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Mirror Contacts for Highly-Reliable Information Relating to Safety-Related Control Functions

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Technical Essay

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MOELLER

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Summary for fast readers

Mirror contacts for highly-reliable information relating to safety-related control functions[1]

- High dependability using newly defined mirror contacts -

In the last few years, the significance of safety-related circuits for personnel protection has become an issue of which there is a general awareness. The issue is not just subject to continuous development and review by the German employers liability insurance association, and for example, the SUVA (Swiss accident prevention authority) in Switzerland, but has also gained additional recognition and significance in safety circuits in the protection of high-value capital investments and guaranteeing a high level of system availability. The readiness for use of safety circuits exists, but there is frequently an element of uncertainty regarding the properties of contacts, the interaction of main and auxiliary contacts and the standardised terms such as "positively-driven contacts" or the relatively new "mirror contact". Positively-driven contacts" only partly fulfil the expectations of the user in safety-related circuits. Clarity is achieved by the use of mirror contacts, whose demands are fulfilled by the new *DIL M* contactors from Moeller. Typical contact properties and the definition will be presented.

Literature:

[1] IEC / EN 60 204-1 "Electrical equipment of machines, Part 1: General requirements", non-authorized raw translation from IEC 60 204-1: 2002 / 44/367/CD (Date 6/2002)

[2] DIN / IEC 62 061 * Classification VDE 0113 Part 50, "Safety of machinery - Functional safety of electrical, electronic and programmable control systems for machinery", draft June 2003

[3] DIN EN ISO 13849-1 (in preparation) "Safety of machinery - Safety-related parts of control systems - Part 1: General principles for design" intended as a replacement for: DIN EN 954-1

[4] IEC / EN 60 947-4-1 and DIN VDE 0660 Part 102 "Low-voltage switchgear and controlgear - Part 4-1: Electromechanical contactors and motor-starters"

[5] Dirk Meyer "Switchgear for Power factor correction systems", VER2100-934 Moeller GmbH, 2003

[6] DIN EN 60947-5-1 (VDE 0660 Part 200):2000-08 "Low-voltage switchgear and controlgear Part 5-1: Control circuit devices and switching elements; electromechanical control circuit devices" (IEC 60947-5-1:1997 + A1:1999 + A2:1999), German version EN 60947-5-1:1997 + A12:1999 + A1:1999 + A2:2000

DIN IEC 60947-5-1/A3 "Low-voltage switchgear and controlgear Part 5-1: Control circuit devices and switching elements – electromechanical control circuit devices – amendment 3 to IEC 60947-5-1 (1997-10) (IEC 17B/1176/CD:2001)

[7] Wolfgang Esser "Aspects of function safe engineering of contact-related control circuits" VER 08+43-787 Moeller GmbH, Bonn, 1993

[8] *UL 508*, "Industrial Control Equipment"

[9] CSA-C 22.2 No. 14, "Industrial Control Equipment, Industrial Products"

[10] IEC / EN 60 947-1, "Low-voltage switchgear and controlgear Part 1: General rules"

[11] IEC / EN 60 947-3 and VDE 0660 Part 107 "Low-voltage switchgear and controlgear Part 3: "Switches, disconnectors, switch-disconnectors and fuse-combination units"

[12] IEC / EN 60 947-2 and DIN VDE 0660 Part 101 "Low-voltage switchgear and controlgear Part 2: Circuit-breakers

[1] Safety-relevant control function: Control function with a determined degree of reliability, which is intended to retain the safe state of the machine and to prevent the emergence of dangerous situations (IEC / EN 60 204-1, draft 2002 [1], in preparation as IEC 62 061 [2] and DIN EN ISO 13849-1 [3]).

Contact types and their tasks

Low-voltage switchgear and controlgear for industrial applications is developed, manufactured and tested conform to the relevant sections of the IEC / EN 60 947 (**Table 2**). Depending on the type of switchgear and protective devices, different constructive demands are placed on the equipment particularly relating to their task and method of actuation. The varying demands which are placed on the contact element or contact, result from the application related as well as from the construction related demands which are listed in **Table 1**. Further influences result, for example, from the type of contact material and the medium in which the contacts switch (air, inert gas and vacuum). Moeller selects the materials because of their physical and technical suitability with consideration of the environmental protection aspects.

The varying demands apply primarily for the **main switching device**, as well as for the **main contact** or main circuit. The main switching devices are applied in main circuits. It is their task during defined exceptional states (overload, short-circuit) to switch the operational load (motor, heating, lighting, etc.) of the switching and protective devices on and off, and they must be capable of switching increased currents which occur infrequently during defined exceptional states (overload, short-circuit). Various typical utilization categories are defined in the standards for correct dimensioning of the main contacts and for application specific selection of the switchgear sizes (e.g. IEC / EN 60 947-4-1 [4]: AC-1, AC-3, DC-5, etc.). The utilization categories in particular, consider the typical inrush peak currents associated with differing types of equipment, such as the extremely high sharp current peaks with capacitors in power factor compensation equipment, which can lead to increased contact wear or to welding of the contacts [5].

