in figure 7.3, provides a 200 ampere three-phase

Figure 7.2: Cam-Lok power connectors, often used to connect equipment to a venue's power feed. Cam-loks can carry very large amounts of current and provide a locking mechanism so the connectors will not come apart under normal conditions. Note the color-coded boots, used to differentiate between ground (green), neutral (white), and the three hot phases (black, red, blue).

Cam-Lok feed, a 120 ampere two-phase *MDS* connection, as well as several 15 to 20 ampere edison and twist-lock outlets. The Alden house dimmer system, stage power outlets, and flown strip lights are also powered from this panel.

Any venue that has been properly wired by a qualified electrician will have a *circuit breaker panel* that are used to shut circuits off in the event that they draw too much current. It is the current capacity of circuit breaker (in amperes) that determines how much current a circuit can supply. The breaker size is chosen relative to the type of cabling and connector used for the circuit, as each have different capacities. Circuit breaker panels provide a convenient means for manually turning circuits on and off. This can be a convenience and a safety feature, as it is much safer to connect power when the circuit is not live. For this reason, many larger feeds will have externally accessible power switches, as in the case of the Cam-Lok feed in Alden Hall at WPI.

7.4 Power Distribution Boxes

A given theatre production will often call for many types of devices to be connected to the power source. Some of these devices, such as dimmer racks, are usually fitted with high-capacity power connectors such as Cam-Loks. This makes sense, as a rack of dimmers has the potential to draw a large amount of current. However, other devices such as small dimmer modules, chain motors (used for lifting lighting trusses and speakers), audio amplifiers, and other equipment tend not to connect directly to Cam-Loks. This is where *power distribution boxes* (*distros*) come in handy.

A distro takes a high-capacity or medium-capacity power feed and splits it into several lower-capacity feeds. For example, distros that have have three-phase Cam-Loks for inputs and several edison, twist-lock, and other types of out-

