Overview of Electrical Engineering for School Design

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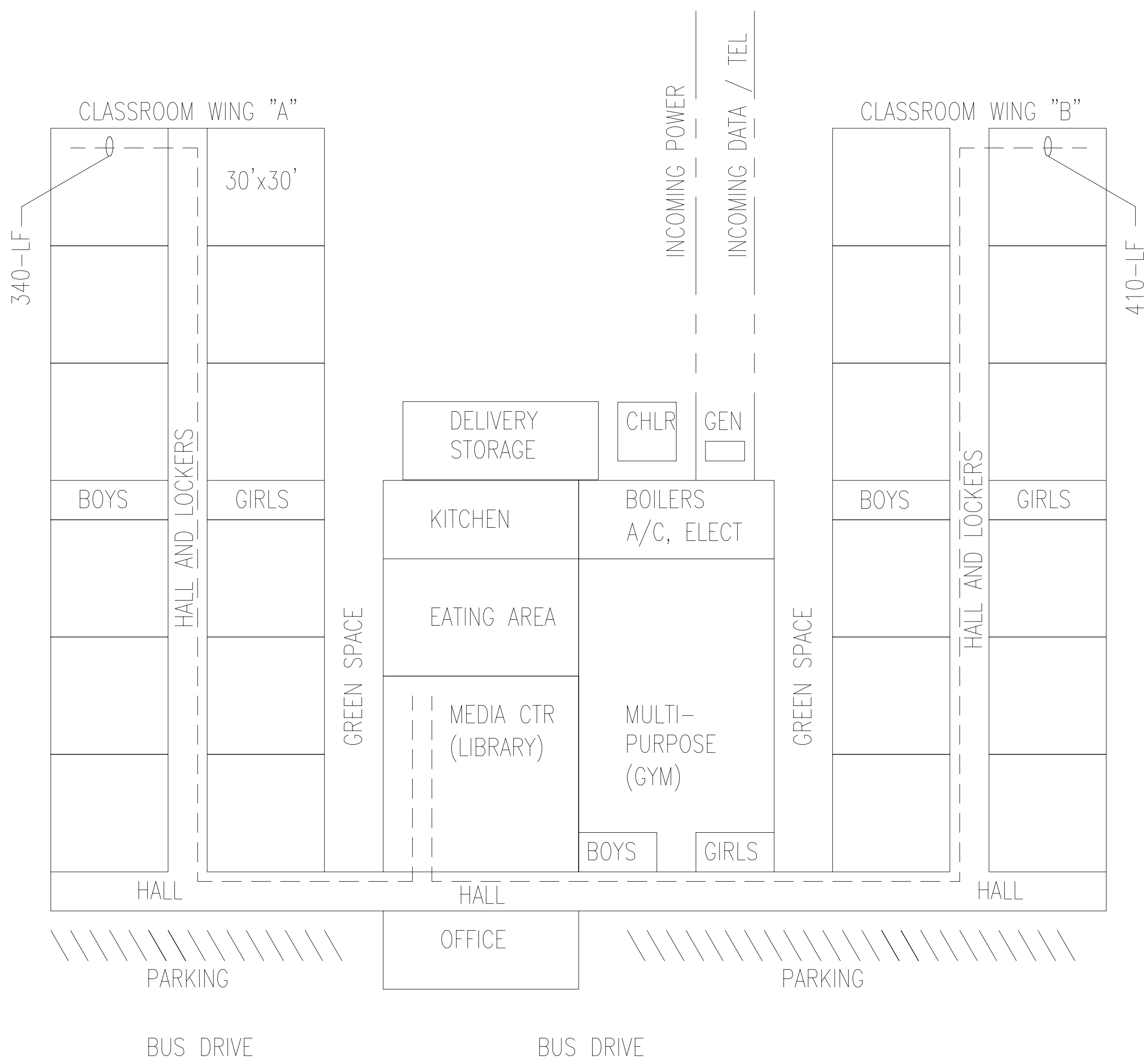
Course Content

INTRODUCTION

Before we start the design, we must identify the scope of work and the players. For this class, the scope is a generic school, containing the components of the following sketch:

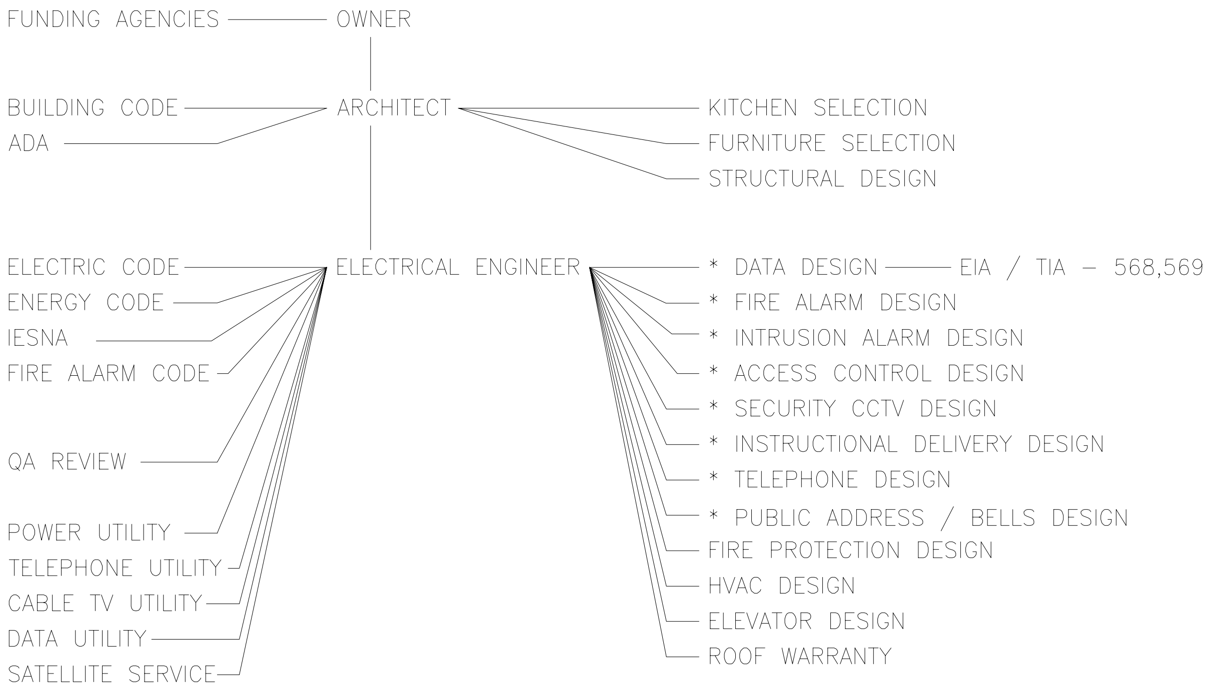


SCHOOL PLAN – ESSENTIAL COMPONENTS

Optional Narrative	In response to users' requests, narrative material is included in this revision of the PDHonline Electrical Engineering for School Design course. Paragraphs in boxes like this one contain references to now obsolete Codes, reports of field experience with Plans Examiners and Contractors and extraneous opinions. Content is not included in the quiz.

Optional Narrative	This is a course on electrical design, in the broadest sense, with a school as the example to see how the tasks fit together. This is not a course in school design. On the other hand, schools have changed considerably in the last 5 years. Unless you have a student with a lot of activities, you probably don't know about the innovations that are now standard. The sketch above is not typical. Schools today are wide (but don't fit well on a single sheet of typewrite paper). The States require that almost all classrooms have outside windows and substantial savings are available if elementary and pre-school classrooms have outside doors. Locker-lined halls are universal for all but the smallest students. The funding agencies will support classrooms, labs, library, gyms and shared eating areas. These will be sized for the student population. It is hard to get money for restrooms, offices, kitchens, teachers work areas and boiler rooms. These will be sized to the minimum regulatory requirements, or a little smaller. Space for data equipment has only recently been recognized as a need and it has been lumped into "media" to share the library. Depending on local conditions, all schools now have central air conditioning and an emergency generator. All schools must take delivery of foodstuffs, replacement light bulbs and lots and lots of toilet paper.

And the players are:



SCHOOL DESIGN – EE RELATIONSHIPS

Optional Narrative	If this course meets its goals, each of the items on this graphic will be discussed in some depth. For now, only the names are explained. The center of the universe is, of course, the electrical engineer. Above him, figuratively, are the Architect and the Owner. The Owner is constrained by the amount of money he has available and any restrictions on spending that money. There can be very, very peculiar restrictions. The Architect supplies the innovation at the earliest stages and supervision through the remainder of the project. The Architect is limited by the building code and local interpretation of federal disabilities legislation (ADA). The Architect works closely with a kitchen consultant, who usually provides his services and very limited information at no charge - in return for a no-bid order on the kitchen equipment. Furniture selection is done the same way, usually with guidance from the Owner, who has long-standing relationships with a certain vendor. The structural designer works closely with the Architect during initial layout of the facility, but must be consulted throughout the project to assure that major (heavy) equipment will be properly supported. Rooftop equipment and piping chases from rooftop equipment involve the structural designer. The electrical engineer works with several well-defined, stable regulations. The National Electric Code, the International Energy Conservation Code, and the Fire Alarm Code are fairly well understood and enforced by reasonable people. IESNA (lighting society) has very generalized opinions about lighting level and design. Typically the project Architect has strong opinions. Frequently, the Owner has had a number of bad experiences he hopes to avoid this time. Coordination and communication are required. Quality Assurance review should be a "behind the curtain" activity, unknown to the Architect, Owner or other disciplines. It works this way on a good job. On a bad job, the reviewer has radically different ideas about how the job should be done and a major brouhaha results. The electrical engineer must work with the Architect to find out from the Owner what services are required in the final school. Are they keeping or expanding the existing distance-learning-via-satellite? Who is arranging for the hardware and installation? For power, telephone, cable TV data, satellite, and other services, questions must be asked and the results document into the construction documents. Typically, the civil and structural disciplines must know what is going on. The list of special system, discussed later, is shown here, most with an asterisk (*) to indicate that each may be performed by the electrical engineer or a sub-consultant. Coordination with fire protection (sprinklers), HVAC and elevator are required to meet life-safety requirements. Roof warranty appears out of place, but can be a very expensive item. If the electrician running power to the rooftop HVAC equipment and the technicians hooking up satellite dishes, district radio and lighting rods make mistakes, the leaks can be expensive.

There are seven distinct sections in this course, corresponding to fairly distinct electrical design responsibilities. They are as follows:

- Pre-design
- Power
- Lighting
- Telephone and Data
- Security
- Special Systems
- Workmanship

Pre-design refers to the scope of the project and the plan of who will perform each task required. Power refers to the copper wires and power boxes between the utility pole and the base receptacle. Lighting includes power boxes, wire and fixtures, but, more-and-more, dimming, daylight harvesting and architectural accents.

Telephone and data have become key services to enable the school functions. Principles of design and design presentation will be reviewed here, but the actual design is often required be performed by a specially licensed sub-consultant. A first-class electronic classroom is indistinguishable from a first-class business conference room.

In earlier days, schools were left unlocked. Today, magnetic locks make it impossible to enter through doors not intentionally unlocked. Detection of intrusion is associated with $100,000's of personal computers and laptop computers in the typical school. Surveillance is required to protect students and staff and to ultimately lock-up any perpetrators.

Special systems are very, very important. They include lightning protection, fire alarms, clock and bell systems, theatrical lighting, television production and satellite television acquisition.

We excluded commissioning and acceptance from this course earlier, but some checklists to evaluate the quality of workmanship will be included. These are key concepts with prominence in the specifications, drawing notes and any walk-thru's or on-site meetings.