Table 3 indicates the specific demands with different examples of switchgear. For example, the lighter contacts of contactors are suitable for frequent switching and a long lifespan, whereas the main contacts from current-zero cut-off circuit-breakers which switch less frequently are optimised for higher contact forces to prevent unwanted dynamic contact bounce with short-circuit currents. A high I_{cw} value[2] is an important selection criterion with these contacts. On the other hand, highly dynamic main contacts are required with current limiting circuit-breakers.

For **auxiliary contacts** or **auxiliary switches** , which are used to mirror the switching state of the switchgear (main contacts) in the auxiliary or control

[2] Rated short-time withstand current: low heating effect with high current conducted over a defined time

Demands placed on contacts		Mainly	
		application dependent	construction dependent
1	Level of rated current and voltage	Selection criteria	Has an influence on the construction
2	Voltage type and frequency if applicable	Selection criteria	Has an influence on the construction
3	Utilization category of the switched load	Selection criteria	Has an influence on the construction
4	Expected mechanical and electrical lifespan	Selection criteria	Has an influence on the construction
5	High levels of overload and short-circuit current possible	Selection criteria	Has an influence on the construction
6	Behaviour during a fault (coordination)	Selection criteria	Has an influence on the construction
7	Frequency of actuation	Selection criteria	Has an influence on the construction
8	Repeatability of actuation On machine actuated position switches, actuation cannot be repeated unconditionally after a contact fault, with control circuit devices it is simply a case of actuating the actuator again.	Selection criteria, consider with circuit design	
9	Geometric dimensioning of the contacts		Dependent on 1 - 8 and on the construction principle
10	Number of contact points (interruption points)		Dependent on 1 - 8 and on the construction principle
11	Necessary contact motion distances		Dependent on construction principle
12	Level of required contact pressure forces		Dependent on 1 - 8 and on the construction principle

Table 1: Differing demands placed on contacts, which are partly dependent on the application, and which are also construction dependent.

IEC / EN 60 947 standards	Assignment of the contact types to the general guidelines and product standards and the demands they place on the main and auxiliary contacts		
	Content	Demands placed on main contacts	Demands placed on auxiliary contacts
Part 1	General rules	Definition of "positively-driven contacts" as a relationship between the main and auxiliary contacts. The definition should only be applied to other parts if they have been specifically mentioned in the definition in part 1	
Part 2	Circuit-breakers	No reference to positively-driven contacts to part 1	No reference to positively-driven contacts to part 1
Part 3	Switch-disconnectors, disconnectors, switch-disconnector and switch-fuse units	No reference to positively-driven contacts to part 1	No reference to positively-driven contacts to part 1
Part 4-1	Electromechanical contactors and motor-starters	No reference to positively-driven contacts to part 1	No reference to positively-driven contacts to part 1, Definition of "mirror contacts" in Annex F
Part 4-2	Semiconductor motor control devices and starters for alternating voltage	Not relevant	Not relevant
Part 4-3	Semiconductor control devices and contactors for non-motor-driven loads for alternating voltage	Not relevant	Not relevant
Part 5-1	Electromagnetic control circuit devices and switching elements	No reference to positively-driven contacts to part 1	No reference to positively-driven contacts to part 1, Definition of "positively opening control circuit isolators" in Annex K, Definition of "positively-driven contacts" in Annex L
Part 5-2	Proximity switch	Not relevant	Not relevant
Part 5-4	Method for estimation of performance of low current contacts	Not relevant	Not relevant
Part 5-5	Electrical emergency-stop device with mechanical interlocking feature	Not relevant	Not relevant
Part 5-3 **Part 5-6** **Part 5-7**	Demands placed on proximity sensors	Not relevant	Not relevant
Part 6-1	Multifunction switchgear; automatic mains transfer switch	No reference to positively-driven contacts to part 1	No reference to positively-driven contacts to part 1
Part 6-2	Multifunction switchgear; control and protective switching equipment (CPS)	No reference to positively-driven contacts to part 1	No reference to positively-driven contacts to part 1
Part 7-1 **Part 7-2** **Part 7-3**	Ancillary equipment	Not relevant	Not relevant
Part 8	Control units for built-in thermal protection (PTC)	Not relevant	Not relevant

Table 2: Assignment of switchgear types to the individual sections of the IEC / EN 60 947 standard and demands placed on main and auxiliary contacts by these standards, as well as the switchgear-relevant sections of the standards.