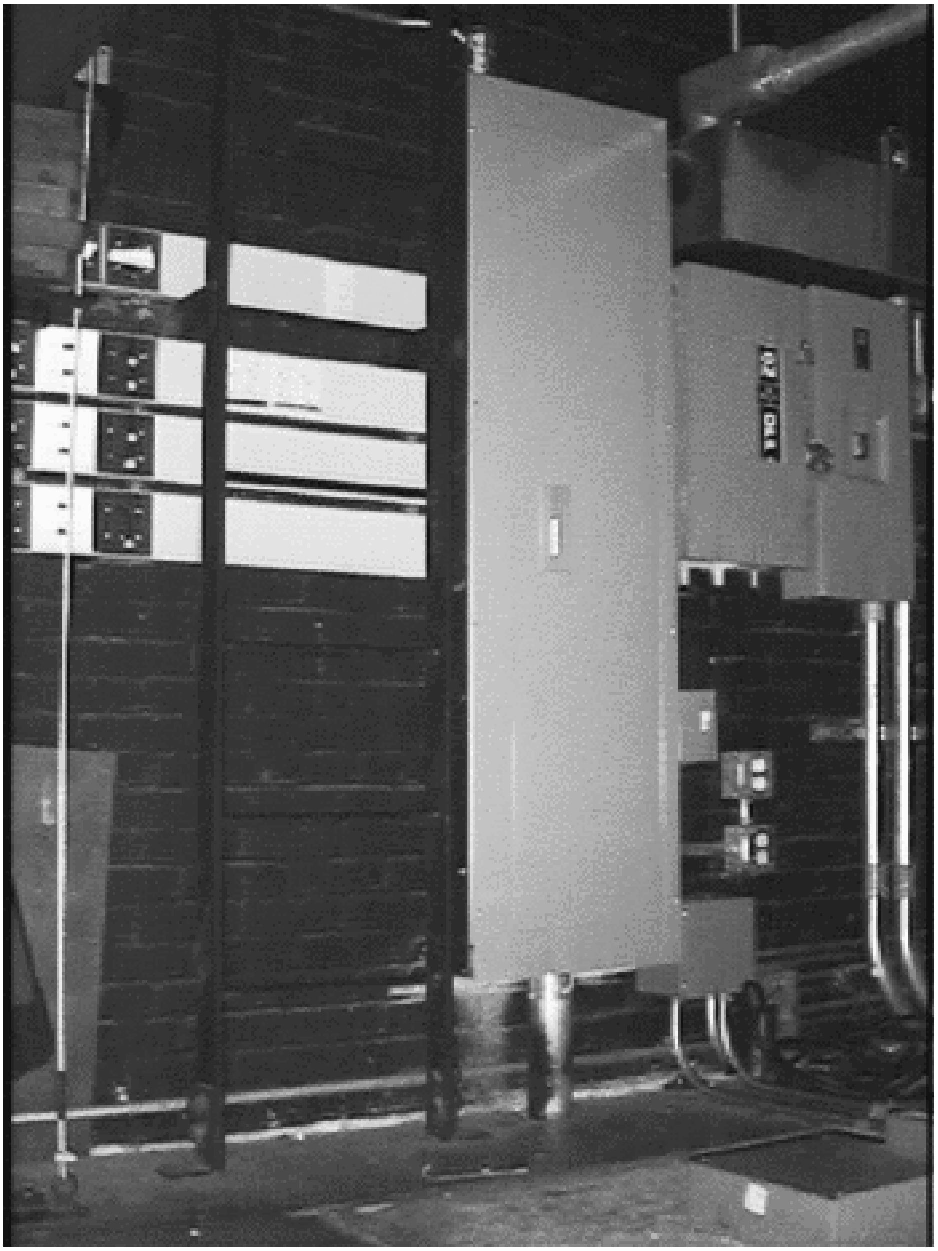

Figure 7.3: The power panel in WPI's Alden Hall. Several different types of power feeds are available from this panel.

puts are frequently found. Sometimes larger distros will have medium-capacity feeds on them, such as MDS connectors.

Most distros provide circuit breakers, much like permanent power panels. These are to protect from current overload on the low-capacity circuits. Again, they also provide convenient switches for enabling and disabling circuits, which can be very useful for safety at times. It is common practice to disable circuit breakers for dangerous equipment such as chain motors when the equipment is not being used. When a lock is applied to the front cover of the distro it makes it difficult for those who are not authorized to use equipment.

7.5 Power Protection

Modern lighting boards, computers, and other equipment are very sensitive devices. Interference or fluctuations in the power supplied to these devices can cause crashes of computers and lighting boards, and in some cases permanent damage. Thus, it is desirable to use some sort of protection on the power line when plugging in these devices.

Most people are familiar with the concept of a surge suppresor for computers and other equipment. Regular, inexpensive surge suppressing power strips can be used to provide a degree of protection for connected equipment. However, more expensive devices that provide more protection and filtering of the power line are available. These devices often come in rack-mount cases and provide several outlets for the connection of equipment. Some models even include a line voltage and current indicators that can be useful when connecting to an unfamiliar power source. These indicators can show faults on the power line before the first equipment is even turned on. One such power protection device is shown in figure 7.6.

Often times, even expensive power line conditioners are not enough protection. This is especially true in cases where computers and computerized lighting boards are used. Having the power go out when working on computer-based equipment can be frustrating, and can often result in lost data, not to mention time.

Because of this, battery backup units called *Uninterruptable Power Supplies* (*UPSs*) have been developed. UPSs continue to provide A.C. power for a period of time in the event of a power failure, through the use of a battery and an inverter. UPSs with different capacities are available, with the largest affording extremely long run times for equipment. Whenever possible, UPSs should be used to run computer-based equipment, to prevent the inevitable situation of losing data because a power cord was tripped over and unplugged!

7.6 Important Considerations

There are several important points that should be taken into account when connecting power to equipment.