PREDESIGN - Controlling Regulations

This topic refers to two distinct types of regulations - funding and legal. Funding refers to requirements of the agency providing the capital funds for design and construction. For schools, these requirements are actually legal, but they are enforced by withholding of funds.

From whom does the electrical engineer get a copy of the funding restrictions? It is very appropriate to draft a detailed letter to the Architect, early in the project, requesting copies or a meeting. Often, no written form exists and, sometimes, the Architect is hesitant to go on record. The form of the list or agenda for the meeting should be much more circumspect, but contain the following items:

Do I include in my drawings and specs

1A) new fire alarm system
1B) upgrade the existing fire alarm system to meet current requirements
1C) voice notification of alarms

1D) fire pump and booster pump

2A) classroom data jacks
2B) wiring from classroom data jacks to the data closet
2C) racks of patchbays and data switches in the data closet
2D) UPS for the data closet racks
2E) homerun fiber from the data closets to the main data center
2F) racks of patchbays and data switches in the main data center
2G) server racks in the main data center
2H) software from servers and clients
2I) high-speed data utility termination racks
2J) high-speed data services from the utility

3A) receptacle boxes and steel conduit from data jacks to above-ceiling space
3B) steel conduit from wall conduit to hallway
3C) ladder cable tray to pick up classroom cables and take them to the data closet and center

4A) data jacks/cables/patchbays/switches for VOIP telephones
4B) instruments (telephones) on desk, on wall or on wall at door
4C) telephone switch in main data center
4D) UPS for telephone switch

5A) preferred classroom lighting levels per calculations, 30fc, 50fc?
5B) dual level switching
5C) motion detectors
5D) preferred lighting levels for offices, gym, library, student eating area
5E) dual level switching, motion detectors

The legal regulations should be identified, by the Architect, in response to the following questions:

Should I base my drawings and specifications on

- 2005 NFPA-70 National Electric Code
- Any local special requirements
- 2002 NPFA-72 Fire Alarm Code
- ASHRAE 90-05 Energy Code
- 2004 NFPA-780, Lightning Protection

PREDESIGN - Construction / Design Estimating

A priority of many stakeholders in school construction is budget control. At the time the electrical engineer joins the project, the budget is only a little flexible between accounts and rigid in total amount. (Exceptions relate to special funding for alternate designs, based upon uncertain, but hoped-for sources.)

The first step, and frequent intermediate step, is the construction estimate. There are three components of a construction estimate - items, cost per item and computations. Items mean preliminary design. Many managers will demand that only bulk $/sq-ft figures be used early in the project. This can be disastrous, if special conditions are known and not included in the costing.

Optional Narrative	Where do the "items" come from? Where do the "costs per item" come from? In 35 years, I have always done a back-of-envelope one-line diagram and consulted MEANS Electrical Estimating Guide (2005, $112, www.rsMeans.com) for unit costs. There are competitive estimating guides available.

For years, a pencil-and-paper estimate was expected, was economically prepared, and met all needs. A recommended form is an 11x17 sheet with large columns and wide ruling. It can be copied down to 8-1/2x11 for easy filing and fax transmittal. A good form is as follows:

Project ________________, by _____________, date _______________								p. __ of ______	
ref	item	count	description	$mat /unit	$mat ext	hr/ unit	hr ext	line tot	group tot
Notes: page tot									

where:
ref = page number in MEANS you used
item = sequential identifier so that you can talk to people on the phone
count = number required in the area under study, as "4" duplex receptacles in a storeroom
desc = precise description, multi-line, as needed, as, "receptacle, including device and faceplate, 25-ft 2-#12,#12G-3/4"C, terminate both ends"
$mat/unit = unit materials cost, from MEANS
$Mat ext = count x unit cost
hr/unit = hours of labor, from MEANS (everybody like to apply their own labor rate at end)
hr ext = count x unit labor
$/hr = local rate multiplier, used for final total and easily adjusted to suit
line tot = line total, this is especially useful if you do a fine-detail breakout
group tot = it is recommended to group items and carry the group totals to a final summary
page tot = alternate check value - all the page totals should equal all the group totals
Notes: = record assumptions built into the estimate

There is a range of electronic estimating tools available today. MEANS has an electronic version, which includes all the cost tables, but aids you in constructing the detailed estimate and estimate summary. Many firms have in-house standard spreadsheets, which may or may-not include cost data but do improve computational accuracy.

MEANS contains a table of probable construction costs on a $/sq-ft basis. It is in section 17100. A small part of the table is paraphrased here.

17100 | S.F. Costs			UNIT	UNIT COSTS			% OF TOTAL		
				1/4	Median	3/4	1/4	Median	3/4
760	0010	SCHOOL Junior High & Middle	S.F.	70.1	86.7	102			
	0500	Masonry	S.F	7.9	10.5	13	8.8	11.1	14.0
	1800	Equipment	S.F	2.3	3.8	5.8	2.6	4.3	5.9
	2720	Plumbing	S.F	4.7	5.1	6.8	5.6	6.8	8.1
	2770	HVAC	S.F	5.3	10.3	14.4	8.7	12.7	17.4
	2900	Electrical	S.F	6.8	8.5	10.2	7.8	9.4	10.6
	3100	Total: Mech & El	S.F	19.6	24.6	32.6	23.3	25.7	27.3

Where:

17100 = MEANS section reference
S.F. = cost per square-foot, building area
UNIT = unit of measure (the entire table contains other units of measure)
UNIT COSTS 1/4 = low-end value of the range of data collected
UNIT COSTS MEDIAN = mid-range value of the data collected
UNIT COSTS 3/4 = high-end value of the range of data collected
760 = section for School, Junior High and Middle
2900 = reference section for detailed break-out of component costs
Electrical = costs for electrical construction
6.8 = the low-end cost collected for electrical was $6.80 per square foot
8.5 = the mid-range value for electrical was $8.50 per square foot
10.2 = the high-end for electrical was $10.20 per square foot
7.8 = the low-end cost for electrical was 7.8% of the total project cost
9.4 = the mid-range value for electrical was 9.4% of the total project cost
10.6 = the high-end for electrical was 10.6% of total project cost.

For a 28,700 sq-ft middle school, 27,800 sq-ft x $8.5/sq-ft = $236,300.

To use this information correctly it is highly recommended that the student study the narrative material in the MEANS Estimating Guide.

Optional Narrative	When I issue a construction estimate, I always say, "Based upon 2007 MEANS Electrical Estimating Guide, the probable cost of construction for electrical will be $236,000 plus contingency." We never say "construction estimate" because some people confuse engineers with tail-pipe salesmen and consider an estimate to be a contract amount. I always call-out the contingency as being excluded because they want to add an overall contingency, not a contingency per discipline.

PREDESIGN - Early Contacts

Optional Narrative	Get permission from the Architect or Project Manager before contacting authorities or utilities. The Architect often has preferred contacts and has intense interest in maintaining good relationships.

You must identify a person, phone number, fax number, and hopefully, and e-mail address for a person at each utility involved, electric power, telephone, cable TV, data, satellite service. If electrical design is doing in-classroom data, you need a computer support contact within the school system.

The utilities, today, are hiding from their customers. It will be a challenge to make contact with the right person at each utility, and, at least one person will change jobs during the course of the project with no notice or arrangement to carry the project forward. Care in maintenance of your utility contact file is very important.

You must have a street address for the construction. It is helpful to have a personal knowledge of the overhead utilities within several blocks. A Sunday afternoon ride, carrying a digital camera can be very valuable.

Sometimes, a school staff person or the Architect will tell you that a particular utility is not within the electrical design scope. Confirm this direction back to the person, in writing, copy your boss and place a copy in your project file.

An electric power utility contact script might follow this form:

> "Hello, this is Ingrid Wallace, I am an electrical engineer with JBL Consulting Engineers. Are you the person I should be talking to about new service (or service upgrade) for William H. Taft High School at 12351 Highland Avenue?
>
> I am glad to share with you everything I know and keep you up to date, but may I first have your direct phone number, fax and e-mail?
>
> Right now, we are planning occupancy in August, 2009, and we have a 480/277V, 1200A switchboard and two 55Ton electric chillers.
>
> (describe the project and answer questions)
>
> What is the procedure for me to request the available short-circuit current at that location?"

The utility will have very limited choices available for the school. Typically, secondary service must be provided - that means that the utility owns the transformers and the revenue meter is between the transformer and the school.

An alternate, primary metering, had the school owning the transformer. The meter was on the high-voltage side or on the low-voltage side with a credit for transformer losses. The only time you see new primary service installations are very large campus complexes and when it lets the utility give a PCB-contaminated transformer to the school.

PREDESIGN - Responsibilities of Architect

The latest interpretation of the American Institute of Architects is that the project Architect is responsible for coordinating all design disciplines and assuring that information flows freely among them. This is some change and has not been universally accepted.

The Architect is responsible for determining the controlling Codes and providing occupancy and construction class information. These numbers are usually on a leadsheet in the plans review set, but often not shared with the design disciplines.

The Architect invests considerable effort in planning circulation of the building. That is, how many people will be expected to be walking each way at various times of the day? The Architect will assume magnetic door hold-opens, to maintain pedestrian traffic. But, he may not tell you if you don't ask or notice them on a door schedule. Magnetic door hold-opens must be released by the fire alarm system and require additional smoke detectors. If he is putting in fire shutters, they will require power and fire alarm connection.

Most Architects have standard treatments for bathrooms, lobbies and offices, usually involving cove lighting, down light cans and surface or recessed 2x4 fluorescents. A few minutes talking to the Architect or one of his designers will give you a head start, well in advance of release of the reflected ceiling diagrams.

Be warned that some funding authorities are demanding detailed lighting drawings at the earliest stages of the project. The work in preparing the drawings is not great, but the Architect may not be ready to commit and it is awkward to change the basic scheme from one review drawing set to the next.

For the state of Ohio and for the city of Detroit, MI, there are published design guides that are rigidly enforced - or the project is stopped until the discrepancies are corrected. No such guidelines were found for the state of New York or for the major municipalities. It is critical to check with the Architect to see if special rules will be enforced on the current school design.

Per the American Institute of Architects, the Architect has final responsibility for coordination of designs. ASME A17.1 controls elevator hardware and NY elevator inspection approval is required to get an occupancy permit for the school. These are Architect responsibilities, but often the electrical designer is better versed in the regulations and has inspection checklists from previous jobs. Offer to work with the Architect, it should involve a single meeting and review of elevator specifications and shop drawing submittals.

PREDESIGN - Use of Sub-Consultants

There are three good reasons to use sub-consultants - to get resources you do not have, to supplement your resources at an economic advantage, to comply with regulatory requirements. Resources you do not have may refer to special tools, special skills or just available hours.

Many vendors do free design if you specify their materials or use their proprietary spec which effectively excludes alternates.

Optional Narrative	Your instructor has strong feelings on this topic - which appear not be shared widely in the consulting community. My interpretation of engineering ethics is that you shouldn't spend extra Client money to increase your profit. The contrary argument is that there are very few superior products, and, if you want the superior product, it is reasonable to let the rep for that product help write the spec and give you installation details.

There are skilled designers who work very efficiently and cheap (project net cost, not $/hr). It would appear that everyone benefits when those skills can be incorporated into the project, with proper supervision, coordination and checking.

Optional Narrative	I have seen this work well and I have seen this work badly. It is not a benefit to rework all the sub-consultant effort the night before submission. The key is the person working on your job. A sub-consultant individual can be very reliable. A sub-consultant firm may not be.

An area to be discussed in more detail later is data wiring. Many funding agencies require the design be performed by a RCDD (Registered Communications Distribution Designer, www.bicsi.org). This license is difficult to obtain and requires annual continuing education and re-testing. Usually an RCDD is a full-time cabling salesman and/or designer. Most electrical engineers cannot justify the time and cost of maintaining the license. This is an appropriate sub-consultancy situation.