Main demands on the main contacts of differing switching and protective devices				
Device type	Typical currents	Typical contact forces	Demands on the operating frequency and lifespan	Demands on the short-circuit breaking-capacity
Contactor relay (auxiliary contacts only)	A few mA to 16 A	Very low	High to very high	No short-circuit switching capacity
Contactor	A few A to 2000 A	Low to high	High to very high	No short-circuit switching capacity
Motor-protective circuit-breaker	0.01 to 63 A	Low to medium	Low to medium	High to very high
Circuit-breakers	20 to 6300 A	High to very high	Very low to medium	High to very high
Switch-disconnector	20 to 6300 A	High to very high	Very low to medium	No short-circuit switching capacity
Control circuit devices (auxiliary contacts only)	A few mA to 16 A	Very low	High to very high	No short-circuit switching capacity

Table 3: Various demands are placed on the dimensioning of the contacts with the standard current ratings, operating frequencies and the switching capacity

circuit, there are also utilization categories defined in the standards (e.g. IEC / EN 60 947-5-1: AC-15, DC-13 etc. [6]). Here too, operational (rated) currents are usually switched and occasionally, exceptional currents must be switched. The exceptional overload or short-circuit currents can occur here too. On auxiliary contacts, the relationship between the level of normal currents for operational switching and the level of controllable exceptional currents is similar, but the absolute values are significantly lower than with the main contacts for construction dependent reasons.
Whereas auxiliary contacts used to be previously part of the basic units, today most of the auxiliary contact modules used are optional units which can be connected to the basic units. They are exchangeable and are available as different types (*m* break contact, *n* make contact) (**Figure 1**). The type of switching device as indicated in **Table 4** also has an effect on the function and dimensioning of the auxiliary contacts. Auxiliary contacts are significantly lighter and more sensitive to impurities, which can lead to contact problems, particularly at low voltages and low currents. The control circuit reliability in the control circuit can be enhanced significantly by the use of multiple parallel circuits. Furthermore, not too many contacts should be connected in series in a control circuit. A control voltage of approx. 230 V AC provides the best basis for exceptional contact security [7].
Today's optimum production methods ensure "contamination free" manufacture of contacts and switching zones. Optimised mating of materials with the movable parts minimise friction over the lifespan of the product and the enclosure protects to a large extent against external damaging influences. If one takes additional consideration of the reduction of the switchgear geometry's, power consumption and the heat dissipation, electromechanical switchgear has been subject to some very positive developments over the last two years. The economic-efficiency and the reliability have been significantly

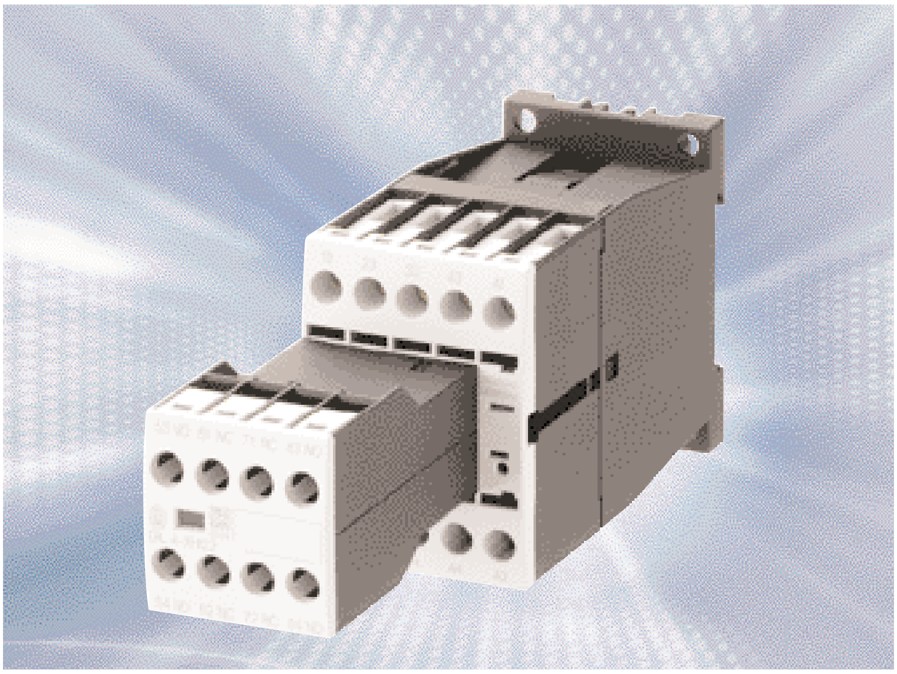

Figure 1: The contactor relay from the new Moeller xStart range features 4 auxiliary contacts in the basic unit. Today, it is generally the case that further contacts (2 or 4 here) are added on an application-specific basis, based on the use of a modular system.