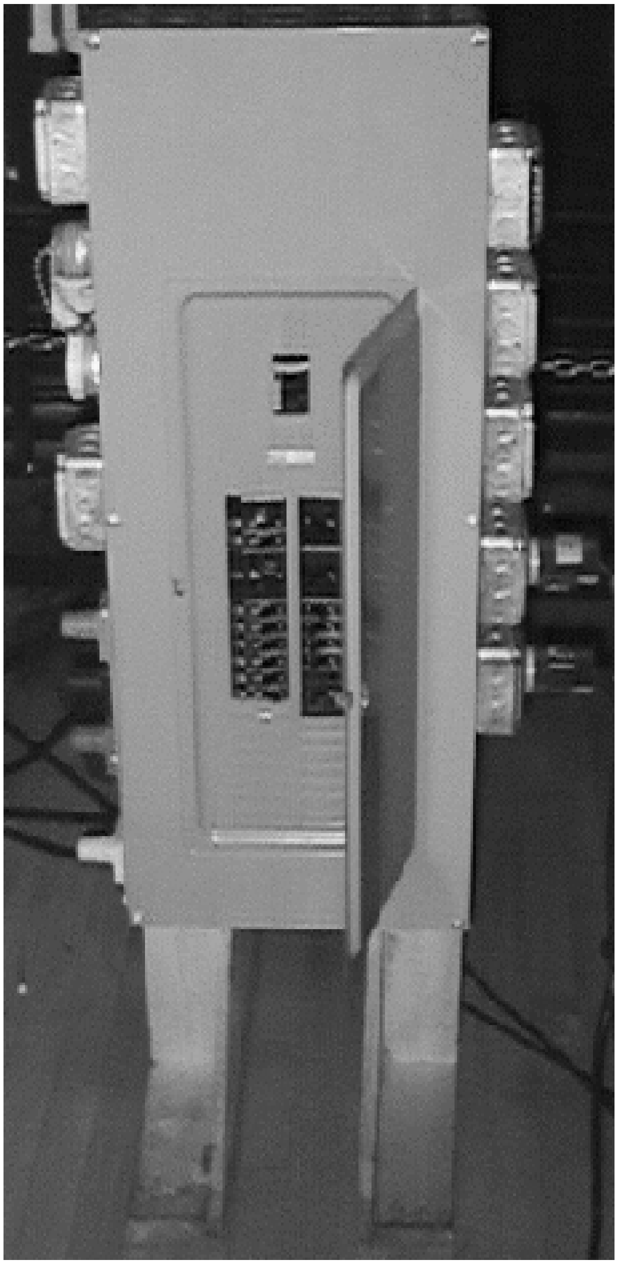

Figure 7.4: A power distro with several types of outputs. Three phase Cam-Lok connectors feed the tap. Several circuits are wired from these, providing single-phase twist, edison and MDS circuits as well as three-phase twist-lock circuits.

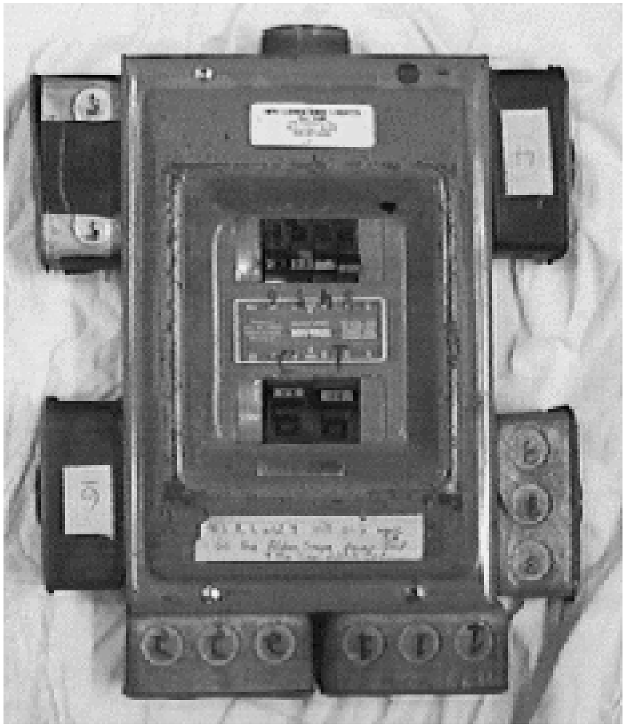

Figure 7.5: A small power distro fed by an MDS feed. One phase provides about 60 amps of current, divided into several edison and twist-lock circuits.

