

Control Wiring

Comparison of differences in IEEE C37 series standards

General Wiring Requirements

General Wiring

- C37.20.2, C37.20.3, and C37.20.9 (draft) all contain the following wording:

Flame-resistant, 600 V insulated stranded copper wire shall be used for internal wiring between components of switchgear assemblies and to terminals for connection to external controls, metering, or instrumentation. Wiring within components is assumed to be covered by standards applicable to those devices and is not covered by this standard. Wiring for the purpose of conveying power to external switchgear loads is not covered by this clause.

The switchgear manufacturer is responsible for the performance of the wiring system provided by the manufacturer within the switchgear. This applies to the integrity of internally generated signals in the control wiring and may require the use of special precautions such as shielded wire and segregation of certain wires.

- C37.21 is similar but uses “switchboard” in place of “switchgear” and also adds “No splices shall be allowed in the switchboard wiring.”

General Wiring (continued)

- C37.20.1 inserts the following sentence after the first sentence of the first paragraph:

“All wire used to connect instruments, meters, relays, or other components directly to the main power circuit of ac or dc switchgear, shall have an insulation rating equal to or greater than the maximum voltage of the assembly and subject to dielectric tests in accordance with 6.2.3.”

General Wiring (continued)

- C37.20.1 also includes the following regarding DC control circuit wiring:

For LV dc switchgear, wiring used to connect instrument, meters, and relays directly on circuits up to 3200 V, and any wiring connected directly to higher voltage circuits in LV dc switchgear rated up to 3200 V, shall use wire rated for the maximum design voltage of the switchgear.

Summary – General Wiring

- The text in C37.20.2, C37.20.3, and C37.20.9(draft) is identical and is appropriate as written – no change needed
- The only difference in C37.21 from the above is the use of the word “switchboard” in place of “switchgear” – no change needed.
- C37.20.1 uses the same text, but adds information for DC switchgear, plus dielectric requirements – no change needed.

Recommendation – General Wiring

- It is recommended that no change be made to the requirements of the general wiring sections of any of the standards.
- Purely for consistency sake, it might make sense to restructure how C37.20.1 is worded (move the extra sentence to a different paragraph, so that the remaining paragraphs are identical in all standards).

Wiring Across a Hinge

Wiring Across Hinge

- C37.20.2, C37.20.3, and C37.20.9 use the same wording:

Wiring that crosses a hinge shall be suitable for this use, as defined by the following criteria:

- a) The wire shall be sufficiently flexible to withstand repeated door movement without sustaining damage to wire strands or insulation.
- b) The loop formed by the wiring as it crosses the hinge shall be secured to the equipment at both ends in such a manner that negligible strain is transmitted to wire beyond the securements.
- c) The wire loop is to be protected between the securements to provide a degree of protection against damage to the wire insulation as the door is moved.
- d) No sharp edges or objects are allowed in the path swept by the wire loop as the door is operated.
- e) Wire shall be No. 14 AWG and larger, and C or D stranding.

Wiring Across Hinge

- C37.21 uses almost the same wording but item e) no longer requires 14 AWG or larger conductors across the hinge:

Wiring that crosses a hinge shall be suitable for this use, as defined by all of the following criteria:

- a) The wire shall be sufficiently flexible to withstand repeated door movement without sustaining damage to the wire strands or insulation.
- b) The loop formed by the wiring as it crosses the hinge shall be secured to the equipment at both ends, in such a manner that negligible strain is transmitted to wire beyond the securements.
- c) The wire loop is to be protected between the securements to provide a degree of protection against damage to the wire strands or insulation as the panel is moved.
- d) No sharp edges or objects are allowed in the path swept by the wire loop as the panel is operated.
- e) For No. 14 AWG and larger wire, stranding shall be C or D stranding.

Wiring Across Hinge (continued)

- Likewise, C37.20.1 also does not require No. 14 or larger across the hinge. It also adds item a), which is actually redundant since all wiring must meet 7.1.3.1.3.

Wiring that crosses a hinge shall be suitable for this use, as defined by the following criteria:

- a) Wire shall be sized according to 7.1.3.1.3, and
- b) The wire shall be sufficiently flexible to withstand repeated door movement without sustaining damage to wire strands or insulation, and
- c) The loop formed by the wiring as it crosses the hinge shall be secured to the equipment at both ends, in such a manner that negligible strain is transmitted to wire beyond the securements, the door can be opened a minimum of 90 degrees, and
- d) The wire loop is to be protected between the securements to provide a degree of protection against damage to the wire insulation as the door is moved.
- e) No sharp edges or objects are allowed in the path swept by the wire loop as the door is operated.
- f) If No. 14 AWG and larger wire is used, the wire shall be Class C or D stranding.