Construction features and influences which are to be mastered	Demands on the auxiliary contact with the product groups			
	Contactor relay	**Timing relay**	**Contactor**	**Overload relay**
	DIL A	*ETR 4, DIL ET*	*DIL M*	*ZB*
Actuation method	Electromagnetic	Electromagnetic	Electromagnetic	Thermodynamic
Mechanical/electrical lifespan	Very high	Very high	Very high	Low
Operating frequency	Normal to medium	Normal to high	Low to normal	Very low
Contact force	Medium	Low	Medium to high	Very low
Contacts per unit	4, 6, 8	2 changeover contacts	1 ... 8	2
Influences from the basic unit	Are part of the basic unit	Are part of the basic unit	Shock	Shock from the contactor
Mostly subject to environmental factors	Normal	Normal	Normal	Normal
Preferred location	Control panel	Control panel	Control panel	Control panel

enhanced. In 1987, the department head for control engineering at *Moeller* wrote: "The higher-level use of contactor relays is practically unavoidable with safety-relevant functions. A particular example is the use in the emergency-stop functions on machines and systems in automation" [7]. This statement remained essentially correct for more than 15 years. The use of mechanical contacts is no longer unavoidable according to the standards, but they are still state-of-the-art in many fields of application and will continue to be a dominant force for the foreseeable future, and in particular, will retain their very economic position.

Auxiliary contact components of modern low-voltage switchgear are very complex. They earn the title of universal contacts when their performance range is closely considered. Originally developed for conventional contactor control circuits with high voltage and current levels, their construction was improved significantly at the start of the 80's and they are now equally suited for low currents and voltages. An obvious division into special contacts for small and relatively large powers should be avoided for logistical reasons, in order to prevent the proliferation of multiple product series. A division of this nature is also not useful from a technical application point of view, as for example, on an overload relay the break contact (NC) generally switches the control voltage with the high level of the contactor control, whereas the make contact (NO) usually transfers the low current / voltage level for a fault signal to an electronic control. The necessity for switching differing potentials has practically totally eliminated the need for changeover contacts.

Typical good pair values which are mastered are usually 230 V / 6 A and 17 V / 5 mA (rated value 24 V). Following this trend, Moeller has achieved good control circuit reliability at 17 V and currents of just 1 mA. As the modern switchgear devices are devices for world markets, they also master the North American "Heavy Duty" characteristic values or the sophisticated contacts of the timing and overload relay to "Standard Duty" conform to UL 508 [8] and CSA-C 22.2 No. 14 [9]. On some devices for use in North America, a note stating "600 V, same polarity" must be observed, and it means that the auxiliary contacts of the same auxiliary switch or auxiliary contact module located alongside one another must be connected to the same control voltage source in order to exhibit the same electrical potential.

Insofar as is possible in terms of the physical and geometric demands on the auxiliary contacts, *Moeller* uses the same auxiliary contact module on many product groups and / or device sizes.

Differing demands placed on the reliability of auxiliary contacts

It is not the objective of this essay to describe the correct constructive dimensioning of contacts, but rather to explain the application-specific demands to be observed, and is intended to represent the effectiveness of an auxiliary contact switch position for safety-relevant use. Briefly: This essay is intended to assist with engineering and not with dimensioning.

The task of the auxiliary contact, can for example, be intended as the control for an indicator light for signalling the switching state or the operating status. The contacts can also be initiated by further switching functions or can inhibit other switching functions as an interlock contact. In the course of this essay, the suitability of the auxiliary contacts for tripping or preventing

Motor-protective circuit-breaker	Circuit-breakers	Control circuit devices	Position switches
PKZ	*NZM*	*RMQ 16 /22*	*AT*
Stored energy mechanism	Stored energy mechanism	Manually actuated	Machine actuated
High	Medium	Medium	Very high
Low to normal	Low	Normal to high	Low to very high
Low to normal	Medium to high	Low	Medium
1… 6	2, 4, 6	1 … 6	1, 2, 3
Shock	Shock	Heat of the indicator light	Are part of the basic unit
Normal to high	Normal	Normal to high	Normal to very high
Control panel, small enclosure	Control panel	Small enclosure, on machine	On machine

Table 4: Auxiliary contacts of different switching and protection devices are loaded in different manners by the basic units and the actual applications. The approximate ratings are mainly true for the main uses of the devices.

further switching is of particular interest. On safety-related circuits for accident-prevention and for protection of capital investment, it is essential to be able to rely on the switch position of the auxiliary contacts and their relationship to the main contacts. It must be possible to determine if the load (the equipment) is switched on or off. On critical safety-relevant circuits, it may be necessary to implement redundant control current circuits[3] or the equipment may need to be monitored by an additional self-acting protection system fitted directly on the equipment (e.g. zero speed monitor, speed monitor, or similar). In addition to the redundancy, diversity[4]) may be required [1]. For certain standard monitoring circuits such as

- emergency-stop monitoring,
- protective door monitoring,
- switching pad monitoring and
- two-hand control,

Moeller provides special prefabricated safety relays of the *ESR* series. In most applications, one usually relies on the reliability of the normal auxiliary contacts.