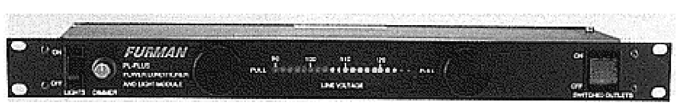

Figure 7.6: A power protection device manufactured by **Furman, Inc.** Devices such as this provide several outlets filtered from EMI and RFI interference.

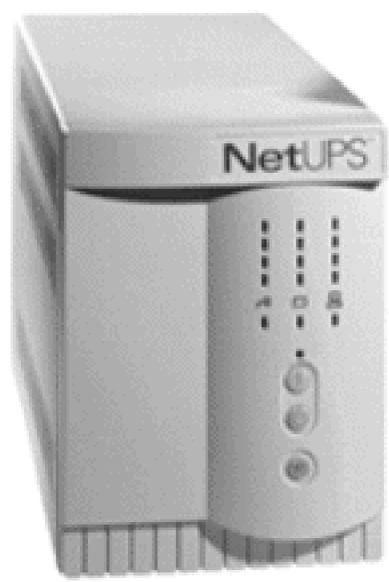

Figure 7.7: An uninterruptable power supply, manufactured by **Exide/Yuasa Corporation**. UPSs provide protection to devices connected to them by keeping them powered in the event of a loss of power.

In an audio system, all devices should be connected to the same ground at the same point. This helps eliminate *ground loops*, a problem caused by different ground levels on different circuits. The problem usually manifests itself as hum in the audio system, but can cause several other problems, some of which can cause people to receive shocks in some cases. For this reason, the amplifiers, sound board, and all other audio equipment need to be grounded at the same point. Ideally, all audio devices are run off of a dedicated distro, solving power ground loop problems. This often means that a long extension cord will have to be run to the remote sound board and equipment, but this is a small price to pay for a clean sounding audio system. Additionally, never connect audio equipment to the same circuit as lighting equipment. Disregarding this recommendation can result in a lot of spurious noise in the audio system, and also can potentially damage sensitive audio equipment.

With lighting systems, it is very important not to plug lighting boards into the same circuit that the dimmers are connected to. Dimmers emit a lot of electrical noise back onto the power line that they are connected to, which can cause lighting boards and other sensitive equipment to have all kinds of problems. A separate circuit should be used for the lighting board. This circuit need not be on the same ground as the dimmers, but it never hurts to go out of the way to make it on the same ground.

Chapter 8

Special Effects

"Effects are illusion and illusion is trickery." – Richard Pilbrow, author of *Stage Lighting*.

Figure 8.1: A scene from the 1995 WPI Masque production of Shakespeare's *King Henry V*. The production made use of dry ice fog and other effects to give the battle scenes a surrealistic feeling.

8.1 Introduction

Sometimes lighting and audio effects alone can not create a desired mood or feeling for a part of a production. Sometimes something a little more spectacular or out-of-the-ordinary is desired. In these cases, special effects can be used.

There are many types of special effects with a wide range of complexities and costs. This chapter will, by no means, cover all types of special effects, but will instead discuss some of the more common ones.

8.2 Animated Costuming

In some productions, very elaborate costumes can be assembled that have animated or moving parts. For example, in the 1994 WPI Masque production of Shakespeare's *A Midsummer Night's Dream*, an animated donkey head for the character of Bottom was created. The head features moving eyelids and ears. To control the head, a radio control scheme was used. Small servo motors inside of the head were connected to the various pieces of the costume. A radio controlled receiver and servo controller inside of the head was used to drive the motors. A hand-held remote control unit was used by an off-stage puppeteer to control the motions of the head while the actor performed her lines.

Many variations on the theme can be implemented. Ideally, a complicated effect like this is conceived and constructed in a collaborative effort. For the best results, a balance between artistic and technical talents should be struck. An animated costume is of no use if it doesn't look good, and the animation mechanisms will not work will if they are not designed and constructed well. Figure 8.2 shows the skeleton and inside of the aforementioned costume head.

8.3 Smoke and Fog

Many productions can benefit from the use of artificially generated smoke. The effect is commonly used in fire scenes, as it can add a lot of realism to a scene.