Summary – Wiring Across Hinge

- All the standards have essentially the same wording as to how to protect the wiring across the hinge.
- C37.20.2, C37.20.3, and C37.20.9 currently require all wiring across the hinge to be No. 14 AWG minimum, and require that the wiring have C or D stranding.
- C37.20.1 and C37.21 allow the wiring across the hinge to be as small as No. 18 AWG, and also allow multi-conductor signal/communication wiring or thermocouple wire to be across the hinge. Only when the wire is 14 AWG or larger, is the wire required to have C or D stranding.
- C37.20.1 introduces the 90 degree swing requirement from the NEC.

Considerations from other Standards

- For residential refrigerators, the wiring is subject to 150,000 cycles of opening and closing the door, followed by dielectric testing. (UL 250)
- Commercial refrigerators and freezers go through 100,000 cycles, followed by a dielectric. (UL 471)

Considerations from other Standards

UL 508A (Industrial Control Panels)

- a) Stranded conductors;
- b) Routed secured and protected to prevent damage; AND
- c) Wiring shall be identified for flexing duty, class K, or welding cable, or machine tool wire 8 AWG or larger.

UL 508 (Industrial Control Equipment) and UL 508C (drives)

- a) flexible cord;
- b) provided with additional insulation; OR
- c) subjected to a 500 cycles of opening door followed by dielectric testing

Considerations from other Standards

UL 891 (Dead Front Switchboards)

- a) Stranded conductors;
- b) If larger than 6 AWG, copper conductors of extra flexible type; AND
- c) Routed secured and protected to prevent damage

UL 1008 (Transfer Switches)

- a) Multi-stranded;
- b) Flexible or extra flexible construction; AND
- c) Protected where the wiring can contact grounded surfaces

Recommendation – Across Hinge

Use most of wording from C37.20.1, modified as shown below:

Wiring that crosses a hinge shall be suitable for this use, as defined by the following criteria:

- a) The wire shall be stranded wire, and
- b) The wire shall be identified as flexible wire, and able to withstand repeated door movement without sustaining damage to wire strands or insulation, and
- c) The loop formed by the wiring as it crosses the hinge shall be secured to the equipment at both ends, in such a manner that negligible strain is transmitted to wire beyond the securements, and
- d) The wiring shall not prevent the door from opening a minimum of 90 degrees, and
- e) The wire loop is to be protected between the securements to provide a degree of protection against damage to the wire insulation as the door is moved, and
- f) No sharp edges or objects are allowed in the path swept by the wire loop as the door is operated, and
- g) If the wire is No. 14 AWG or larger wire, the wire shall be no less flexible than Class C or D stranding.

Wire Size

Wire size

- C37.20.2, C37.20.3, and C37.20.9(draft) all use the same language:

7.3.3.2 Wire size

Wire shall be suitable for the anticipated maximum steady-state load. The size chosen should also accommodate voltage drop within the switchgear, including the effect of intermittent heavy loads (shunt trip coils, inrush from relays, and the like). The following criteria shall be used as minimums:

Maximum steady-state load (A)	Minimum wire size (AWG)
$30 < \text{Load} \leq 40$	No. 8
$20 < \text{Load} \leq 30$	No. 10
$15 < \text{Load} \leq 20$	No. 12
$10 < \text{Load} \leq 15$	No. 14
$7 < \text{Load} \leq 10$	No. 16
$\text{Load} \leq 7$	No. 18

EXCEPTION: Multiple-conductor cable (two or more insulated wires inside a common insulated jacket) used in logic-level and/or supervisory circuits may use wire sized as required by the circuit.

Wiring for control loads over 40 A shall be applied using ampacities from the 75 °C column of Table 310.15(B)(16) (formerly, table 310.16) in National Electrical Code® (NEC®) (NFPA 70).

Wiring for current transformer and shunt trip circuits shall be no less than No. 14 AWG, regardless of load.

Thermocouple wiring is specifically excluded from the above ampacity requirements. It shall meet the voltage, current, and temperature requirements of the circuit in which it is used and the location where it is installed.