PREDESIGN - Time, Date and Form of Deliverables

At the kick-off meeting for the project and at every meeting during the project, it should be restated what form, what date and what time the next project deliverables are due. It is unfortunate how many projects approach an intermediate review with no definition as to whether electronic drawing files are required, or electronic print files (.pdf) or paper full-size plots or paper half-size plots.

Almost every job has games played on day and time of delivery. A good delivery target is end-of-business on Friday, which everyone interprets as start-of-business Monday, giving them 16-easy-hours of additional work and up to 60-hard-hours. One lead designer recently stated in an e-mail, "My set doesn't have to be done Wednesday; my QA-guy is out of town until next Monday." From his viewpoint, this was a valid conclusion. However, the other designers needed his best, most complete work, to coordinate with their work.

In the American Institute of Architects paradigm for a project, the three sections are Schematic Design (SD), Detailed Design (DD) and Construction Documents (CD). We have just discussed some aspects between negotiating for the design contract and the completion of Schematic Design.

Power

In this section, we will discuss the down-and-dirty aspects of electrical design - for power distribution. To establish context, please consider the following generic one-line electrical diagram:

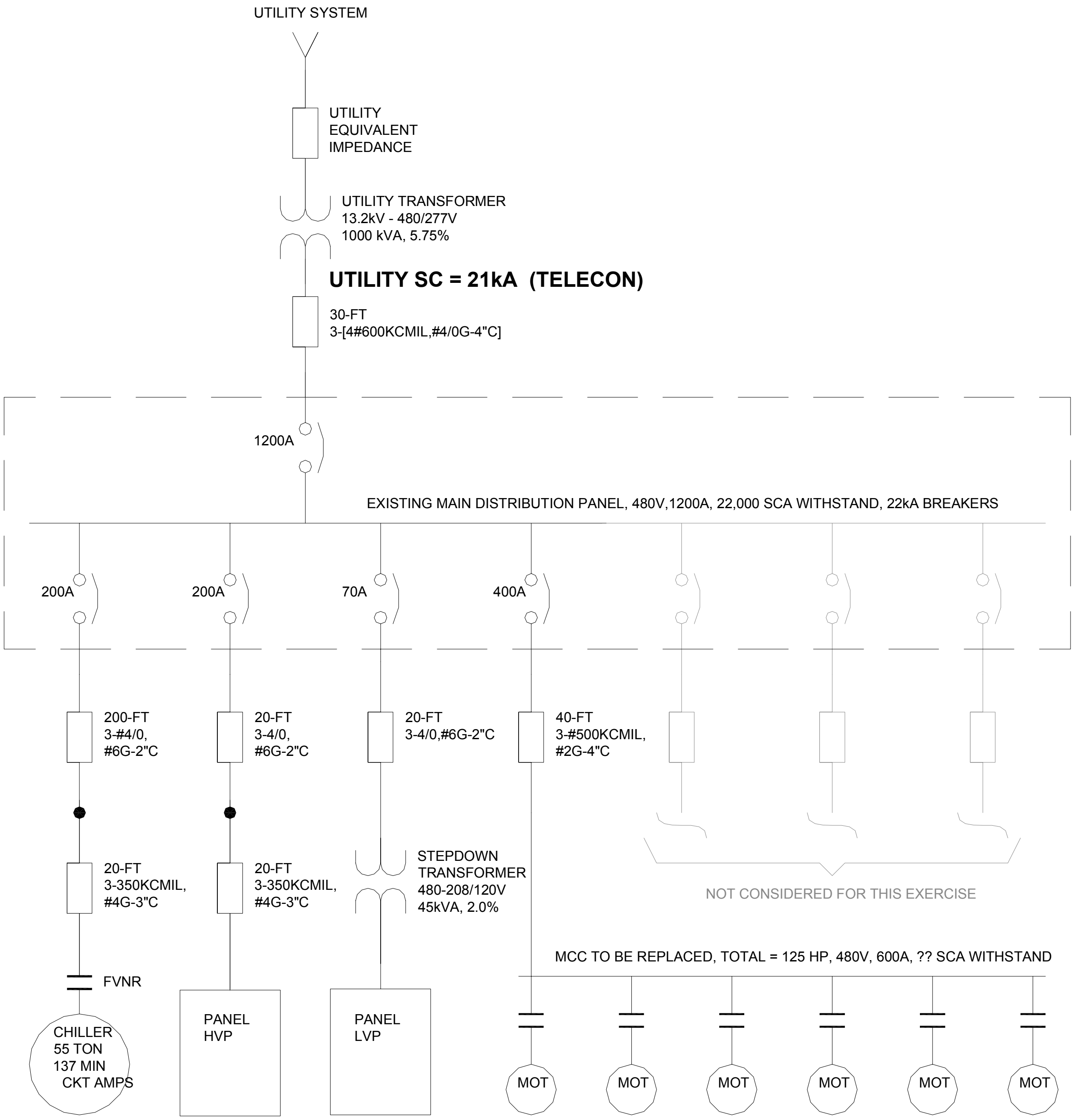


FIGURE 1 - COMPONENTS, CONNECTIONS, NAMEPLATE INFO

This drawing was prepared for the PDHonline course on minimal short-circuit analysis, so it emphasizes cable impedances more than a normal one-line. However, the components are all of interest to our present activity.

At the very top is the utility electrical service. Per the National Electrical Code, there should be only one service per building. There are many exceptions, so this may not actually be the case, but there is one main service and its associated main disconnect switch (or circuit breaker).

There is a main distribution panel or switchboard, and we will discuss the difference. There are feeder breakers and feeder circuits to HVAC equipment, to various elevator loads, to the cafeteria, auditorium, gym, library and administrative offices. There may be emergency power. There must be power distribution panels and transformers. Ultimately, there are power receptacles and technology receptacles.

Power - Electric Service

The goal is to design a system which is capable of bringing enough power into the school. MEANS Table D5010-1150 is paraphrased below:

Table D5010-1151 Nominal Watts per S.F. for Electric Systems for Various Building Types						
Type of Construction	Lighting	Devices	HVAC	MISC	Elevator *	Total Watts
College, science building	3.0	3.0	5.3	1.3		
College, phys ed	2.0	1.0	4.5	1.1		
School, elementary	3.0	1.9	5.3	1.3		
School, junior high	3.0	1.5	5.3	1.3		
School, senior high	2.3	1.7	5.3	1.3		

* Elevators are listed in Table D5010-1152 as ranging from 10-50 HP

The college science building and phys ed buildings are included here to show that specialized construction have little effect on the total watts per square foot.

For our junior high example, (lighting + Devices + HVAC + Misc) x 27,800 sq-ft
= (3.0 + 1.5 + 5.3 + 1.3) x 27,800
= 11.1 w/sq-ft x 27,800 sq-ft
= 309 kW

I = kW / (1.732 x kV)
= 309 / (1.732 x .48)
= 372A at 480V

provide 25% spare capacity

kW = 309 x 1.25 = 386 kW (use 400 kW)

I = kW / (1.732 x kV)
= 400 / (1.732 x .48)
= 481A (use 600A)

Therefore, based upon only the square footage of the school and MEANS, we estimate a requirement for 400 kW, 481A at 480V and 600A main disconnect and main panel.

We tell the utility we have 309 kW connected load and are designing the system for 400 kW.

Optional Narrative	The formula I = kW / (.732 x kV) is a form of the definition of 3-phase power, kW = kV(l) x I(l) x (1.732) The 25% spare capacity is a restatement of the National Electric Code rule that a protective device may not be loaded more than 80%. The nominal spare capacity, calculated this way, is also a requirement of many funding agency design guides. The choice of 480/3/60 utility service is based upon the economies available from 277V lighting, associated with 480/277 service.

Power - Main Switchboard

A switchboard is a much more expensive distribution panel. They are constructed to pass different UL tests. The switchboard is intended for high-abuse industrial applications. The distribution panel used to be flimsy and a little bit shoddy. No more. Panelboards are used almost exclusively in shopping malls, office buildings and schools. They are more compact, easier to maintain and much less expensive.

At this point in the design, the electrical engineer pulls out his Square D, Cutler-Hammer, Siemens or General Electric catalog and looks for a 480/277V, 600A power panel with Service Entrance Rating. Until the utility available short-circuit current is known, it is best to use a very high value, 65,000A. Provision for 8 3-pole, 400A circuit breakers should be adequate. Note the list price for your next estimate and the linear-feet of wall space required. A phone call to the factory rep would be of value to be sure you haven't missed something.

Optional Narrative	We selected the 480/277V and 600A in the utility service section. Service Entrance just means that the panel has been tested by UL for use as a main disconnect switch (required by the National Electric Code). Short-circuit withstand is a complex subject. You will always be safe selecting a switchboard rating one "notch" higher than the utility short-circuit available. (The difference is the momentary contribution from your chiller.) There is a new PDHonline course on minimal short-circuit analysis. In big power panels, high-amp circuit breakers take more space than low-amp. 400A is a very, very common value, to feed remote panels or major equipment. Small loads should be fed from a distribution panel, perhaps adjacent to the main distribution panel. Why 8 – 400A circuit breakers? Well, 28,700 is a small school. 100,000+ sq-ft is more common. You will definitely need a distribution panel at each of the main school components shown on the introductory school plan diagram. Receptacles will be fed by local transformers and 120V panelboards.

Power - HVAC Power

It is very, very difficult to get preliminary HVAC power requirements from the mechanical designer. If he does give you numbers, they will change (usually increase) before the project goes out for bid.

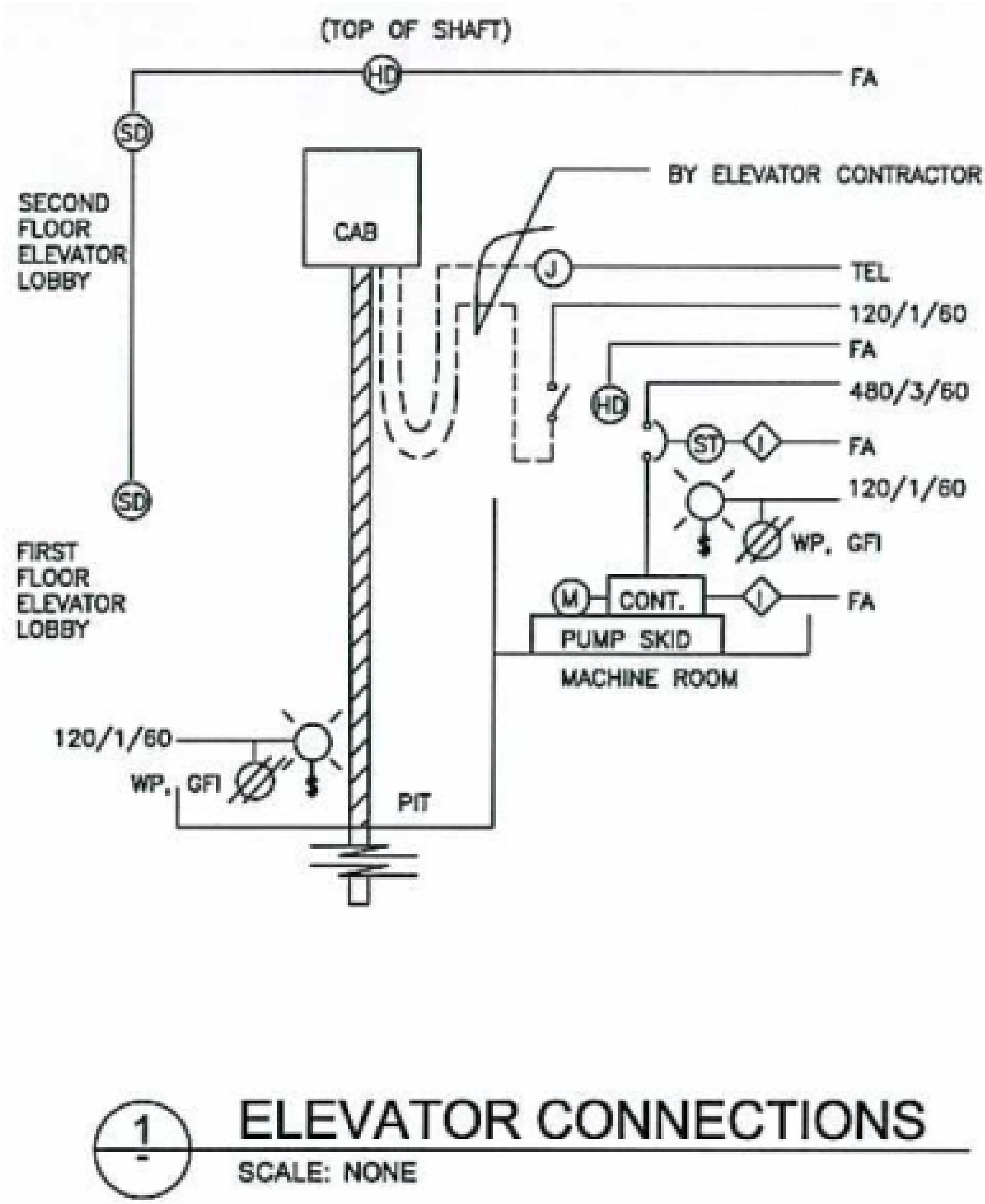
In spite of all the details which must be considered by the HVAC designer, from our viewpoint, all he does is deliver large quantities of cool air or hot air. Cool are comes from a chiller and some fans or several rooftop units containing refrigeration and fans. Hot air comes from a boiler, some coils and fans or rooftop units with gas-fired coils and fans or rooftop units with electric coils and fans. Fortunately, electric heat load is just a little less than refrigerated air conditioning cooling load, and they don't run simultaneously.