Commercially available machines are available that use a chemical fluid to generate smoke. The fog fluid is generally made out of glycol and water, making it relatively non-irritating and safe for use in a theatre setting. Machines are available with remote controls that allow smoke to be discharged with the push of a button. Also, most remotes allow control of the volume of smoke discharged. A typical smoke machine is show in figure 8.3

The smoke produced by most commercial smoke machines tends to diffuse relatively quickly. For a more low-lying fog effect, *fog machines* are often used. These machines use *dry ice*, which is solidified carbon dioxide, due to an extremely low temperature. The machines are fairly simple in construction. A large drum holds water which is heated by an electric heating element. At the top of the drum, a basket holds chunks of dry ice. This basket can be lowered into the water with an external control. The top of the drum is sealed, save for an exit point for a large hose. When the basket is lowered into the water, the

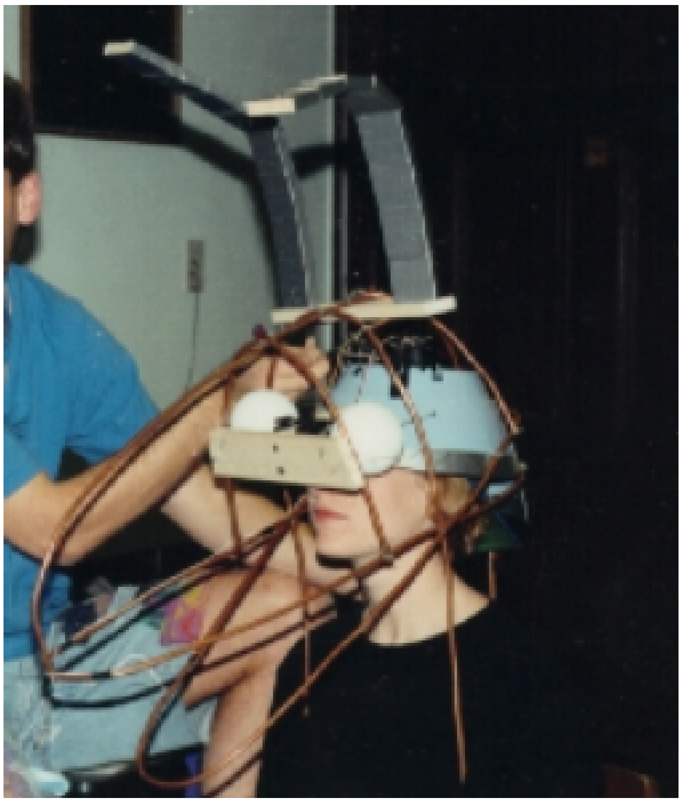

Figure 8.2: The skeleton of an animated costume head, designed and built for the 1994 WPI Masque production of *A Midsummer Night's Dream*.

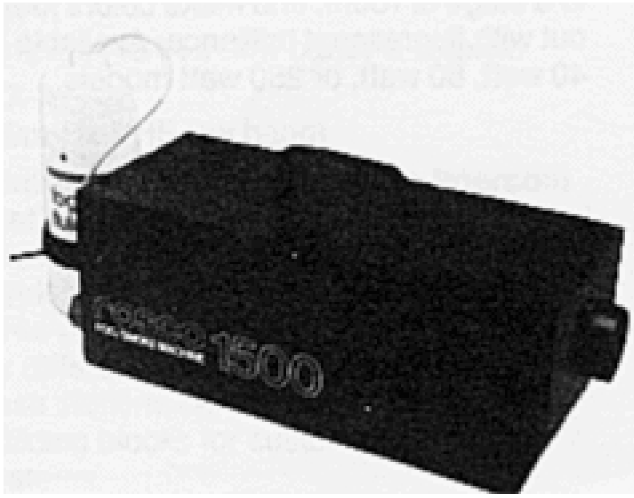

Figure 8.3: A **Rosco Laboratories, Inc.** smoke machine. WPI owns a model similar to this.

dry ice sublimes, and a thick, white carbon dioxide fog is formed. This fog is heavier than air, so it tends to hug the ground as it comes out of the hose. Fog machines produce a very believable effect, and the fog produced is completely harmless. Figure 8.4 shows a typical dry ice fog machine.

Often both smoke and fog are used together to produce a very interesting effect. As usual, it is important to not over-use either effect, as they tend to lose their impact the more that they are used.

