Category confusion

One of the most contentious and often misunderstood aspects of machinery safety is choosing the category of control circuit for a particular machine, writes Martin Keay.

There are several categories of control circuit defined in European standards: categories 0, 1 and 2 for stop circuits, and categories 0 and 1 for emergency stop circuits. But the categories that cause the most debate appear in BS EN 954-1 *Safety of machinery – safety related control circuits.*

BS EN 954-1 defines five categories of control circuit – B, 1, 2, 3 and 4 – but before we start worrying about the detail of each category, it is important to understand that category selection should be an integral part of the whole process of machinery risk assessment, rather than an exercise carried out by the electrical department in total isolation.

In machinery risk assessment the first step is to identify and evaluate the hazards on the machine, then use this information to decide which hazards need to be eliminated. This hazard information will be used to produce a provisional design for safeguarding the machine, which may include fixed guards, interlocked guards, interlocking devices, stop buttons, control relays, emergency stop buttons, photosensitive devices and so forth.

The next phase of machinery risk assessment considers what happens if any of these safeguarding features fail, are defeated, are wrongly adjusted or missing. This is the point in the machinery risk assessment that the category of control circuit becomes important, because the effects of these failures can be minimised by selecting a suitable category of control circuit.

Risk assessment should also be applied to the control circuit components to estimate, in the light of experience, what is the most likely reason for failures and how often those failures are likely to occur. Mechanical wear or damage and deliberate defeat need to be considered as well as the more obvious electrical and fluid power failure modes.

This failure mode analysis, as it is sometimes called, should also help to decide whether the extra expense and complication of a category 2, 3 or 4 circuit can be justified. For instance, if contactor welding is identified as a hazard, but very unusual and even then only after extended operation, it may be more appropriate for the manufacturer to recommend that a contactor is renewed after five years of operation, rather than installing a monitoring system that may only detect a fault once in 20 years.

So what are the different categories of control circuits and when should they be used?

Category B is the basic category for safety related parts of control circuits, requiring that the circuit and components comply with the relevant standards, and use basic safety principles that are suitable for the specific application, so that they are able to withstand the expected operating stresses.

Loss of safety function

However it is recognised that in a category B circuit a single fault can lead to the loss of the safety function and so category B is generally considered to be only appropriate for machines which contain minor hazards.

In category 1, 'well-tried' components are used to give improved resistance to faults. A 'well-tried' component in this context means a component which has been widely used in the past with successful results in similar applications, or has been made and verified using principles which demonstrate its suitability and reliability for safety-related applications.

Monitoring relay: *Pilz PNOZX4 emergency stop and safety gate monitoring relay*

Typical 'well-tried' components include contactors with guided contacts, positive mode limit switches, captive-key mechanical interlocks, mechanically reliable push buttons and rotary isolators. However plug-in relays, reed switches, proximity switches, and photo-sensitive devices are known to have high failure rates and cannot be considered 'well-tried'. They should not therefore be used in a category 1 control circuit.

Well tried means reliable

A well tried component must be both mechanically and electrically reliable and so, for instance, designs of push buttons that fall apart when they are hit hard, or limit switch cams that are only attached to shafts with grub screws, need to be avoided if the category 1 status of a machine is to be maintained.

As with category B, the failure of a single component in a category 1 circuit can lead to a loss of the safety function, however on some well-tried components certain faults can be excluded because the fault rate is known to be very low.

In categories 2, 3 and 4, improved resistance to failure and loss of the safety function is achieved predominantly by improving the structure of the safety-related part of the control system.

In category 2 circuits, safety functions are checked periodically to ensure that they are being performed. The safety functions can be checked using the machine's PLC, but one of the most convenient methods of checking is to use a monitoring relay such as those made by Pilz. BS EN 954-1 does not stipulate how often checking should take place, so to understand the level of safety being provided in a category 2 circuit, it is important to establish how often checking occurs, and which functions are checked.

In categories 3 and 4, additional resistance to failures is provided by designing the circuit so that a single fault will not lead to the loss of the

safety function, which is usually achieved by duplicating the circuit. But here too there is debate and confusion.

Some people, particularly in Germany, consider that it is sufficient to wire up two sets of contacts in a single interlocking device to achieve category 3. But if this interlocking device were to become unscrewed from its fixing position, the safety function would be lost, because both circuits would be immobilised simultaneously. So is this really category 3 or is it necessary to have two interlocking devices on every guard door to achieve category 3 and 4?

In category 4, and whenever reasonably practicable in category 3, faults will be detected and the machine brought to a halt. However one of the problems with category 3 circuits is that because circuits are duplicated, faults can go undetected and may therefore accumulate to the point where the safety function is lost following a single additional fault.

