Immunity - Radiated and Conducted - the effects of equipment external to the organ producing interference radiated through the air and conducted through the mains that may cause the pipe organ to malfunction. Degradation in performance is acceptable, and may be specified by the supplier of the equipment. Memory corruption in piston combination systems may not be desirable but is allowable.

Radiated Immunity - usually tested in a screened room. Sometimes mobile phones manifest a problem in this area. If a problem, restrict the use of mobile phones.

Conducted Immunity - usually tested in a screened room. Modern lighting systems may cause problems. Is it the organ or lighting system?

Electrostatic Discharge ESD - May be a problem with some displays and keying systems.

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Low Voltage Code of Practice

INTRODUCTION

It is fair to say that no standard exists for the low voltage wiring of pipe organs despite many thousands of instruments giving reliable service. What has evolved is that some of the larger companies have developed an "in-house" style or design which has been adopted by smaller companies. In recent times the use of solid state systems, which generally fit into a smaller footprint than the earlier electromechanical switching systems, has necessitated changes in design and layout.

Pipe organs vary in size - small chamber organs to large Concert Hall / Cathedral organs. One size does not fit all. Aesthetics play an important part in the external appearance of the organ, yet little or no attempt is made by some organ builders to apply the same principles to internal electrical components and connections.

MAINS WIRING AND ELECTRICAL STANDARDS.

In the UK the main regulation and control of mains electrical installations is by means of Building Control and the IEE regulations. Some differences exist in the way England, Scotland and Northern Ireland enforce the legislation. All 240 or 415 volts ac mains wiring should be carried out by approved electrical contractors to BS 7671. This will include all fixed mains wiring from the distribution board to plug socket outlets. Suitable fusing must be provided together with a low impedance earth connection.
Note: BS 7671 only covers fixed mains installations to the plug socket. It does not cover any equipment that is plugged into a mains socket.
A box or portable organ with a three core mains would need to be correctly fused and be the subject of periodic Portable Appliance Testing. The owner of the organ would be responsible for testing and maintaining the electrical integrity of the organ. Also, any mobile console that is plugged into a 13 amp socket with a three core mains flex should be periodically PAT tested by the owner.

Fixed electrical equipment that is sited within the organ casework is not subject to any PAT testing.

ELECTRICAL PRODUCT STANDARDS.

The purpose of EU Directives is to allow the free movement of goods across all 27 member states. Within the EU all electrical products must conform to a product specific or generic standard. All EU Directives are concerned with the safety and welfare of the user and compliance is usually indicated by the CE mark. The principle Directive for electrical equipment is the Low Voltage Directive 73/23/ECC dated 19th February 1973, amended by 2006/95/EC dated 12th December 2006.

The Low Voltage Directive (LVD) is an electrical safety Directive that applies to all electrical products which are designed to operate with a voltage rating of 50 – 1000 volts ac or 75 – 1500 volts dc and whose hazards are primarily of an electrical nature. Therefore, the Low Voltage Directive only applies to the mains side of power supplies.

The essential requirement of the directive is that electrical equipment may be placed on the market only if it has been constructed in accordance with good engineering practice in safety matters in force in the Community, and it does not endanger the safety of persons, domestic animals or property when properly installed and maintained and used in the application for which it was made.

EN 60950-1:2006 is the specific standard that relates to information technology equipment and best fits the control systems that are installed in the pipe organ. In other parts of the world similar standards also exist which are partially distilled from the EU Directive. The application of a safety standard is intended to reduce the risk of injury or damage due to the following:

1. electric shock
2. energy related hazards
3. fire
4. heat related hazards
5. mechanical hazards
6. radiation
7. chemical

Distinction is made between the user and service personnel who should be suitably trained and competent to enter inside the organ case and service the various mechanical and electrical elements of the organ.

Appendix D. EMC Directive

This Directive is possibly the most difficult to comprehend. The pipe organ builder is required to prove that the complete product, the pipe organ, is compliant with the various parts of the Directive. Advice should be sought from the supplier of any electronic equipment.

Very briefly, the EMC Directive is a further piece of legislation introduced to protect the health and safety of the public at large. The increased sales of consumer products containing some form of microchip has increased the invisible electromagnetic "smog" with the result that some products malfunction when subjected to certain forms of external interference. Most people are aware of the restrictions placed on the use of mobile phones and other electronic equipment in areas that use life supporting electronics such as hospitals and aeroplanes. The purpose of the Directive is to create a level playing field so that any interference from an external source does not have any life threatening consequences. The Directive gives levels for how much a product can radiate and how much radiation the product should tolerate. Normally, tests are carried out to a generic standard that covers apparatus intended for use in residential, commercial and light industrial environments, for which no dedicated product or product family emission standard exists.