Wire size (continued)

- C37.20.1 uses the same language, but adds a line:

Wire connected directly to the main power circuit of the dc traction power switchgear bus system shall be at least No. 14 AWG.

- C37.21 uses the same language, but adds a note:

NOTE—Where long connections to the control source are necessary, the cable must be large enough to prevent excessive voltage drop.

Summary – Wire Size

- C37.20.2, C37.20.3, and C37.20.9 all have a conflict with respect to wire size. They have ampacity tables that go down to No. 18 AWG, and allowances for smaller multi-conductor signal/ communication cables, but the requirement that all wiring must be SIS wire effectively requires 14 AWG minimum, since the definition of SIS wire according to the wire and cable standards requires 14 AWG minimum.
- C37.21 avoids this conflict by specifically allowing other types of wire when required for a component.
- C37.20.1 also avoids the conflict by saying SIS is preferred, which allows any wire type to be used.

Recommendation – Wire Size

- Maintain the common wording currently in the standards, but revise the last paragraph as follows:
- ~~Thermocouple~~ When required for connection to a specific component, low-energy signaling and communication wiring is specifically excluded from the above ampacity requirements. It shall meet the voltage, current, and temperature requirements of the circuit in which it is used and the location where it is installed.

Wire Type

Wire type

- (Control) wiring shall be 600 V, 90 °C, and flame-retardant
- Shall meet the requirements of NEMA WC70 / ICEA S-95-658 as applicable. (C37.20.1 does not include “as applicable”)
- Type SIS as listed in NFPA 70 or an equivalent such as XHHW, or RFHH-2
 - C37.20.1 says SIS is “preferred”
 - C37.20.1 includes “RFHH-3”
 - “or the like” appears after XHHW and RFHH-2 in C37.20.1 and C37.20.3
 - C37.20.1 also includes the statement “Other wires which meet the requirements of this clause are also acceptable.”
- C37.20.1 also states “Wiring used for connection directly on circuits above 600 V shall be rated for the voltage involved (or higher), 90 °C, and shall be flame-retardant.”
- C37.20.2 also states “In addition, wiring used for dc circuits for rated voltages of 48 Vdc or above shall not contain PVC insulation.”

Wire type (continued)

- C37.21 also includes several clauses that aren't in the other documents:

EXCEPTION: In addition, low-energy signal wiring may be used as required by the manufacturer of a specific component. This exception includes wiring such as the following:

- Remote thermal devices (RTDs)
- RS232 conductor
- RS485 conductor
- Thermocouples
- Coaxial cables
- Fiber optics
- Ribbon cables
- Shielded twisted pair
- Unshielded twisted pair

Special consideration of such wiring should be given with respect to criteria in 7.1.5.1.1.

Low-energy signal wiring shall be separated from wiring operating at higher voltages unless both wires are insulated for the highest voltage.

Summary – Wire Type

- C37.20.2, C37.20.3, and C37.20.9(draft) still require the use of SIS wire (or two alternates). There are no exceptions.
- C37.20.1 suggest the use of SIS, but since it uses the word “preferred”, it is not a requirement at all.
- C37.21 requires the use of SIS except for low-energy signal wire when required for a specific component.

Suggestion – Wire Type

- Suggest adding the “Exception” from C37.21 to all the documents. This solves the wire ampacity issue as well:

EXCEPTION: In addition, low-energy signal wiring may be used as required by the manufacturer of a specific component. This exception includes wiring such as the following:

- Remote thermal devices (RTDs)
- RS232 conductor
- RS485 conductor
- Thermocouples
- Coaxial cables
- Fiber optics
- Ribbon cables
- Shielded twisted pair
- Unshielded twisted pair

Special consideration of such wiring should be given with respect to criteria in 7.1.5.1.1.

Low-energy signal wiring shall be separated from wiring operating at higher voltages unless both wires are insulated for the highest voltage.

Motion

To continue work in the ad-hoc for the purpose of proposing common requirements (expected to be included in amendments at a later date) for C37.20.1, C37.20.2, C37.20.3, and C37.21 such that the “Wire Type”, “Wire Size”, and “Wiring Across the Hinge” sections have requirements that are consistent across all the standards, with the understanding that C37.20.1 will retain any special requirements for DC control wiring that may not exist in the other standards.

Furthermore, to provide these requirements to the working group for C37.20.9, such that these requirements will also be harmonized.

Thanks for your consideration!