If you have not explored the different types of switching devices and their typical unique features in great detail, it is typically assumed that the auxiliary contacts always assume the same switch position simultaneously with the respective main contacts. However, this obvious assumption is not always possible to realise, and not just in terms of timing. For example, the linear motions of the actuators of the main and auxiliary contacts may vary in length, so that pretravel path and the slowdown paths leads to differing switching time points. On early-make contacts, late-break contacts or overlapping contacts, the differing switching points are purposely introduced and used for technical purposes. Overlapping contacts are required for example for interruption free switchover operations.

Standard conform “positively-driven contacts” only partly fulfil the expectations of the switchgear users

The term “positively-driven contacts” has never actually fulfilled the expectations of the switchgear users. The user simply expects an unambiguous and reliable statement concerning the status of the switched equipment. He would like to use the positively-driven contact elements, e.g. for safety-relevant self-monitoring on the machine control circuit. Most definitions of the “positively-driven contacts” relate exclusively to the auxiliary contacts and only to the continuously differing switching state of break contacts and make contacts. Further limitations of the term will be explained later. In conjunction with accident prevention on power operated presses in the metal processing field, the term “positively-driven contacts” was defined for press safety controls as one of the first safety-related solutions in electrical control engineering field. This term was first described by the German employer’s liability insurance association guideline ZH 1 / 457.

The term “positively-driven contacts” initially referred to contactor relay and auxiliary contacts only. The positive opening operation of the auxiliary contacts ensured over the entire lifespan of the device that the break contact and the make contact of a device could never by closed

[3] Redundancy = usage of more than one device (system), to ensure that another function is fulfilled if the device (system) malfunctions. Terms: full or partial redundancy, online redundancy, off-line redundancy

[4] Diversity = avoidance of faults and / or malfunctions by the use of differing functional principles: Break contacts and make contacts, components of different construction type, electromechanical and electronic components, electrical and non-electrical systems

simultaneously, but rather that in a destroyed state (one contact welded), a defined contact clearance of at least 0.5 mm (on the break contact) was guaranteed. Here you must consider, as in **Figure 2**, that the contact bridge of a contactor may become slightly skewed, if one of the externally situated contacts welds. For this reason, it is recommended on high power contactors that have a larger bridge width, and which have standard side mounting auxiliary contacts, to connect the side-mounted right and left side auxiliary contacts in series for monitoring circuits. In a critical skewed position, both contacts do not have the same switch position and this irregularity can be evaluated by the circuit.

As there is little difference for small switching duties (< 4 kW) between the main contacts and the auxiliary contacts, the switchgear manufacturers fulfilled the customer requirements and soon referred to "positively-driven contacts" with small contactors beyond the terms of the official definition. This served to confirm the speculation of the switchgear users that the switching states of main and auxiliary contacts are the same with *all* switchgear frame sizes.