The key to electric design to support HVAC is the words, "Single Point Power". If these words appear in the HVAC equipment list, then the HVAC manufacturer has to worry about all the little electric things that go together for a chiller, or air handler and controls. If the special words do not appear, then the electrical designer must provide power for a supply fan, for a return fan, possible an electric reheat coil, a control panel, possibly a heat wheel, and pumps.

Keep checking the HVAC equipment lists to see how many devices are being specified, how big they are and whether the special words exist.

Power - Elevator Power

Elevator power is easy. After the Architect chooses the elevator, provide the power listed in the cut-sheet. The hard part is keeping track of all the electrical details associated with the elevator - car telephone, car fan, pit power, pit sump pump, shaft powered smoke damper, lobby smoke detectors and fire alarm connections. The HVAC components and some elevator components change between projects. Start out with a full-complement and delete them as it is verified they are not needed. A conceptual diagram for elevator services is included below:



where FA = fire alarm
HD = heat detector
SD = smoke detector
cab = elevator car
J = junction box, limit of electrical contractor's responsibility
tel = telephone
GFI = ground fault interrupter receptacle
ST = shunt-trip (remote control) circuit breaker
I = fire alarm supervisory monitoring of shunt-trip power
M = pump motor
CONT = elevator controls

Power - Cafeteria / Auditorium / Gym / Lib / Admin

There are two types of power required for these spaces - equipment power and receptacle power. In theory, there should be three distribution panels in the janitor's closet for each space - power 480V, lighting 480V and receptacle 120V. In fact, power 480V loads are usually pulled off the lighting 480V panel, even though equipment starts will cause a flicker in the lighting. If it is equipment used for 5-min once a week, this is acceptable. If it is an old copier that pulls inrush with every copy, it is time to replace the copier.

Special loads may be electrically operated partitions or curtains or electrically raised basketball backboards.

A power one-line diagram detail that applies to each of the 4 spaces indicated follows:

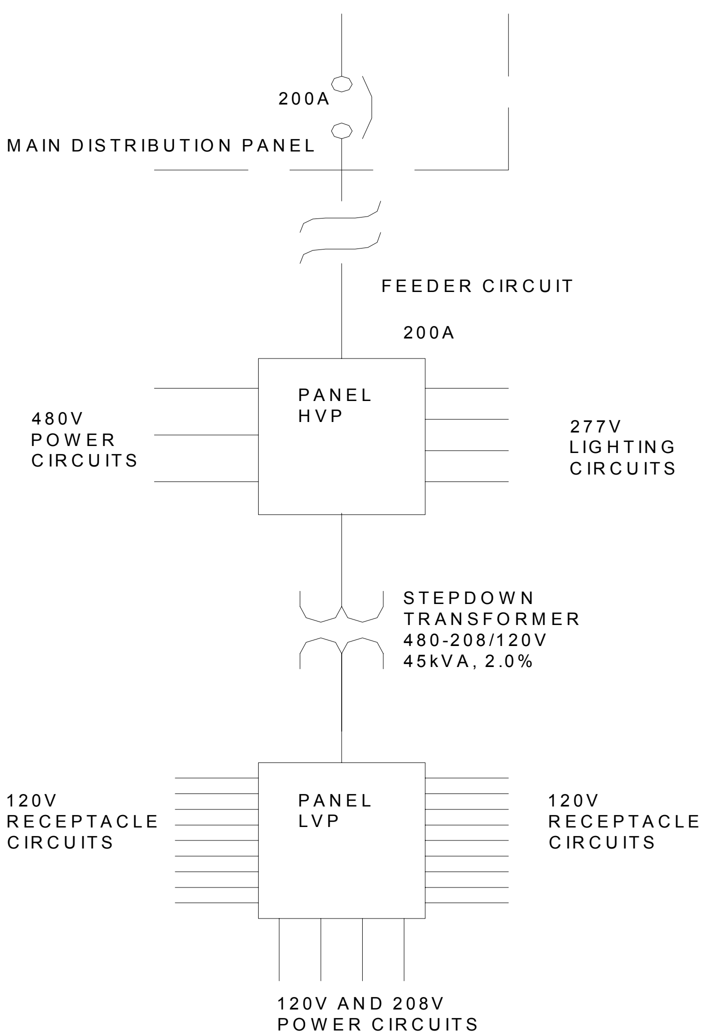


FIGURE 2
LOCAL ELECTRIC
CLOSET

where 200A = feeder breaker in main distribution panel
feeder circuit = 4 #3/0,#6G-2"C
PANEL HVP = area 480/277V, 200A, 3-ph, 4W, 42-pole, 22,000 AIC lighting panel
POWER CIRCUITS = special-purpose devices in area; HVAC comes from boiler room
TRANSFORMER = dry transformer to provide receptacle voltage
PANEL LVP = area 208/120V, 150A, e-ph, 4W, 42-pole, 10,000 AIC receptacle panel

Optional Narrative	The discussion of the main distribution panel indicated 400A feeders to remote 400A panels. This is right for large loads and right for early stages of the project when the magnitude of loads is not known. A more reasonable value, however, is a 200A breaker to a 200A remote panel, shown here. The feeder circuit sizing, 4 #3/0,#6G-2"C, comes from digging through several tables in the National Electric Code, or from using a summary schedule or vendor-supplied "slide rule". The choice of panel HVP, 480/277V, 200A, 3-ph, 4W, 42-pole, 22,000 AIC, is a generic power panel. Maximum size per the National Electric Code is 42-poles. 22,000 A interrupting capacity is a conservative size, before the short-circuit study is performed. The 45kVA dry-type transformer is very generic. 30kVA and 45kVA are most common, though larger and smaller are available. The choice of panel LVP, 208/120V, 150A, 3-ph, 4W, 42-pole, 10,000 AIC, is a generic receptacle panel. The 150A rating was selected to match the transformer, using NEC tables or a vendor-supplied "slide-rule".

Power - Emergency Power

Emergency power means exit signs and egress lights. Today, security and communications are commonly included as life-safety loads. Lights in the electrical room are emergency loads, and by the same reasoning, a few lights in the administrative offices could be emergency loads. If there is a refrigerator for medicine, it is an emergency load.

Power for life-safety emergency loads is required by law. There are three common methods of providing the power - local battery packs, central batteries and a central emergency generator. Exit signs and egress lights with built-in batteries cost $20-150 each and require no special wiring. A central battery system costs $10,000+ and requires special wiring throughout the school. A central generator costs $10,000+ and requires special wiring throughout the school.

Exactly the same regulations apply to all three solutions - monthly testing, logging of the testing, maintenance when out of service.

A power one-line diagram for a generator system follows:

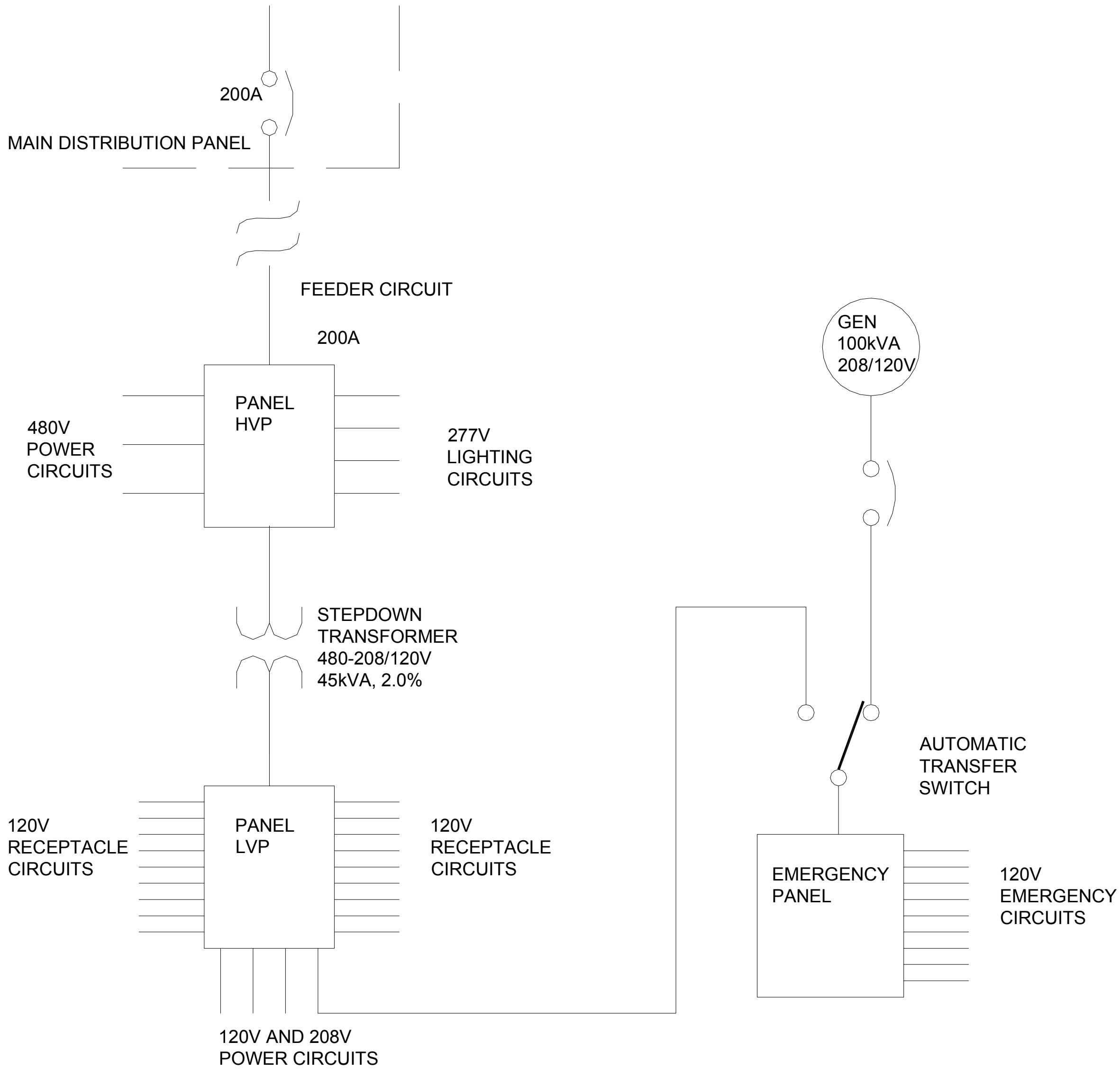


FIGURE 3 - ADDITION OF EMERGENCY POWER

where GEN = generator, usually diesel, specified, installed and maintained per NFPA 110-2005
ATS = automatic transfer switch, senses loss of power, starts generator, transfers load to gen
EMERGENCY PANEL = all wiring from this point to emergency load must be isolated (separate conduits) from normal wiring

