From the Workbench of Allen Miller . . .

Theatre Organ and the 1990 National Electrical Code

For the first time in many years, the National Electrical Code (NEC) has been revised, including major changes which affect pipe organ installations. The changes were not established without considerable input from the pipe organ industry, and the changes were made to set a uniform standard of good wiring practice.

Members of the American Pipe Organ Builders of America and the American Institute of Organ Builders helped draft the pipe organ section of the code, working with the National Fire Protection Association.

The new Code takes into consideration solid-state components and power supplies which were not in use when the original pipe organ section of the Code was written. Many of the changes are a considerable departure from previous standards, and definitely affect the wiring of theatre organs.

If you are involved in moving, restoring, maintaining, rewiring, or otherwise improving an existing pipe organ, you must be aware of the changes. Original wiring practices and materials are still valid only as long as no changes, modifications or additions are made. All work done after January 1, 1990 should follow the new NEC.

It is not within the scope of this article to cover all of the changes, and much of the NEC was left purposely "general" to give organbuilders some freedom in adapting their individual designs. The National Electrical Code 1990 is available in bookstores or electrical supply houses for about $25, or may be ordered directly by calling 1-800/344-3555.

Specific Changes and New Requirements

The NEC section of interest is Article 650, which covers electrical circuits and controls of the sounding apparatus and keyboards of pipe organs. Electronic organs are covered in a separate section.

The source DC power must be a transformer type rectifier with a potential not greater than 30 volts. This precludes the use of original generators. The rectifier enclosure must be grounded, but not the low voltage side (plus or minus DC).

It should be noted that certain rectifiers of recent production (Astron, for example) DO have their negative terminal grounded to the case. Check with the manufacturer for proper procedure to eliminate this common connection if measurement with an ohm meter confirms a resistance of less than 1K between the output and the case.

Cables must be no smaller than AWG#28 for signal circuits (key contacts) and not less than #26 for magnet operating circuits. In addition, magnet return wires must be no smaller than #14. This refers to individual chest commons.

Insulation must be plastic. This includes modern telephone cable, hookup wire, and nylon/solvar types of wire such as is used by Peterson. Cotton covered (DCC) wire and enamel insulated wire is specifically prohibited. **This means that you may not use original cable if you move or otherwise modify the original wiring of a theatre organ.**

Cabling and bundling of wires and returns is covered by the NEC, and all cables (bundles) must have an outer wrapping or covering which is fire retardant or flameproof unless the cable is completely encased in a metal raceway or conduit. Most electrical tape previously used in pipe organ cabling is not fireproof, and would not be suitable. You can test fireproofing of tape by attempting to burn a short piece. If the tape will burn all by itself, it is not acceptable. If it won't burn at all, or will burn ONLY while a match is held to it, it is acceptable.

It is worth noting that standard Inside Telephone Cable is suitable for pipe organ wiring.

All circuits except for the main supply conductors must be protected from overcurrent by fuses or other such devices rated at not more than 6 amps.

Fortunately, as radical as the fusing requirement may seem, it is not very difficult to implement. Some relays, such as Peterson's have this protection built in. Z-Tronics relays call for such protection in the installation procedures. Other relays, such as Wilcox-Devtronix, Trousdale, and S'Andelco, and even original electro-pneumatic relays can be fused without major fuss.

The easiest way to comply is to run a separate return for each rank and fuse each return. In most cases, the return from each bottom board can be fused.

Within the console, SAM (Stop Action Magnet) units such as Syndynes draw enough current such that it is safe practice to run separate feeds and returns for every 10 stops (at 15 volts) and install fuses accordingly.

It might be worth noting that the popular use of double ceramic toggle magnet Syndyne SAM stop action units requiring 48 volts appears to be in violation of the new (and old) electrical codes. Even if more than 30 volts was allowed at all, a 2 amp fuse would most likely be required at the common feed for each SAM unit. Fortunately, for those desiring a toggle more like original Wurlitzer "C" springs, Syndyne offers a special unit with one ceramic and one plastic magnet which feels the closest to original toggle to this technician, and will operate reliably at 15 volts if carefully adjusted, or at 20 volts in "worst" cases.

American Wire Gauge

For those not understanding American Wire Gauge (AWG), this is a standard way to designate the cross sectional area of wire. The smaller the gauge, the LARGER the size and current carrying capacity of the wire. It is helpful to remember a rule of thumb that any AWG size wire has twice the current carrying capacity of a wire size three gauges smaller.