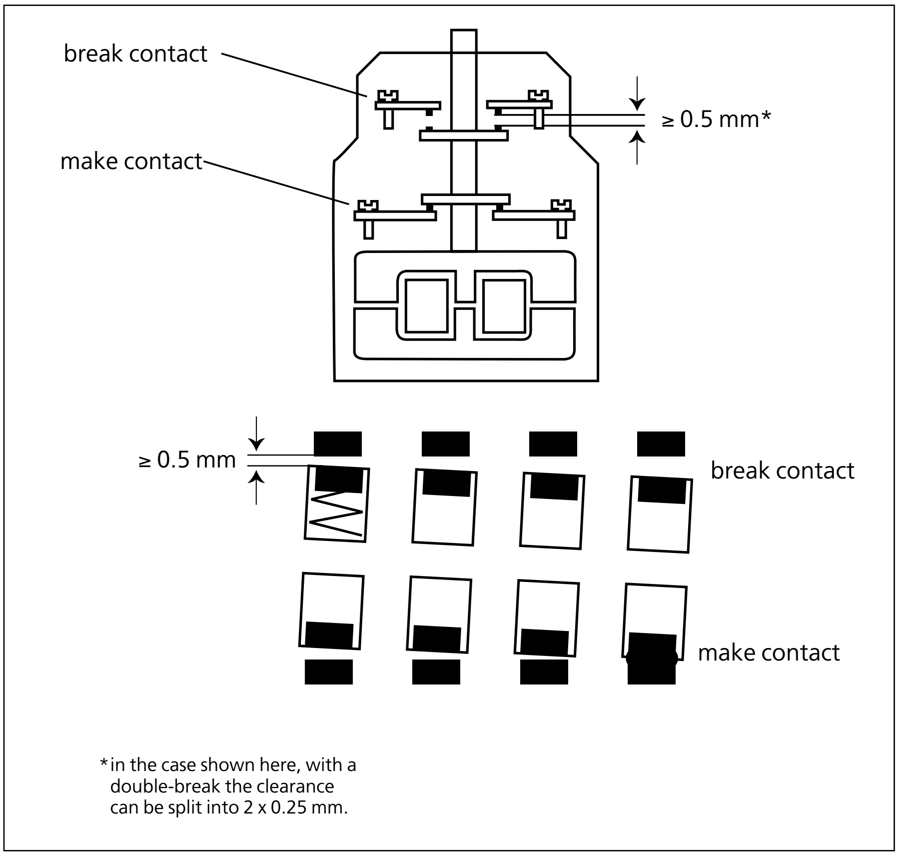

Figure 2: If for example the outer right make contact welds on a contactor, the contact bridge of the switched off contactor may skew. With "positively-driven contacts" it is required that the break contact does not close in this case, but rather, that a clearance of 0.5 mm is retained between the contacts for the entire lifespan of the contactor. Various safety circuits are based on the assumption that the break contact and make contact of a contactor can never close simultaneously.

> *Not very helpful in allaying the confusion is the definition of positively-driven contacts in the IEC / EN 60 947 Part 1 [10]. In this generic 60 947 standards series, it is stated that "the positive opening operation of a switching movement is, at which it must be ensured ... , that the auxiliary contacts of mechanical switchgear must always be located in the respective switch position, which corresponds to the open or closed state of the main contacts."* It conflicts with the demands of the other product standards of this series.

However, the specific parts of the generic standard are obligatory for individual switchgear types with the construction and testing of the switching and protective devices. In these parts, there is no reference to the definition in part 1, but rather, you are referred to the design of the auxiliary contacts for all switchgear devices in Annex L of the IEC / EN 60 947-5-1.

In the description of the field of application of this Annex, the above mentioned limitation appears, that the Annex only applies for positively driven auxiliary switch elements, at which for example, on contactor relays the actuating force is internally generated in the switchgear. Only in this case can the manufacturer safely assess the levels of force which occur. In real terms, this means that switchgear with external actuation, such as pushbuttons or end switches, can never feature positively-driven contacts due to the non-limited actuating forces. For these devices a reference is made to "positive opening" to IEC/EN 60 947-5-1, Annex K, which must break welded contacts in exceptional cases (see below).

Annex L returns to the original definition of the ZH 1 / 457, where positively driven auxiliary contacts are constructively implemented, so that the *m* break contact and *n* make contact cannot be closed simultaneously. This demand applies to the actuation devices when they are destroyed:

- as long as one of the *n* make contacts is closed, none of the *m* break contacts may be closed,
- as long as one of the *m* break contacts remains closed, none of the *n* make contacts may be closed.

The minimum contact clearance intended in the ZH 1 / 457 is stated in Annex L, as a declaration by the manufacturer of minimum clearance of 0.5 mm after an impulse voltage test. No statement is made stating that the switch position must be the same for the main and auxiliary contacts. Positively driven auxiliary contacts *must* be identified in the circuit diagram and can be marked on the device with symbols conform to Annex L.

Clarity with the newly defined mirror contacts

Mirror contacts are constructed and tested conform to IEC / EN 60 947-4-1 [4], Annex F. By definition, a mirror contact must always be an **auxiliary break contact**. A contactor may feature multiple mirror contacts. *Switchgear without auxiliary break contacts can never feature mirror contacts according to the definition*. The contacts that are mirrored are the **main circuit make contacts**. *As a result, a contactor relay can never feature mirror contacts because it does not have main contacts.*

At the current time, mirror contacts are currently known exclusively when used with contactors. **As long as any main contact of a contactor is closed, a mirror contact** (auxiliary break contact) **may not be closed**. This definition also applies when the contactor is not supplied with actuating voltage. Sufficient contact clearance of 0.5 mm is guaranteed by the manufacturer on the mirror contact, during a simulated welding of a main contact by an impulse voltage test. This test must be successfully passed after the end of the performance test.

A typical application for mirror contacts is to implement very reliable monitoring of the switched state of a contactor in machine control circuits. On the other hand, the standard emphasises that it is not prudent to rely exclusively on mirror contacts as a safety device, and it recommends self-monitoring of the mirror contact circuit.