Accumulation of faults

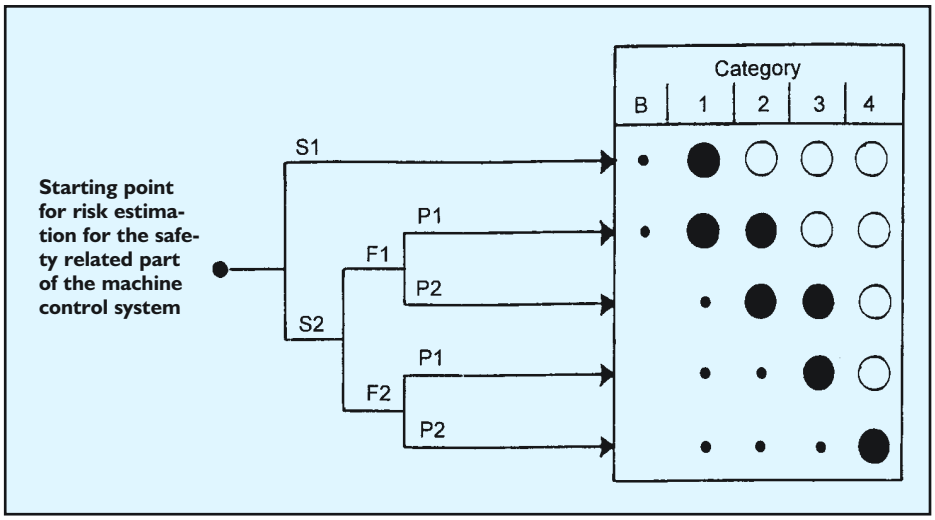
In a category 4 circuit the objective is to detect every fault immediately. However, in practice this is not always possible, so the resistance to the accumulation of faults must be specified for a category 4 circuit.

This all begs the question that since there are potential weaknesses with all categories of control circuit, apart from category 4, should category 4 be used in every situation?

Until recently this might have been thought to be an entirely impracticable suggestion, because achieving category 4 is very complicated using hard wiring techniques. However, with the new BUS safety systems, which have been approved as category 4 in Germany, it should be relatively easy to apply category 4 to almost any machine.

But be careful. While BUS safety systems have been approved in Germany, they have not yet been accepted by the HSE or at a European level by CEN or CENELEC. Indeed, it boils down to exactly the same issue discussed in the last issue of *Machinery Update*. Is it acceptable to depend on electronics and software when it comes to matters of safety? So let's leave BUS safety systems to one side at the moment.

Whatever category of control circuit is chosen it must be maintained in good working order, and the more complex the system, the more difficult it is to keep running. Moreover, systems that keep stopping the machine, for no obvious reason, have a nasty habit of being bypassed or disconnected in the long dark hours of the night shift.



Assessing the risk: *Decision tree for selection of categories from BS EN 954-1*

Severity of injury	Frequency of exposure to the hazard	Possibility of avoiding the hazard
S1: Reversible injury	F1: Infrequent access	P1: Possible to avoid injury
S2: Irreversible injury	F2: Frequent access	P2: Not possible to avoid injury

● Preferred category
• Possible category
O Over engineered for the risk

There is also a danger with category 3 and 4 circuits in that people assume that any fault will be detected automatically, absolving them from the need for routine visual inspection of safety components ,to check they are in good working order and are not about to fail.

So choosing too high a category of control circuit may actually be counter productive.

BS EN 954-1 uses a decision tree to explain how the category of control circuit should be selected, which includes the variables of the severity of the injury likely to be caused, the frequency of exposure to this hazard and the possibility of avoiding an injury if a safety component fails. But how does this work out in practice?

Pie and tart machine standard

Probably the best way to explain this is to follow the decision making process used by the writers of the European standard for pie and tart machines, which is shortly to be published.

Pie and tart machines come in various shapes and sizes, but they all include a heated forming tool, which can cause a disabling injury. On semi-automatic pie and tart machines an operator has to place dough into the machine, operate the machine and then remove the formed pie. This means that the operator has to place his hands in the danger area on every cycle of the machine and, if the forming tool moved when his hands where in this area, a serious injury would be almost inevitable.

Consequently the European standard requires these machines to have safety circuits that conform to category 3, so that no injury can occur even if one of the safety components fails.

On higher speed pie and tart machines, the operator places dough into a rotating carousel and does not have to reach into the danger zone every cycle, although it is common for a trip flap to be fitted to these machines to stop the rotary table if the operators hands are in the way. The standard requires that these machines are fitted with a category 2 control circuit, which monitors the trip device and stops the machine if the trip device fails.

There are also fully automatic pie and tart machines. These machines are only required to have category 1 control circuits, unless they are fitted with trip devices in which case the circuit must be category 2.

Many people find it perplexing that the small low-cost semi-automatic machine is expected to have a category 3 circuit, while the much more expensive automatic machine is only required to have category 1. This is because it is not the sophistication of the machinery that influences the choice of category, but the frequency of exposure to the hazard, coupled with the operator's ability to avoid injury if a component fails.

In the semi-automatic machine the operator is exposed to the hazard on every cycle and cannot avoid injury if a component fails, whereas on the fully automatic machine, operators enter the danger zones infrequently and have a much better opportunity to avoid injury should a component fail.

So finally the message that comes through from discussions with the HSE electrical specialists is: Don't dismiss the humble category 1 circuit. Well-tried components in a hard-wired single circuit that are regularly inspected and maintained have served British industry well over the past 25 years. ■