Thus, a #14 wire will carry twice as much current as a #17 wire would, or four times the capacity of a #20 wire. Since wire is only available in even gauges between #4 and #28, the rule is only helpful as an approximation.

Large wire sizes below #1 are expressed in 0's, such as 00, 000, 0000, usually referred to as 1/0, 2/0, 3/0, 4/0, or "four 'ought."

Wire should be sized according to the maximum current it may be required to handle as well as the minimum voltage drop allowable. The latter depends upon the length of the wire. As a rule, a #14 gauge wire will safely carry a continuous current of up to 15 amps without getting noticeably hot. A #12 gauge wire will safely carry about 25 amps. Using the 3 gauges = 2x formula, you can "guestimate" current capacity of about any gauge wire.

OHM's Law

You can calculate current draw of a magnet using Ohm's Law which states:

I = E/R

Where I = Current in Amperes; E = Volts; R = Resistance in Ohms.

For example, a standard 180 ohm Wurlitzer chest magnet on 12 volts draws 12/180 or .0666 Amps. Ten notes being played on a chest will add up to .666 Amps. It can be seen that a 6 Amp fuse will carry enough current to supply all notes of a standard 73 note chest under these conditions.

Likewise, a 28 Ohm SAM unit will draw .536 Amps at 15 volts, thus a 6 Amp fuse will handle 10 SAM units at 15 volts. A console with 150 stops would draw 80 amps when using a General combination. This kind of current draw is not to be taken lightly, and is just a part of the reason for updating the NEC. With high current supplies other than "pulse" type with capacitor storage, or with battery assisted supplies, most all electric consoles could be considered "welding equipment!"

Voltage Drops

A simplified table of resistance per foot of standard cable used in pipe organ is given from which you can figure voltage drop in the cable. To do this, add the resistance of the wire to the resistance of the magnet to get the total resistance of the circuit. Then divide this total resistance into the supply voltage to get the Amperage of the circuit.

WIRE RESISTANCE PER FOOT

WIRE	OHMS
28	.0653
26	.041
24	.0257
22	.0162
20	.0101
18	.00651
16	.0041
14	.00257
12	.00162
10	.00102
8	.000653
6	.000410
4	.000259
2	.000162
0	.000102
00	.0000811

A complete table may be found in the National Bureau of Standards Handbook.

Transposing Ohm's Law for voltage, we get E = IR, or voltage = current times resistance.

If you take the current in the total circuit and multiply it by the resistance of the coil, you will arrive at the actual voltage across the coil. Likewise, the total current times the resistance of the wire will give you the voltage drop in the wire.

Some technicians like to size chest cables so that the voltage drop is less than ½ volt. With #24 wire and 180 Ohm magnets, this would limit the cable length to about 300 feet.

Solid-state relays with the drivers located in the chambers obviously eliminate the problem of voltage drop due to wire resistance except for the main rectifier feeds to the driver boards and chest commons. It should be taken into consideration that a transistor requires about .6 volts to operate, and thus most solid-state relays have a voltage drop of between .6V and 1.5V depending upon the design. Also, the rectifier voltage will drop as more notes are played.

Sizing the main feeds and returns to avoid additional voltage drops under maximum load will help reduce voltage loss to the chests. Another solution is to avoid long feed and return lines altogether by installing a rectifier in each chamber. In such cases, it will be necessary to establish a common negative or signal "ground" reference between each separate rectifier and the console or solid-state relay apparatus. Usually a relatively small conductor, such as #18 will suffice. The relay manufacturer should be able to assist you with proper hookup procedure.

This article is intended to inform the reader of the new code, a reasonable interpretation of its intent, and some guides for its implementation. Local codes may vary in their interpretations, and we cannot cover all circumstances. You should also be aware that other articles in the code cover 120 and 240 volt wiring systems, and that Article 518 imposes additional requirements for Places of Assembly accommodating over 100 persons.

Fortunately, the major organ supply houses and builders of electrical accessories and solid-state equipment are attempting to comply wiht the new code and should be able to assist you with specific questions concerning installation or use of their products.

I wish to acknowledge Jack Bethards, Richard Peterson, and the American Institute of Organbuilders for their input.