The definition of mirror contacts can only contribute, due to the construction conditions, to the relationship between the main circuit make contact and the auxiliary break contact. These construction related conditions are justified by the fact that the main contacts and the auxiliary contacts almost always have their own contact bridges, and that the forces acting on the main and auxiliary contacts are of a different magnitude. It is not simply possible to demand, that a welded auxiliary contact of an energised contactor should act on the main contacts of a heavy switching duty contactor, and keep it in the switched on position.

More exact information through positively driven mirror contacts

Annex F of IEC / EN 60 947-4-1 [4] allows the use of mirror contacts in addition to the demands on positively-driven contacts, to Annex L of IEC / EN 60 947-5-1. The term from the header "positively driven mirror contacts" cannot be found in the standards. It is the logical combination of the author from the facts presented in Annex F and L. According to **Table 5** there are *unambiguous* and *many* possible relationships which exist between the switch positions of the main and auxiliary contacts.

Simple and clear relationship with Moeller switchgear and protective devices

Table 6 lists the types of all current *Moeller* contactor relays and contactors, and indicates which contactors avail of positively-driven contacts and mirror contacts, in accordance with the declared definitions of the Annex in the described standards. As already described, larger contactors with a welded main contact can result in the main contact bridge being skewed. For this reason, on contactors with a similar type of contact, a contact of the side-mounted auxiliary switch should be connected in series on the left and right sides. On *DIL M* and *DIL P* contactors where internally situated (*DIL...-XHI(C)11-SI*) and externally situated (*DIL...-XHI(C)11-SA*) auxiliary switches are used, the contacts on the internally situated auxiliary contact are to be used.

Main contacts (usually make contacts)	**Auxiliary contacts**	
	as **mirror contacts**, to *IEC / EN 60 947-**4**-1, Annex F*	As **positively-driven contacts**, to *IEC / EN 60 947-**5**-1, Annex L*
	Statement due to the relationship: Mirror contact to main contact	Statement due to the relationship: Positively driven make contact to mirror contact (break contact)
• If any one of the main contacts is closed	• All other auxiliary contacts **must** be open.	• The auxiliary make contact may close only when all auxiliary contacts break contacts are open. • It is also very probable, that the auxiliary make contacts are also closed, if the main circuit make contact is closed.
• If all main make contacts are open	• All auxiliary break contacts **may** be closed	• If an auxiliary break contact is closed, all auxiliary make contacts must open. • It is also very probable, that the auxiliary make contacts are also open, if the main circuit make contact is open.

Table 5: A truly reliable statement is only made in the orange field. The blue fields are only probable statements.

<table>
<tr><th rowspan="4">Type</th><th colspan="4">Contacts for safety-relevant control functions</th></tr>
<tr><th colspan="2">Positive opening operation of the contacts to
IEC / EN 60 947-5-1, Annex L</th><th colspan="2">Mirror contacts
to IEC / EN 60 947-4-1, Annex F</th></tr>
<tr><th>Integrated auxiliary switch in basic unit to contacts in the auxiliary contact module*</th><th>Between the contacts within an auxiliary contact module*</th><th>Integrated auxiliary break contact* to the main contacts</th><th>Auxiliary break contact in the auxiliary contact module* to the main contacts</th></tr>
<tr><th colspan="2">Contactor with AC or DC operation, with screw or cage clamp connections</th><th colspan="2">Contactor with AC or DC operation, with screw or cage clamp connections</th></tr>
<tr><td>DIL A-22 (31)</td><td>Yes</td><td>Yes</td><td colspan="2">No main contacts available</td></tr>
<tr><td>DIL M7-10 to
DIL M32-10</td><td>Yes</td><td>Yes</td><td>No auxiliary break contact available</td><td>Yes</td></tr>
<tr><td>DIL M7-01 to
DIL M32-01</td><td>Yes</td><td>Yes</td><td>Yes</td><td>Yes</td></tr>
<tr><td>DIL M40 to DIL M65</td><td>No auxiliary contact available</td><td>Yes</td><td>No auxiliary break contact available</td><td>Yes</td></tr>
<tr><td>DIL M80 to DIL M150</td><td colspan="4">Not currently available</td></tr>
<tr><td>DIL ER-22 (31)</td><td>Yes</td><td>Yes</td><td colspan="2">No main contacts available</td></tr>
<tr><td>DIL E(E)M-10</td><td>Yes</td><td>Yes</td><td>No auxiliary break contact available</td><td>Yes</td></tr>
<tr><td>DIL E(E)M-01</td><td>Yes</td><td>Yes</td><td>Yes</td><td>Yes</td></tr>
<tr><td>DIL R-22 (31)</td><td>Yes</td><td>Yes</td><td colspan="2">No main contacts available</td></tr>
<tr><td>DIL 00 (A)(B)M -10</td><td>Yes</td><td>Yes</td><td>No auxiliary break contact available</td><td>Yes</td></tr>
<tr><td>DIL 00 (A)(B)M -01</td><td>Yes</td><td>Yes</td><td>Yes</td><td>Yes</td></tr>
<tr><td>DIL 0(A)M to DIL 3M85</td><td rowspan="5">No integrated auxiliary contact available</td><td>Yes</td><td rowspan="5">No integrated auxiliary contact available</td><td>Yes</td></tr>
<tr><td>DIL 4M115 and
DIL 4M145</td><td>Yes</td><td>Connect 1 right and 1 left SI auxiliary switch contact in series</td></tr>
<tr><td>DIL M185 to
DIL M1000</td><td>Yes</td><td>Yes</td></tr>
<tr><td>DIL H1400 to DIL H2000</td><td>Yes</td><td>Yes</td></tr>
<tr><td>DIL P160 to DIL P800</td><td>Currently not tested</td><td>Currently not tested</td></tr>
<tr><td></td><td colspan="4">* generally does not apply for combinations with early-make contacts and late-break contacts</td></tr>
</table>