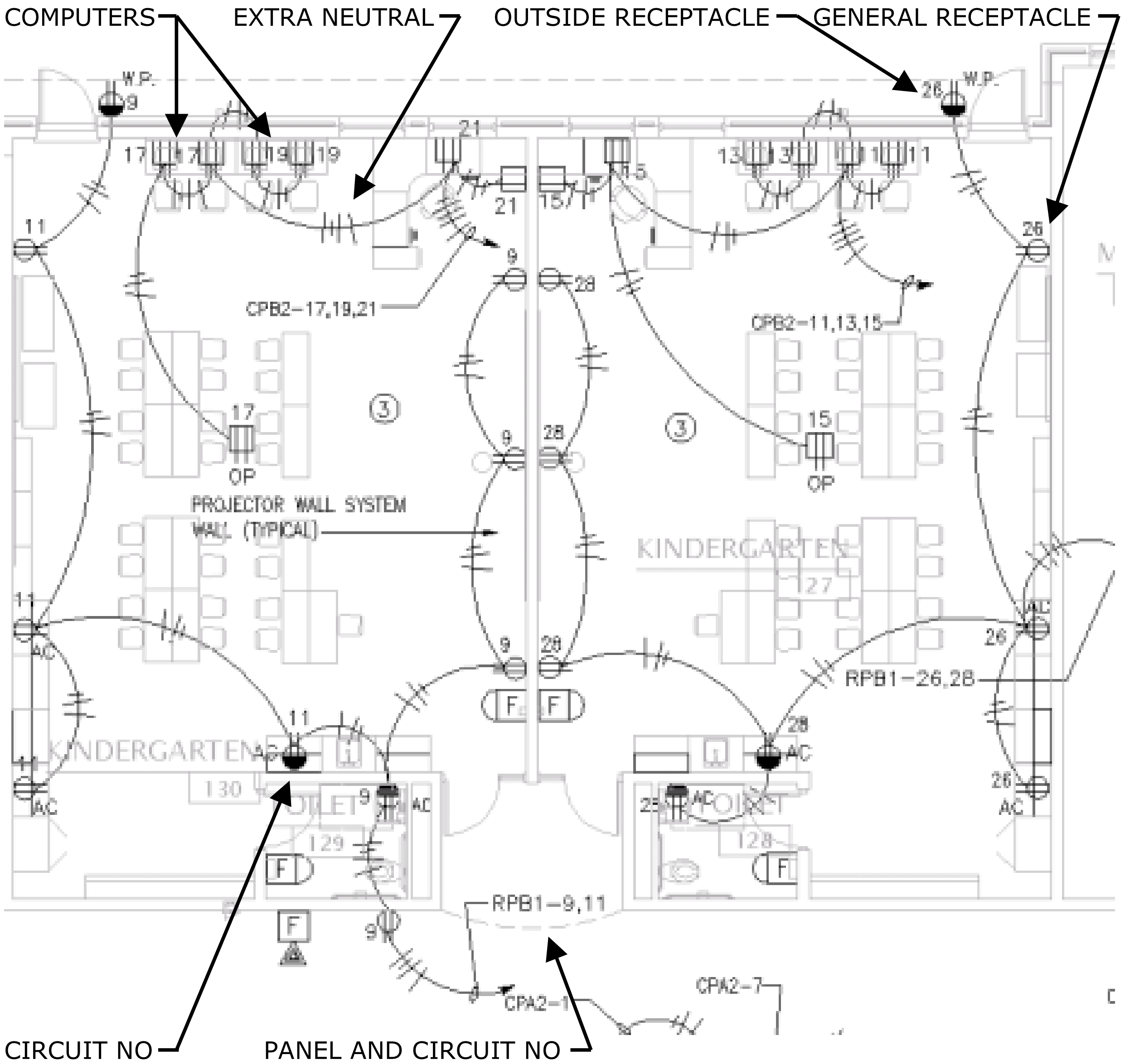
There is a PDHonline course on emergency generator selection and application.

Power - Power Distribution and Closets

Since we discussed Cafeteria / Auditorium / Gym / Lib / Admin previously, what is left is classrooms. The National Electrical Code requires upsizing power conductors when voltage drop reaches 3%. This is enforced through the International Energy Conservation Code and ASHRAE 90.1. The magic number is 100-ft. When receptacle conductors must travel more than 100 ft, the wire size must be raised from #12 to #10. Until recently, panels were placed in the hallway about every 200-ft to avoid the problems and costs of upsizing the wire. Then the high-level school people decided that hall panels are not a good idea, both from accessibility to little hands and from the hazard when any maintenance is required. Suddenly, lighting and receptacle panels moved to the janitor's closet, next to the slop sink. This is the situation in many, many schools built during the 1960's.

Today, it is recommended that dedicated electrical closets be part of the school design, with minimum space about 5-ft x 7-ft. All of the problems of electrical closets return when we discuss data closets.

The plan drawing for power and general receptacles looks like the following:



Power - Power and Teledata Receptacles

Optional Narrative	Schools from the 1920's had four classrooms sharing a single receptacle circuit. Early personal computers drew 400W. Four computers could be plugged into the outlets in the four classrooms. In the 1990's when politics drove states and communities to spend money on personal computers for schools, it soon became apparent that additional receptacle circuits were required. Standards were written by non-technical administrators, on the advice of computer salesmen to require pristine power for the classroom computers. A new panel must be installed at the service point, with a transient voltage surge suppressor (TVSS) and superior ground connection. Dedicated computer circuits with oversize neutrals must be distributed to the computer labs. A new panel must be installed in each lab, with it's own TVSS. Each computer power circuit must have a power conductor, a neutral conductor and a ground conductor. Today, a student computer with an LCD screen draws 50W, and 38 computers can be connected to a single receptacle circuit. But, we are expected to install new panels, TVSS and oversize circuits with oversized neutrals.

The most strict design guides from the funding agencies call for each technology outlet to be fed by a dedicated power conductor and a dedicated neutral conductor. There must be a ground conductor, but it may be shared. The feed to the panel must have 3 power conductors and at least double-size neutral conductor. There must be a TVSS in the main panel and a TVSS in the local panel.

The plan diagram above, for a kindergarten, contains computers and technology power receptacles.

We move now to lighting design.

Lighting - Lighting Levels

Optional Narrative	Lighting is a very flaky field. If you say "lighting level in the classroom of 30-fc (obsolete Imperial measure). That means that a light meter should report 30-fc. Right? No. Never (or maybe for 1-week in 10-years). Light bulbs, fluorescent, incandescent, halogen, metal-halide or high pressure sodium, start bright and continue to dim out through their lifetime. If you want 30-fc and you do standard calcs for 30-fc, you get 40-fc initial, and it depreciates over time to 30-fc, then 20-fc, then fails. That is lamp depreciation. Open lamps collect dirt. It blocks the light and reduces the effectiveness of reflectors. Closed fixtures collect dirt on the lens - there is something about static electricity that makes a lens first choice for any dust particle. Lamps have a life, but most keep going for a long time after they are dead. The building where I work has decorative metal-halide lamps on the building and high-pressure sodium street lights 10-ft away. The street lights throw shadows from the building lights on the side of the building. Additionally, the human eye responds to light logarithmically. That is, it takes a 1000W lamp to look twice as bright as a 100W lamp. The difference between 150W and 175W in unperceivable.

Before the additional confusion of mandatory energy conservation, the lighting society published minimum light levels and made available a method to predict the levels produced by specific fixtures in a specific room. The list for schools was as follows:

ELECTRICAL
SYSTEMS CHAPTER 8: SYSTEMS AND MATERIALS

SCHOOL LIGHTING LEVELS - 2003

ROOM TYPE CLASSIFICATION	2000 IES FOOTCANDLES	RECOMMENDED DESIGN FOOTCANDLES DIRECT LIGHTING(1)	RECOMMENDED DESIGN FOOTCANDLES *INDIRECT* LIGHTING
ADMINISTRATIVE			
Offices/Receptionist	50	50	40
Storage Rooms	-	25	25
Restrooms	5	25-30	25-30
Conference/Resource Rooms	30-100	50	40
Health Clinic	50	50	40
Teacher Prep/Workroom	50	50	40
CLASSROOMS-GENERAL	30	50	40
Art Rooms/Kiln	50	50	40
Modular Technology Labs	-	50	40
CADD Labs	30	30	30
Industrial Tech/Production Labs	100	60	60
Computer Labs	30	40	40
Graphics Labs	30-100	50	40
Life Skills Labs	50	50	50
Science Labs	50	50	50
Laundry Rooms	-	25	25
Music Rooms	30-50	50	40
Large Group Instruction Rooms	30	50	40
MEDIA CENTER	-	50	40
Active Areas	30 vertical	50	40
Inactive Areas	5 vertical	40	40
ATHLETIC AREAS			
Gymnasium - Elementary School	100	50	-
Gymnasium - Middle School	100	50	-
Gymnasium - High School	100	60	-
Multi-use P.E. Rooms	-	50	-
Locker Rooms	10	25	25

Note that the 50-fc required in 2003 cannot be met by 99% of the commercial lighting fixtures - in the number permitted by the Energy Conservation Code. The only compliant fixture discovered, thus far, is the Lithonia RT-5(tm).

Lighting - Lighting Fixtures (Luminaries)

Lighting fixtures come in incandescent, halogen, compact fluorescent, old fluorescent, new fluorescent, metal-halide, high-pressure sodium and some additional forms just entering the market.

They can be recessed-mount, surface-mount, pendant-mount and track-mount. Schools use recessed 2x4 new fluorescent (T-5), recessed downlight cans, a very few specialized architectural fixtures and some maintenance fixures.

Wonderful catalogues without prices are available on the internet and in paper from manufacturers such as Lithonia, Holophane, Hubbell and more and more and more.

Lighting - Exterior Lighting

Exterior lighting includes wall wash, parking lots and security. Wall wash is a surface-mount metal-halide or high-pressure sodium that lights the building and the yard or lot nearby. Something like this is required by the building code at pedestrian entrances and exits.

Parking lots are normally lit by small "shoe box" fixtures on 20-ft poles. The catalogs identify each fixture with a spacing-to-mounting-height figure. This tells you how many you need for a specific lot after you have chosen a pole height. If the count is too high, use a longer pole and the count reduces proportionately.