Emissions - Radiated and Conducted - the effects on equipment external to the organ from interference radiated through the air and conducted through the mains by the pipe organ.

Radiated Emissions - the most difficult to determine. For small consumer products this is normally determined using an open area test site at 30, 10 or 3 mtrs. Larger installations require site testing once the whole installation is complete. Generally, only electronic equipment with clock frequencies greater than 9 kHz need to be tested. Clock speeds and software configuration can significantly change the levels of radiated emissions.

Conducted Emissions - determined using a Line Impedance Stabilisation Network (LISN). Usually any problems can be corrected by fitting external filtering.

Return cables need more careful consideration, but as a general rule 2.5 or 4.0 sq mm should be used. This should be confirmed by calculation.

Feed cables from power supplies will need to be checked for volt drop under worst case conditions.

For long cable runs voltage drop should be considered using the following equation:

Volt drop per cable = Current in *amps* x cable factor x length in *metres*

Area sq mm	Cable factor
0.22	0.085
0.5	0.037
0.75	0.025
1.0	0.018
1.5	0.013
2.5	0.008
4.0	0.005
6.0	0.003
10.0	0.002
16.0	0.001
25.0	0.0008

Users should not be exposed to any hazards that are likely to cause injury. Normally this is not a problem as the user, the organist, has only contact with keyboards, drawstops, piston and playing aid buttons.

A good example of this approach is a television set. The user has access only to controls and the service person needs to remove the rear cover of the set to gain access to the electronics. A warning label is affixed to the rear cover warning of the danger. This is a simple approach and worthy of adoption by pipe organ builders to restrict access to the inside of the organ to only suitably competent persons.

A further issue is the question of insurance. Organ builders' insurance covers only persons in their employment or acting on their behalf.

ELECTRIC SHOCK.

Normally pipe organs operate from 12 to 24 volts dc. This low dc voltage, which is below that referred to by the Low Voltage Directive, is generally provided by some form of voltage converter that reduces the mains voltage to 12 to 24 volts dc. The use of CE compliant power supplies will ensure that the low voltage output is completely isolated from the mains input so that during operation and fault conditions there is no chance of any person that touches the low voltage terminals receiving an electric shock. It is therefore vital that organ builders use only power supplies that are compliant with TUV EN60950-1 and other safety standards such as UL 60950-1.

Older installations should be checked to see if the power supply is compliant and that there is no possibility of mains voltage appearing on the low voltage output terminals. Transformers should comply with EN 61558-1 and have the primary and secondary windings separated by an earthed screen.

ENERGY RELATED HAZARDS

The standard refers to a maximum energy level of 240 VA that should not be exceeded between two opposing voltage terminals without some form of barrier. The purpose of the barrier is to prevent the two low voltage output terminals being accidentally bridged by a metal object. Accordingly, all circuits with a current of more than 13.3 amps at 18 volts dc should be provided with an insulated barrier between the two terminals.

Shrouding or covering the terminals should only be considered if it is impracticable to fix an insulating barrier between the two terminals. This is because it is still possible to bridge the terminals if the cover is removed.

Those organ builders who prefer to use four or eight way earthing blocks are recommended to position the blocks with a minimum separation of 50mm with an insulating barrier placed between so that there is no risk that the two terminals can be bridged with a metal object.

See appendix A for details of connectors and terminals.

FIRE

The standard also refers to circuits that have a lower energy level of less than 100VA. At 18 volts dc this equates to circuits with a current of 5.5 amps or less. Care should be exercised in mounting printed circuit boards with power devices so that in the event of a fault condition the immediate area is not ignited.

Protection against fire is achieved by limiting the current flow so that components and wiring do not ignite and cause a fire. Power supplies that comply with EN 60950-1:2006 will normally have some form of over current protection. This will generally be higher than is permissible for most of the wiring within the pipe organ and some form of secondary fusing will be required to protect these circuits.

Fusing -

Fusing is often seen as a nuisance and is often neglected. The purpose of a fuse is normally to protect the conductor from overheating and thus preventing a possible fire source. In a pipe organ, if the volt drop is to be kept to acceptable levels cables will normally carry considerably less than their safe current. In this situation the fusing must be designed to protect the components at each end of the cable. This may be provided in the form of individual fuses or, with modern systems, some form of protection included within the system.