Table 6: **Positively-driven contacts and mirror contacts with Moeller contactor relays or contactors**

Similar terms which are open to confusion

Contacts with positive opening or positive operation are frequently confused with positively-driven contacts. As the term mirror contact is relatively new, uncertainty exists among the users. There is a risk of confusion with the following, similar terms:

Safe isolation
A safe isolation is achieved for example by insulation, which fulfils higher demands than the basic insulation. It is achieved by reinforced or double insulation. Safe isolation is demanded with the generation of a protective extra low voltage (PELV), with safety transformers between the primary and secondary windings and between all active parts of PELV low voltage circuits and other circuits (with dangerous touch voltages). For details see IEC / EN 60 947-1, Annex N.

Protective separation safety measure of an individual circuit to IEC / EN 60 364-4-41, for protection against electrical shock (protection with indirect touch). These protective measures prevent dangerous touch voltages from contact with bodies (enclosure, inactive parts), which assume the voltage of the active part after a fault in the basic insulation.

Potential isolation (galvanic isolation)
Separation of electrical potentials. There are no conductive connections between the different circuits. A potential isolation can be achieved using certain transformers, with batteries or different generators, where the voltages are not connected to one another. Optocouplers are used for example, to protect electronic circuits from destruction by higher voltages. Interface elements perform similar tasks between control and load circuits.

Isolating function / isolating characteristics
A function for shutting down the power supply to the entire system or part of a system, whereby the system or system section is disconnected for all electrical energy sources for safety reasons. Indication of the position of the main contacts must be unambiguous and effective.
The isolating device must have an interlock feature for the off (isolated) position to IEC / EN 60 204-1. According to IEC / EN 60 947-3 [9], enhanced demands are placed on the tenacity of the operating elements, in order to prevent that the operating element can be switched to the off position when a switch has welded.

Isolating gap, visible isolating gap
Clearance between the open contacts or the conductive parts of a pole of mechanical switchgear connected to them in the open position, which fulfils the stipulated safety requirements for a disconnector. It is demanded to IEC / EN 60 204-1:2002 for power disconnecting devices (main switches). If the isolating gap is not visible, the off position may not be indicated using a switch position indication, before all (main) contacts are actually open and a sufficient isolating gap conform to IEC / EN 60 947-3 [11] exists between all contacts.

Positive opening (of a contact) (not to be confused with positive opening operation!) To IEC / EN 60 204-1:2002 and IEC / EN 60 947-5-1, Annex K; positive opening is defined as the assurance of contact separation as a direct result of a defined motion of an operating unit of the switch via non spring parts (e.g. not dependant on a spring for operation). This feature is demanded to IEC / EN 60 204-1:2002, for example with emergency-stop devices. Every control circuit isolator with positive opening must be permanently externally marked on the outer side with a legible standard symbol.
Also in regard to positive opening, there is a definition in the IEC / EN 60 947-1 which refers to the position of the main contacts. In this definition, the switch-specific parts of the IEC / EN 60 947 is also not referred to.

Positive opening clearance
Minimum clearance from commencement of the actuation of the operating unit until the position in which the positive opening of the contact to be opened has ended.

Inevitable effect
Connection between the operating unit and the contact, which transfers the force applied to the operating unit directly to the contact (IEC / EN 60 947-5-1).

Non-inevitable effect
Connection between the operating unit and the contact, which limits the force applied to the operating unit (IEC / EN 60 947-5-1).

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