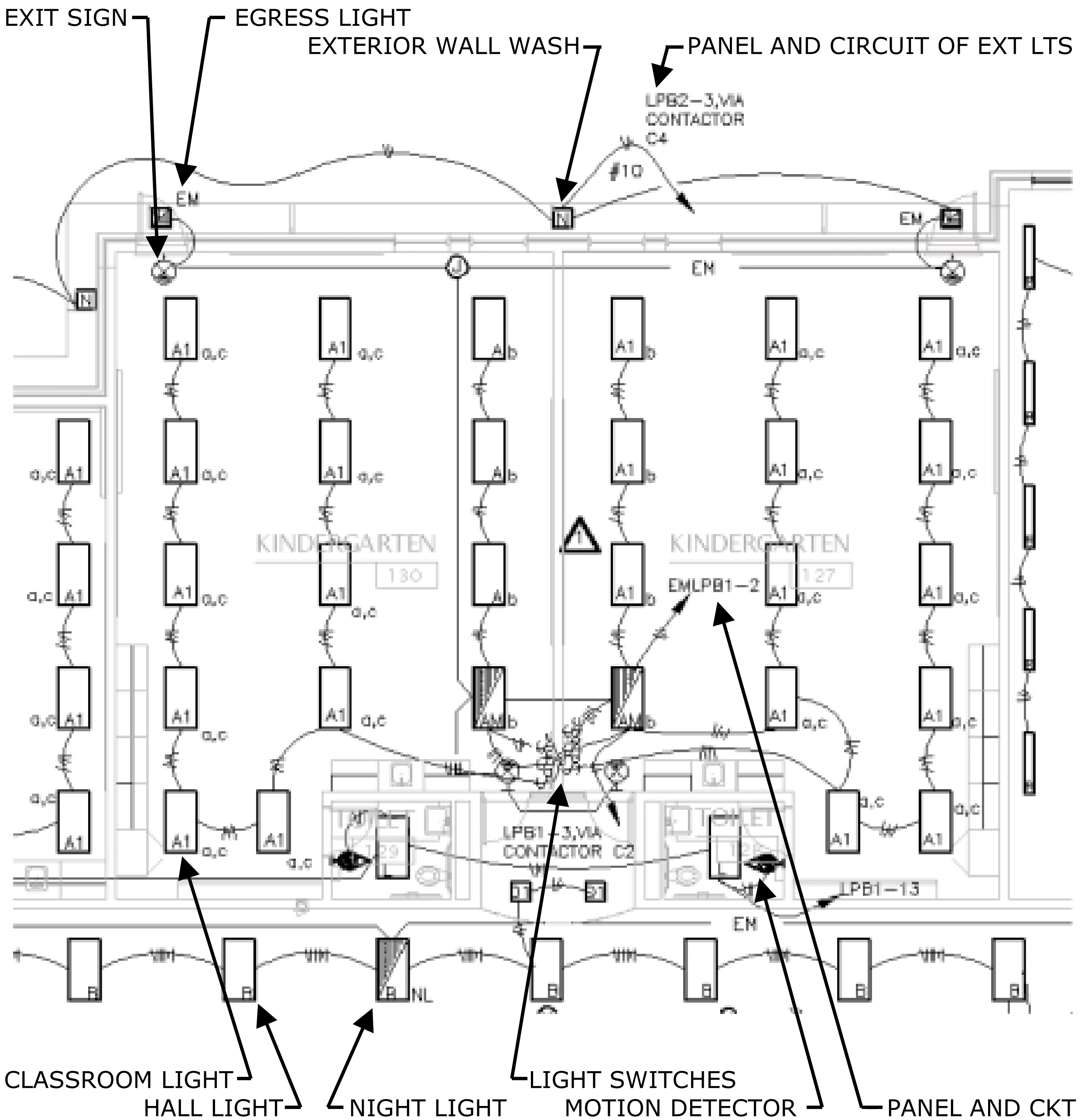
Security lighting has three purposes - comfort level, CCTV observation and police observation. Most people are more comfortable walking through a well lit parking lot. There will be complaints when a lamp burns out.

If CCTV observation is in place, it needs light to pick up images, but not as much as you might think. Most places rely on police driving by occasionally to deter vandalism. Some lighting must be present to illuminate the perpetrators. Shoe boxes on 20-ft poles work. Properly placed wall washes work. Bollards, 3-ft posts with down-lights, work.

Lighting - Lighting Power Distribution

As discussed previously, the main distribution panel provides a feeder circuit to the local 480/277V lighting panel. The lighting panel provides lighting circuits which travel around an area. Each room has a wall switch and then the power goes to the fixtures in that room.

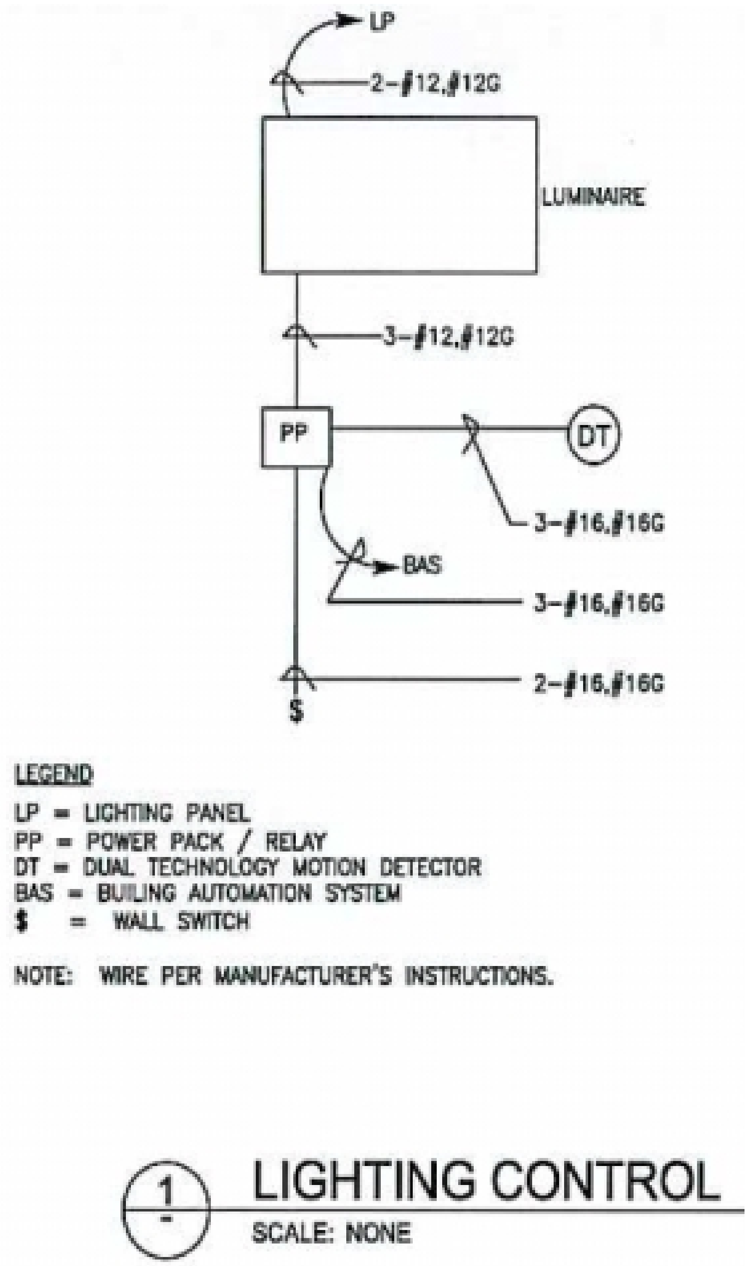
A single 277V circuit provides 16A (80% x 20A rating), or 16 x 277 = 4432 va
A 2x4 fixture draws somewhat less than 100 va. Therefore, 44 fixtures can be supplied by a single circuit, or about 4 classrooms. A sample lighting wiring plan follows:



Lighting - Lighting Control

The purposes of lighting control are user convenience and energy conservation. User convenience means that the teacher can dim the lights while using video projection, but leave enough light for notes and to control the students.

Energy conservation means complying with contradictory arcane arbitrary bureaucratic regulations. As alluded to in the fixture selection section, the funding agency design guide specifies minimum fc and maximum w/sq-ft. Both are measures of lighting level (with a given fixture or type of fixture). When a minimum and maximum are specified, only the range in between is available as a solution. Unfortunately, the maximum w/sq-ft is below the minimum fc - and - they want to review the calculations.



Other energy conservation requirements from the funding agency design guide include 2-level switching, preemptory motion detectors, time clock control and lighting control from the building automation system. 2-level switching used to mean that the outside tubes in all 4-tube, 2x4 fluorescent fixtures were on one switched circuit and the inner tubes were on another switched circuit. This still works, but newer electronic ballasts permit the same result with hi-lo levels on only two tubes.

Preemptory motion detectors means that the wall switches can turn lights off, but only the motion sensors can turn the lights on. This is how the hardware comes from the factory and how the manufacturer's installation instructions work. The National Electrical Code requires that hardware be installed per the manufacturer's instructions or the Electrical Inspector is supposed to red-tag the job. An installation detail for motion detectors follows:

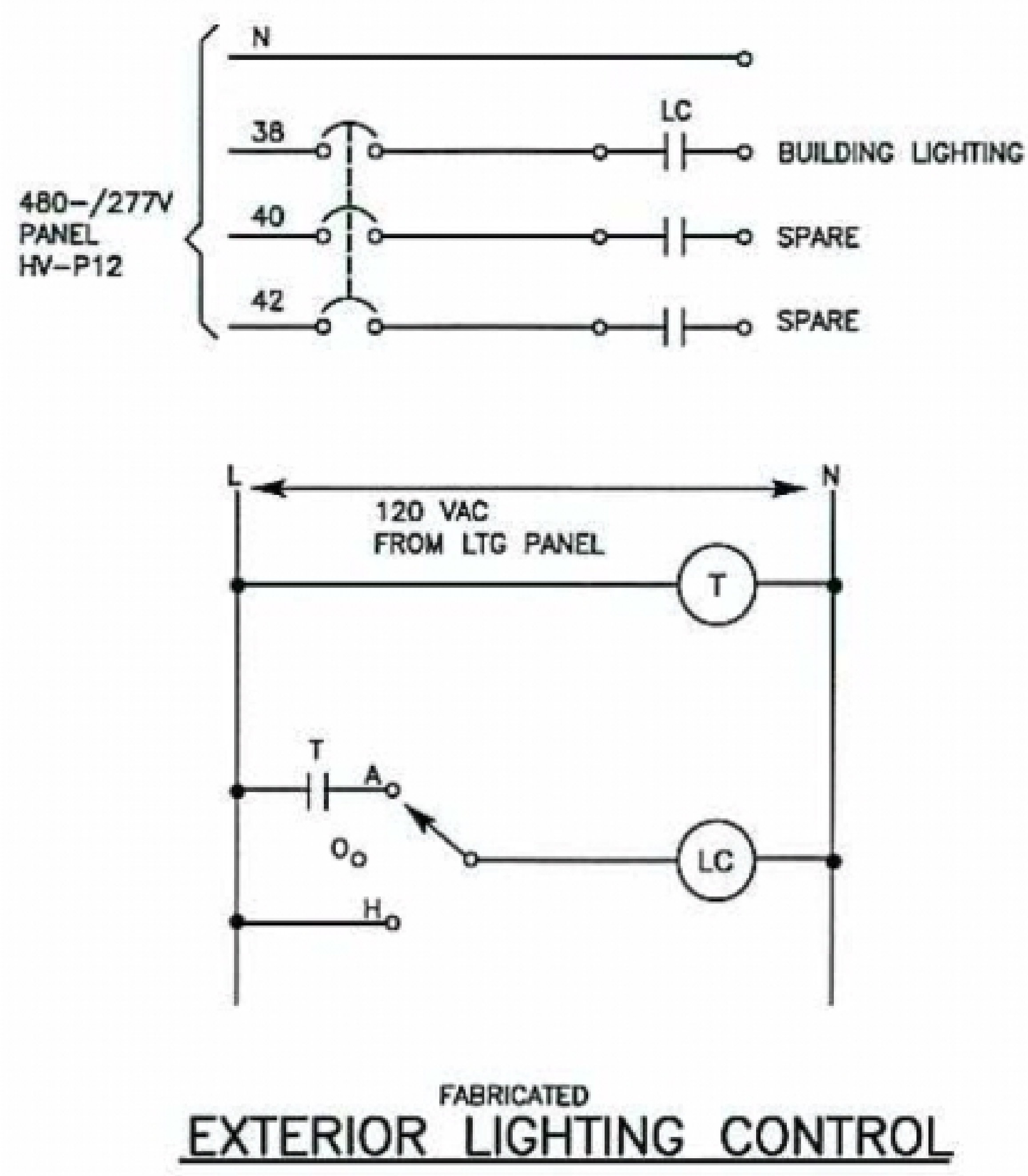
The #16 conductors are low-voltage and do not have to be in conduit (but usually are, per project specifications). The dual technology motion detectors use infrared and ultrasonic. The ultrasonic can "see" behind partitions, as bathroom stalls. The dual technology detector turns off the lights when everyone is working quietly.