See appendix B for the fuse rating of copper wire.

Appendix C. Current carrying capacity of connection wires

Using a supply of 12 - 24 Volts DC most of the connecting cables will be sized to keep the volt drop to an acceptable level and, generally, be well within the safe conducting current. It is simple to verify this by calculating the main cable runs.

Cables should be to a British Standard or other relevant standard and, for use in America, may need to be UL approved.

The tradition of using red for positive and black for negative should be continued.

Current carrying capacity of Tri-Rated control & switchgear cable:

0.5	sq mm	16/0.2 mm	10 amps
0.75	sq mm	24/0.2 mm	13 amps
1.0	sq mm	32/0.2 mm	18 amps
1.5	sq mm	30/0.25mm	22 amps
2.5	sq mm	50/0.25mm	31 amps
4.0	sq mm	56/0.3 mm	41 amps
6.0	sq mm	84/0.3 mm	53 amps
10.0	sq mm	80/0.4 mm	75 amps
16.0	sq mm	126/0.4mm	100 amps
25.0	sq mm	196/0.4mm	136 amps

The current in a conductor can be calculated by using Ohms Law.

Current = Voltage/Resistance

For a typical action magnet with a resistance of 100 Ohms working on a voltage of 15 volts dc.

The current is equal to 15/100 = 0.15 amps.

As a general rule all inputs from keys, stops, thumb pistons and playing aid buttons should be wired using 0.5 sq mm cable.

Wiring to action magnets should use 0.5 sq mm cable.

Wiring to slider solenoids should use 1.0 sq mm cable.

Appendix A. Connections & Termination.

The main purpose of a connector or terminal is to safely join two electrical conductors so that electric shock or the risk of combustion are eliminated. Also very important is the reliability of the connection. It is important that the terminal or connector is rated to safely carry the current that will occur during the operation of the organ. Attention to detail is vital to make a good connection that will last at least 25 years.

Many types of connectors and terminals found in pipe organs:

Brass studs.
Crimp terminals.
Pin terminals.
Insulation displacement connectors.
Test pins in purpose made test boards.
Terminal strips with cable protection.
DIN 41612 or other two part connectors.

Appendix B. Ratings of tinned annealed solid copper wire used as a fuse.

35 Swg	5 amps
29	10
25	15
24	17
22	25
20	33
18	45
16	70
14	100

Circuits for drawstop and slider solenoids which are driven with a pre-determined timing pulse should not need additional fusing. Most slider control cards are fused to protect the electronic device during fault conditions.

Older types of systems using multi-contact relays need more careful consideration.

See appendix C for current carrying capacity of cables.

HEAT RELATED HAZARDS

All power supplies generate heat. Steps should be taken to allow the free circulation of air and not to entomb power supplies in wooden cabinets that may compromise ventilation. Where possible, all circuit boards containing power devices should be mounted vertically to allow the free movement of air.

MECHANICAL HAZARDS

In some large pipe organs vibration may be a problem. In such circumstances it is advisable that any electronic control system is fixed to a solid support that is free from vibration. The organ builder should also mount power supplies so that no movement is possible.

RADIATION HAZARDS

Normally this is not an issue but the organ builder must be aware that the pipe organ must also comply with the EMC Directive.

See appendix D for a brief description of the EMC Directive

CHEMICAL HAZARDS

This is not relevant to pipe organ installations.

DECLARATION OF CONFORMITY AND SUPPORTING PAPERWORK.

The pipe organ builder is responsible for placing the pipe organ, the product, on to the market and making the necessary Declaration of Conformity, DOC, to prove that the product complies with the relevant Directives. In the case of most pipe organ installations this will be supported by a Technical Construction File (TCF) which will probably take the form of a job file containing all the technical information relating to the pipe organ and the installation. This file may not be restricted to details of electrical/electronic equipment and may contain other technical data.

OTHER DIRECTIVES

Machinery Directive

The impact of this Directive is small and relates generally to equipment that has moving parts. Obviously an area of interest is blowers, bellows, feeders and swell mechanisms. The Directive also covers stop start switches. Mains switches fitted to the side of reservoirs to activate low voltage power supplies are clearly not compliant.

QUALITY MANAGEMENT SYSTEM.

In other industries quality management systems are designed to put in place procedures that make sure that the various Directives and standards are observed. The purpose of any quality system is to demonstrate to the customer that some form of system is in place that will guarantee that the pipe organ is consistently made and serviced to a determined quality standard.

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