8.4 Pyrotechnics

Another class of effects that can be effectively applied to theatre is *pyrotechnics*. Explosions, flashes of light, sparkling effects, and puffs of smoke are all possible to achieve using pyrotechnics.

Any pyrotechnic device used in a theatre setting is *electrically triggered*. Devices called *electric matches* are used to ignite whatever type of pyrotechnic material is being used. Pyrotechnic material is placed in *pots*, which are bases with very strong metal walls to hold the pyrotechnic material, and hookups for electric matches. They also have a connection for the *pyrotechnic ignition control* box, which is a special controller used to set off the effects.

Two main types of pots exist. One type is for flash-style effects, where a large flash of light and a puff of smoke are produced. These pots tend to have a very wide top so that pressure can not build up and cause an explosion. Figure 8.5 shows a typical flash pot. The other type of pot is the *concussion pot*, which differs from the flash pot in regards to the shape of the pot. It is typically a narrow, thick-walled tube that tends to allow pressure to build up such that a

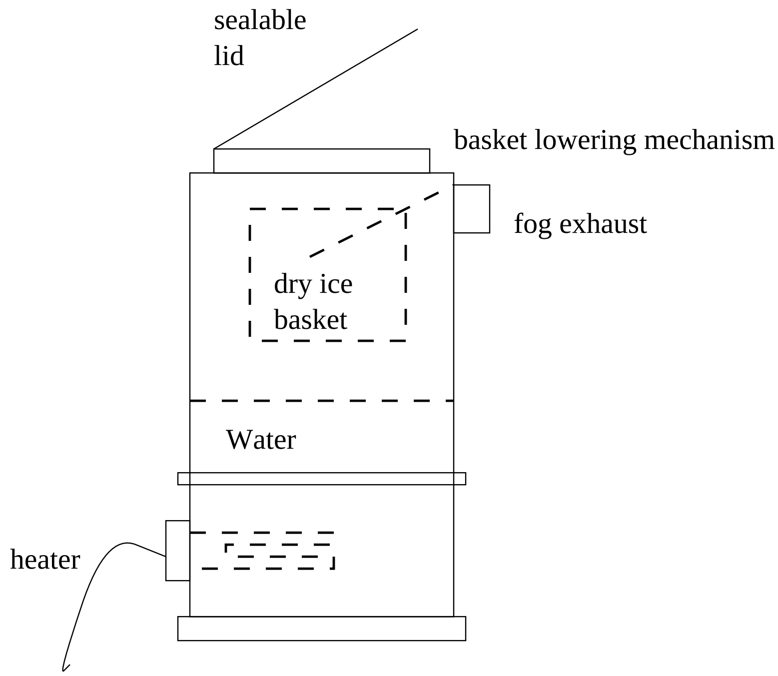

Figure 8.4: A typical dry ice fog machine. Two similar foggers are owned by WPI, and often used in theatre productions.

concussive sound will be created when material is ignited in it. Figure 8.6 shows a typical concussion pot.

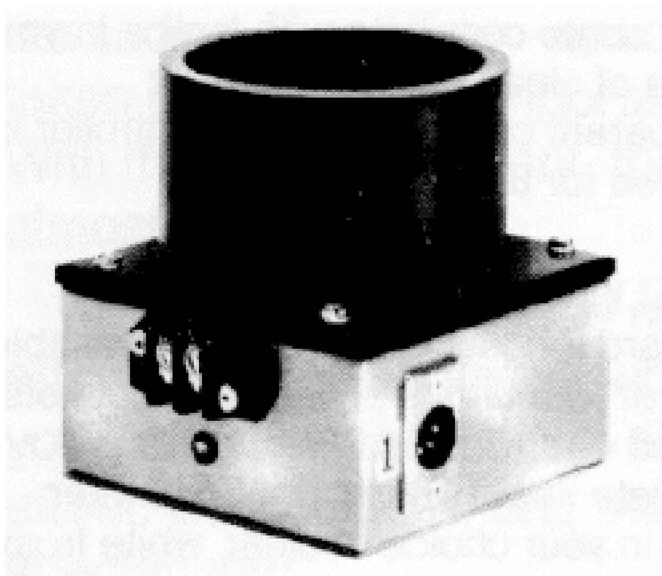

Figure 8.5: A *flash pot*, a device used to contain a pyrotechnic effect. The effect produces a flash of light and a large puff of smoke.