This power pack (power switching, low-voltage power supply and logic) accepts external commands, nominally from the building automation system, to turn ON the lights and to turn OFF the lights. This is very valuable for security (ON) and energy conservation (OFF). This control scheme is done on a per-room or per-space basis. The manufacturer is WattStopper (www.wattstopper.com) who publishes some excellent application guides. There are competitors and alternate technologies available also.

Lighting contactors are the 1880 technology (original Thomas Edison). The time clock operates the coil. The coil pulls in the contacts. The lights come on. The mechanical clocks are understandable and the system is totally reliable, except for requiring reset after a power interruption. Time clocks are shown on the plan drawings earlier, for external lights and hallway lights.

Optional Narrative	The latest electronic time clocks follow the Microsoft convention of concealed essential commands, unrecoverable errors and unreadable documentation.

A detail for a lighting contactor follows here:



where: 38, 40 and 42 = circuits in panel HV-P12 which are controlled
38 = single circuit for all exterior wall wash fixtures
40, 42 = were spares, but later used for parking lot lights
T = astronomical time clock (follows sunrise and sunset)
H-O-A = hand-off-auto selector, off when malfunctioning, hand to check lamps
LC = lighting contactor
BAS = fourth position on selector switch if building automation control is to be included

Building automation is the current buzzword for HVAC controls. The HVAC control vendors want to run the fire alarm, building lighting, emergency smoke removal, access control, and intrusion alarms. They do not understand life-safety and requirements for UL-approved components and certified technicians. They also do not like to include manual overrides. Maintenance contract profits far exceed installation profits.

We proceed now to discussions of telephone and data.

Telephone and Data - Main Teledata service

The National Electric Code has slowly taken over on-premises telephone and data wiring. This occurred as the telephone utilities slowly distanced themselves from it and third-party service organizations have grown. Unfortunately, the Electrical Inspectors, who enforce the National Electrical Code, are not trained in telephone and data. That leaves the design engineer and construction manager to supervise the installations.

The National Electric Code requires organized telephone and data delivery points, grounding and lightning protection. The organized delivery point is met by a backboard where the cable enters the building. (Entering the building can be in the middle, if the cable in under a minimum 2-in concrete slab.) Grounding means a substantial connection to the building ground system. Usually a copper busbar is installed for convenient connection of all the required equipment to the ground. Rack must be grounded and it is good practice to run a dedicated green wire for each piece of equipment to the ground bus.

Selection of telephone and data communications devices (modems, codecs, switches, etc) is not difficult, but the technology advances significantly every 18-months and the manufacturers prefer that high-markup distributors answer questions. It is critical to get detailed connection diagrams and full technical product literature. Again, the equipment will be obsolete almost immediately and the installer will be out of business, absorbed by a national firm or the only technician familiar with your installation will be gone.

Use of sub consultants is discussed at the beginning of this course.

Telephone and Data - Teledata Distribution Closets

There is a rigid set of rules for installation of premises data wiring. They are compiled in EIA/TIA 568 and 569 and published in a readable form in ITSIM (www.bicsi.org).

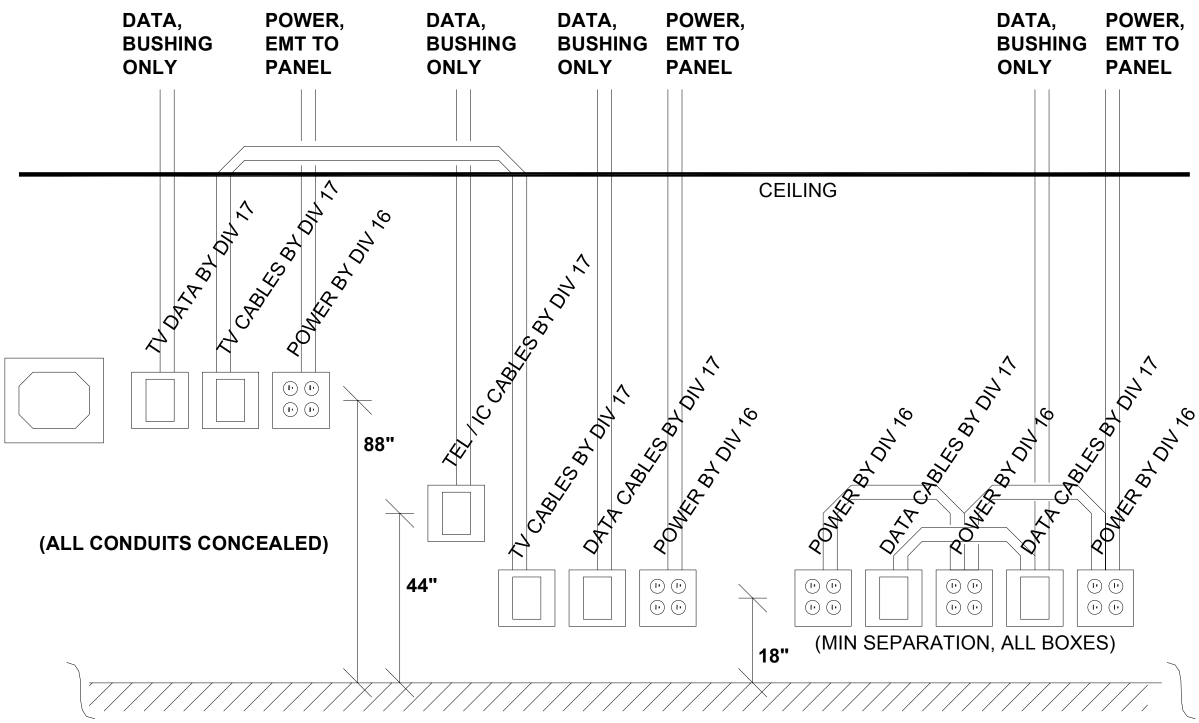
Optional Narrative	EIA = electronics industry alliance, mostly defunct today (www.eia.org) TIA = telecommunications industry association (www.tiaonline.org) 568 = commercial building wiring standard 569 = commercial building standard for telecommunications pathways and spaces ITSIM = Information Transport Systems Installation Manual ($99 manual or CD) BICSI = building industry consulting services international, formerly an organization of Bell telephone company building industry consultants , meaning now suppressed, just the guy with the whip

There are three key factors regarding data closets - space, power and HVAC.

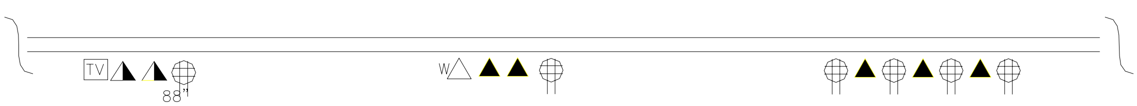
Telephone and Data - Teledata Receptacles and Wireless

Optional Narrative	Used to be, telephone was telephone and data was data. Then, data started taking over unused telephone wiring. Then, data started installing new telephone wiring. Then, data upgraded the requirements for telephone wiring. Then, telephone started using spare data wiring. Today, telephone and data are almost indistinguishable - sharing cabling, racks and outside service providers.

Always put in at least two RJ-45 jacks, one for telephone and one for data. It is desirable to have a duplex, or preferably a quadriplex power receptacle adjacent to the data/ telephone. A sample technology installation detail follows:



TECHNOLOGY GROUPS - ELEVATION



TECHNOLOGY GROUPS - PLAN VIEW

This detail was prepared in response to the request of a school district which preferred to extend their existing co-axial TV system, extend their existing Centrex phone system and install a new data system. There are major economies of construction and maintenance in combining these as different faces of data.

Telephone and Data - Instructional Delivery

Optional Narrative	A popular buzzword in educational circles today is "instructional delivery". Until recently, it meant a bank of DVR and VTR players in the library (media center). The classroom teacher arranged in advance to put a particular video on a particular channel, and the class watched. The next generation was super-humdinger automated DVR and VTR and the teacher could call for the video from a personal computer on the school network. Some states have made efforts to centralize the service and provide high-speed data links to the schools. For the electrical designer, it means almost nothing. The technology guys are already calling for larger conduits than will fit in a standard wall box. Then, they ask for cable bend radius which is impossible in a wall box.

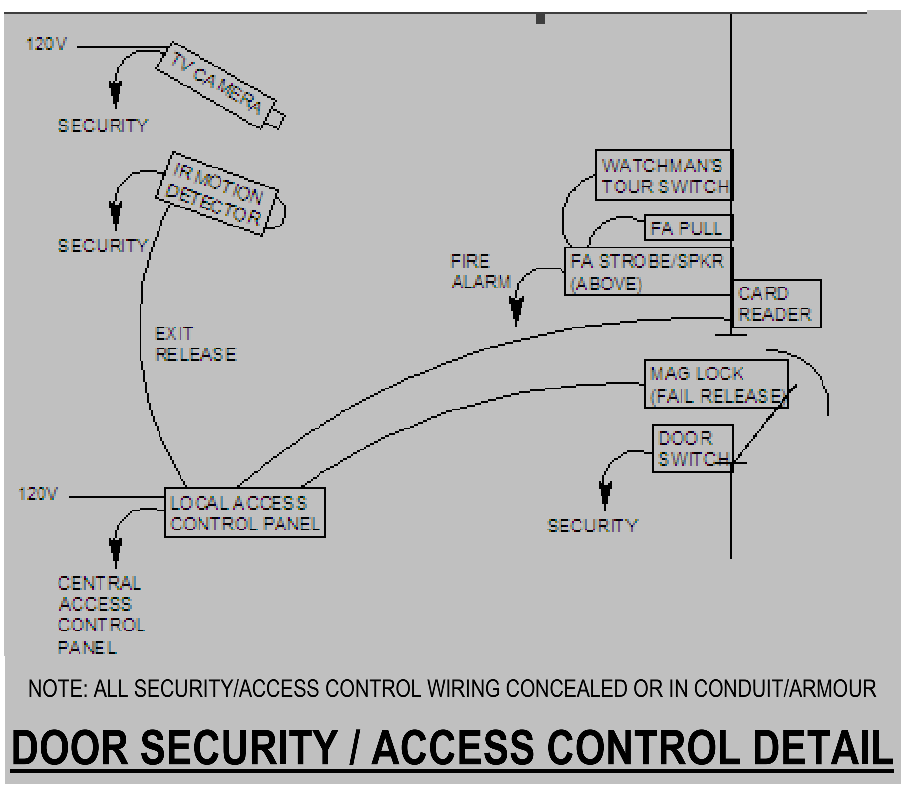
With instructional delivery, more data cables may be required, depending upon the system in fashion on the day the funding is approved.