Special chemical compounds are used for each pyrotechnic effect. These compounds are purchased from theatre supply houses, generally an an *A/B mixture*. This means that the materials are shipped such that they are not capable of being ignited until mixed together. Once the materials are mixed, the pyrotechnic compound is considered *live*, and treated with the same care as gunpowder. **These compounds should not be stored live!** Mix only as much as is necessary for a given performance. Mix it at the beginning of each performance, and discard any leftover material by following the disposal directions on the packaging. Appropriate chemical fire extinguishers should be present on both wings of a stage, should a small fire start due to pyrotechnics.

Pyrotechnics are among the most dangerous effects used on stage. The potential exists for people to get badly hurt, sets to catch on fire, or any of a number of other unpleasant things. For this reason, they must be used with *extreme* care. It is imperative that no flammable materials are within the vicinity of a pyrotechnic device when it is set off — this means actors, curtains, the set, etc. It is common practice to locate the *pyrotechnician* (person in charge of assembling and igniting the pyrotechnic effects) in one of the wings of the stage so that they have a clear view of the pyrotechnic devices before deciding to fire them. It is important to keep in mind that if the pyrotechnician judges that it would be unsafe to fire a device, the resulting missed cue is lot better than a potential fire!

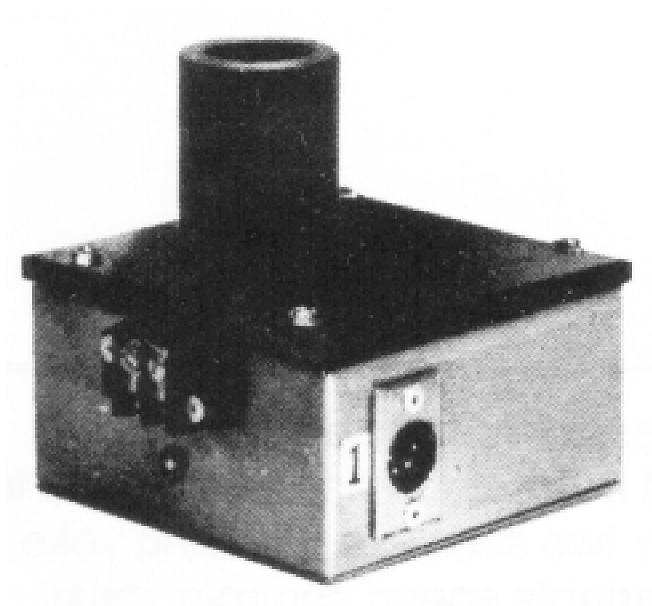

Figure 8.6: A *concussion pot*, another device used to set off pyrotechnic effects. Concussion pots produce a loud explosion and a small amount of smoke, making them most useful for simulating a loud cannon fire or something similar.

Many states and cities require that pyrotechnicians be licensed before they can legally use pyrotechnics on stage. Even without this requirement, a safety-minded, conscientious and sane person should be chosen as the pyrotechnician.

Appendix A

Acknowledgements

This book would not have been possible if it were not for the help of several individuals and organizations. I can't thank these folks enough for the help they have given me:

- Sarah Schlesinger - For proofreading and editing, much of the raw information for the costuming chapter, and lots of other random ideas and encouragement.
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Appendix B

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About the Author

Stephen Richardson is a fourth year interdisciplinary student at Worcester Polytechnic Institute in Worcester, Massachusetts. His major is a strange cross-breed of Electrical Engineering and Computer Science, reflecting his strong interest in both fields.

Steve is an active member in the WPI theatre community, having held many production positions during his undergraduate college career. In addition to direct involvement in theatre productions, he has served two years as technical director for the college's audio and lighting group, and one year as business manager for the college's cast of *Alpha Psi Omega* (the national theatre honor fraternity).

In addition to being a full-time geek, Steve also enjoys some artistic ventures, such as music and literature. This book is his first foray into writing a substantial work.

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