Constructive suggestions include double-wide extra-deep receptacle boxes and not less than Cat-6 copper. Some schools have had fiber optic to each classroom for years. It works and "dark fiber" is inexpensive. Activate only the strands which are needed by aggressive technically adept teachers, not every room.

We move on now to discussions of security for the school

Security - Access Control Scheme

At one time door locks were access control, then keypads, then swipe cards and now non-contact cards (very, very similar to RFID). While access control was maturing, perimeter monitoring (intrusion alarms) were also maturing and began to overlap. Fire alarm has always been there and also requires a pull station and strobe/horn at each door. The technology becomes massive at each door. The following detail was prepared for an industrial assembly plant. The designer wanted to put a TV camera watching the outside of the door, too, but the Union objected.



Optional Narrative	This TV camera appears to operate on 120V. In fact, it requires a receptacle and comes with its own "wall wart" for 12V or 24V power. The TV cable may be co-ax, fiber-optic or Cat-6 data. If pan-tilt-zoom are required, that control comes down the co-ax or data line - no additional cables are required. The infra red motion detector (PIR) is a backup to the door switch. The local access control panel is a scheme which continues to operate with a cut data cable or out-of-service main panel. The access control panel releases the magnetic lock when the motion detector signals or if a local push-to-exit button is installed. The control logic is programmable. Some doors stay locked unless the fire alarm is pulled (so the fire alarm gets pulled a lot). The door switch indicates to the monitoring point if the door has been wedged open. The card reader requests entry from outside. Programming for specific users and specific times of day are common. The fire alarm pull is self-explanatory. The fire alarm notification device is a strobe/speaker instead of a strobe/horn. There is almost no cost increment, a better life safety system results and the speaker can be used for public address. The watchman tour switch was part of the fire alarm and standard for this Owner. Again, the security system was compromised at design stage by the elimination of the outside TV camera.

Security - Perimeter Monitoring (Intrusion Alarm)

Perimeter monitoring is intended to make a record of persons accessing the facility during "off hours". It can work in conjunction with access control or be a separate system. Today, it usually is incorporated into the CCTV monitoring system - the motion detector alarms, the TV goes into high-resolution recording at that location. The alarm system records the location and the time; the CCTV records the activity, location and time.

Optional Narrative	CCTV has matured radically in the last five years. Co-ax and video tape are marks of an obsolete system. Analog cameras are limited to about 320x240 resolution and require a close-up to identify the suspect. Digital IP cameras, using the data network record a minimum of 640x480 and are available in 1600x1200 at a small incremental price. 1600x1200 gives you the close-up at the door, along with two more close-ups on each side. Cost is 1/5 a pan-tilt-zoom analog camera. Video tape media deteriorate with use and age. A hard disk drive runs and runs and runs, then dies some day. With only a small increment in cost a RAID storage system can be used, whereby a single drive failure does not lose any data.

	Think $1,200 each for 1600x1200 cameras and $8,000 for a 16-channel dvr, sometimes called nvr. Wiring is Cat-6 data, with a single cable handling many cameras at 100 Mbps. (Security cameras take 1 or 2 pictures per second, not continuous motion.)

Security - Security Control Center

The electrical designer usually brings conduits or cable tray from the remote security devices back to a central monitoring facility. Neither the power nor the HVAC requirements are great for the security control center, but many, many conduits will be entering the space A ground bus off the power service entrance ground is desirable.

Optional Narrative	If the electrical designer has partial or full responsibility for the security control center, there are several points to consider - redundancy, ease of use and flexibility for expansion. It is important to have at least two complete, identical consoles. Periodically, one or the other will be out of service. Security is very close to life-safety and must be maintained. The two consoles should be separated enough that technicians can get at the sick one while the operator uses the healthy one. It is critical to group controls that are used together. If the operator will invest 90% of his actions in verifying a person at the door and overriding the magnetic lock, then the screen and the override control should be adjacent, and not require the operator assume an awkward position to use them. If it is expected that supervisors will regularly want to monitor a particular door or area, provide a separate screen and chair; consider a remote feed to a conference room. (Browser-based digital video recorders are almost standard today and very, very flexible for remote monitoring.) A visit to any existing security control center will reveal that it has grown since first installation, usually in a very ugly way. Provide large and extra raceways from the above-ceiling space. Provide large cross-over conduits from one side of the room to the other. Provide receptacles at 2-ft intervals to source all the plug-strips which will appear. Consider an 8-in or even 12-in surface raceway around the perimeter of the room.

We move on now to special systems that didn't fit in any of the general categories.

Special Systems - Public Address, Clocks, Bells

Clock systems, typically, do not work well or long. Many funding agencies are requiring inexpensive quartz clocks in the classrooms, instead. There are a few national suppliers, who work with protected distributors. That is, you pay the local guy's commission, whether you use his help or not. Consult with the Architect and Owner for preferences, then let the distributor design it for you.

Public address almost always includes the bell function today. There are a few national suppliers of school pa systems. Again, they tend to use protected distributors. Try NOT to include intercom in the pa. It works much better as part of the telephone/speakerphone.

Special Systems - Lightning Protection

Optional Narrative	Watch out for the smoke and mirrors. The science involved in lightning strikes is only now beginning to be understood. Statistically, local regions can only predict the number of hits per month. At this time, the only UL-approved lightning protection system is a series of Franklin air terminals, about 20-ft apart, around the perimeter of the roof and crisscrossing it at slightly greater spacing. There must be numerous downcomers of 4/0 braided copper and a ground ring circling the building. If you specify a copper/bronze NFPA-780 system with UL-Master System label, you will have exercised due diligence. A number of installers can bid on it and the Owner will get a totally conventional system. The installer will recommend relaxing the specification to aluminum conductors and hardware. It is an advantage for him, not for you or for the owner. Copper conducts better and your really want that stuff conducted away. A very friendly fellow in a checked suit may offer you an "active" lightning protection. He will have documents and pictures, but he will not have a UL-label Make sure you understand who takes on the liability for a destructive strike and consequential damages after installation and see if a maintenance contract is required.

Specify a copper/bronze NFPA-780 system with UL-Master System label. Take the PDHonline course on lightning protection if you want details.

NFPA-780 has a *computation form* to use in determining whether a lightning protection system is required or not. It is self-explanatory and always yields a result, "Decide for yourself if you want one." Lightning protection is installed when a catastrophic lightning strike is well-remembered by one of the persons on the school side of the table. [Form has been replaced by calculation of assumptions, and N(d) > N(C) --> lighting protection should be installed]

A good grounding system, including rooftop, is required by the National Electric Code, there is no choice. Franklin rods or an active lightning avoidance system is optional, and almost certainly more expensive than rebuilding after a strike. Be warned that the components of a Franklin system bring 50-75 cents per pound on the scrap market. It is common to visit a school roof and find only the holes where the lightning rods and cables were installed.

Special Systems - Fire Alarm System

Fire alarm is hard-core life-safety. As with other special systems there are local vendors who will be very pleased to design the system for you, and, usually, provide the PE seal required by the local Building Standards Department. Very, very rarely another firm will bid on the job based upon a proprietary specification. This may be advantageous to the Owner, especially if he wants to duplicate existing systems at other locations and simply extend his maintenance contract.

The principles of fire alarm design are, pull stations, smoke detectors, heat detectors, kitchen tie-in, elevator tie-in, sprinkler tie-in, strobe/speakers, annunciator and water flow bell. There must be a pull station within 5-ft of every personnel exit door from the building. Consider the plastic guards that sound locally.

Smoke detectors go every 30-ft down the halls, in restrooms and places of assembly. They cost about $50 ea, installed, so be generous. Heat detectors go in the boiler room, mechanical rooms, kitchen, art room and any place that vapors might be present to cause false alarms on smoke detectors. Again, $50 ea, installed.

If the kitchen has chemical suppressant fire protection, then the system must be connected to the central fire alarm (mostly for notification of trouble). There are details on fire alarm elevator connections. See the elevator detail near the beginning of the course. For this section, just be aware that there are several communications channels between the elevator controls and the fire alarm control panel.

The plumber must install sprinkler flow switches and valve tamper switches. The fire alarm must accept signals from them.

Strobe/speakers and a voice-notification alarm system are recommended. As indicated in an earlier section, cost increment is minimal and life-safety benefits are substantial.

The water flow bell outside has nothing to do with the fire alarm, but the sprinkler guys don't like to install water-driven bells, so we usually put in an electric bell as part of the fire alarm. Some localities also require an outside strobe to tell the fire fighters which building is in alarm.

An annunciator is a small screen that indicates where the detector is located that initiated the alarm condition. Vendors like to sell LCD graphic screens. Fire fighters and persons over 50 years of age, with old eyes, prefer an etched graphic and LED indicator.

Special Systems - Theatrical Lighting

The story is getting repetitive. There are only a few national manufacturers. They have protected distributors. No matter who you buy from, the authorized distributor gets the commission. It would appear reasonable to have him help with the design and specification. This is all true, but...

The rep will give you a drawing which can be read only by his firm and his factory. The factory provides the software to do this work very quickly and accurately. A few competitors may be able to decipher the diagram and no-description parts list, but this is dangerous for them. Also, how do you review the submittals?

Second, the major US manufacturers are from 20 to 50 years behind state-of-the-art. Broadway, Europe and the world use DMX-512, a digital protocol with digital lightboards, remote dimming modules and automated spotlights. Spotlights from Australia have 2 to 5x the luminous efficiency of US models, and offer long-life lamps and dichromic reflectors that reduce heat on the stage. The significance of this, for schools, is that kids don't have to handle hot equipment, don't have to climb ladders for lamp replacement as often and equipment and conductors are smaller and less expensive.

Optional Narrative	I enjoy designing theatrical lighting. You can do a credible job after spending about two hours at the local library skimming books on the subject. They give many examples and it is easy to extract the common form and apply it to your job. The local rep will review it for you, but it leaves a bad taste in his mouth to have to bid a job. Be warned, though, that you will need more circuits than you expect. A 48-ch dimmer with 48 outgoing circuits is about minimum. Outgoing raw power with remote dimmer modules is more attractive, design-wise, but more complicated to design and more complicated to revise when you receive comments.

Special Systems - Television Production

Optional Narrative	The problem with electrical design for television production is that there are so many different ways to handle the studio and control room. Everyone has opinions. There will be space and financial constraints. Without exception, though, there will be many conduits, or trenches, connecting the consoles with the racks and the control room with the studio. It is essential to segregate power and video and audio. Fire stopping is required by Code, but must be of a form to permit frequent cabling changes.

Invest the effort to get a good scope of work, what is included and what the limitations are. Provide at least 50% spare conduits. Expect layout and scope revisions, including moving to a different part of the building.

Special Systems - Satellite Dishes and Miscellaneous Antennas

Satellite dishes and wiring and miscellaneous antennas and wiring are not really an electrical design responsibility. On the other hand, they exist, or will exist, and somebody has to keep track and coordinate with general trades.

There are three problems - structural mounting, grounding/lightning protection, and cable entry to the building. Communications suppliers and end-users have very creative definitions of minimal mounting, including things like rope and rags tied together. The National Electric Code requires that equipment be securely mounted and the National Electric Code includes communications devices and cables, Articles 810 and 820.

The National Electrical Code requires that metal structures on the roof be grounded. Even if you are not putting in lightning rods, you need two 4/0 copper downcomers, ground rods and tie-in to the building ground ring. You can connect everything on the roof to a single line.

Cable problems include cable type and building entry. If the cable is to be routed through above-ceiling return-air space, then it must be plenum rated. The required coordination with roofers and glaziers for penetrations has been addressed previously. In a renovation job, any abandoned cables in-place must be removed.

You need a list of dishes and antennas and to check off each as it is coordinated with its owner or provider.

Optional Narrative	How do you know if un-labeled cables are in use or not? No way. Rip them out to comply with Code and wait for the screams.