

Joslyn Clark Controls, Inc.

Questions & Answers on Vacuum Contactors

QUESTION: What happens when I lose vacuum?

Answers such as “It has never happened before” are very unacceptable but one must consider that the chances of losing vacuum are extremely remote for the following reasons.

The interrupter has been designed to withstand a mechanical life in excess of three million operations.

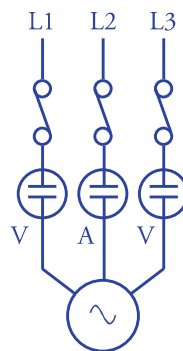
1. The loads, closing and opening speeds, contact movements and hence inertia is extremely low. The interrupter has been designed to withstand a mechanical life in excess of three million operations; i.e. one operation is open and close.
2. Mechanically, the interrupter is very well protected therefore the risk of failure as a result of seals cracking, or the interrupter being hit by a wrench, for example, are virtually eliminated. The vulnerable part of a vacuum interrupter is the bellows. In cases of lost vacuum, it is almost 100% where the failure occurs. Joslyn contactor interrupters are designed to prevent any twisting motion or over compression of the bellows in both the initial assembly stage, final operation, or by field personnel. In addition, the bellows are designed for operations for a mechanical life movement 200% greater than that seen in actual operation. It is for these reasons that we consider these precautions in design and quality control in the manufacture of the product, this is what would happen if the interrupter lost vacuum.

When operating the contactor closed, the contactor is designed to carry maximum current whether the contacts are in vacuum or in air on a continuous basis. An amount of contact pressure, of course, would be lost if vacuum were lost as a result of atmospheric pressure assistance on the contact being neutralized. However, the over travel spring has sufficiently low resistance values on the contact face even though the contacts may be sitting in the air instead of vacuum. Therefore, the contactor will run continuously in this condition without overheating.

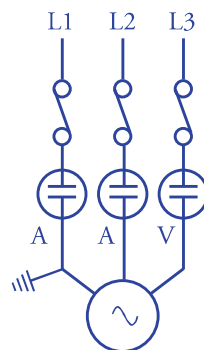
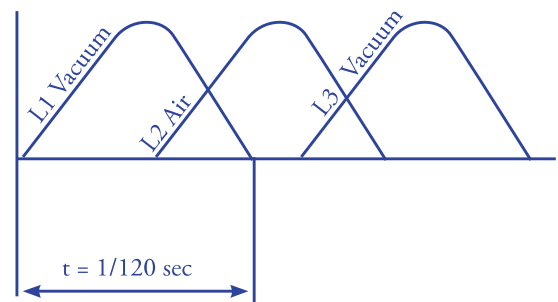
Referring to the diagram in Fig 1, we simulate the situation with the contactor closed and motor running when vacuum is lost on the center phase interrupter. When a trip signal is applied the contactor behaves exactly as it would under normal conditions. That is, mechanically all poles start to open and continue to the fully open position. Referring to the simple circuit diagram, current in phase 1 will be switched off at current zero, being as that phase interrupter has a vacuum seal. The center phase 2 which has no vacuum now goes through its switching operation

and an arc is drawn across the open contacts and as current approaches zero, the arc will naturally go out at zero the reignite an arc, the current then continues to flow. Phase 3, which is in a vacuum, then goes through its arcing cycle and at a current zero, the arc then goes out and ceases to flow. Having isolated

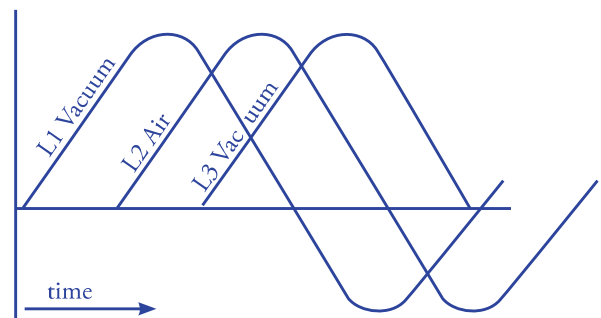
Fig. 1



Switch off with one interrupter down to air.



Switch off with either one interrupter down to air with ground on same leg, or two interrupters down to air with no grounded leg.



two phases of the three-phase circuit, the current still flowing in phase 2 now ceases and the circuit is switched off. The timeperiod is less than one cycle and no damage has been done to the device. Under this condition the contactor could be signaled to reclose and the contactor would perform normally under this condition.

The above explanation satisfies the condition where one switch fails, however, the possibility could exist where two failed or a ground fault existed on a phase that had also had a failed switch. Under this condition the current would continue to flow, an operator condition and would isolate the system upstream. If the fault went unnoticed the arcing would continue until heat buildup in the interrupter created a break in the interrupter bottle. This would result in a loss of arc containment and a phase to phase or ground fault would occur. This would be instantly

cleared by backup fuses or other upstream protection.

This is the sequence of events that would occur and it should be always remembered that the risk of one switch failing is even less likely, but in the event that this should happen, no major problems would occur as backup short circuit protection would very rapidly clear the fault. Again as a reminder, a phase to phase fault could be cleared by a fuse in less than $\frac{1}{4}$ of a cycle, such as a situation would mean that the pole assemblies on faulty phases would have to be replaced.

Question: Are there devices that would detect loss of vacuum?

Joslyn has prepared designs for detecting loss of vacuum on their high voltage systems. These however, do not work effectively below 10kV. Other bridge network designs are available, suitable for lower voltage systems. These however are bulky and costly and have a major disadvantage that you must always have a voltage applied to the contactor for the system to detect loss of vacuum. Therefore:

1. The isolator switch must always be closed with the contactor open before such systems are effective and it obviously does not monitor a situation described previously where the loss of vacuum may occur when the contactor is closed and the motor running.

It is therefore Joslyn's policy to create a design and a quality control procedure in the manufacture of the switches whereby the risk of loss of vacuum in the field is reduced to an absolute minimum.

Question: How do I detect full loss of vacuum?

This can be done in a variety of modes. While claims are made by some manufacturers that vacuum devices have eliminated maintenance. This is really asking for trouble. We consider the customer should implement some preventive maintenance program to insure that he receives the best return on his investment.

Question: What are the effects of switching transients and are suppressors necessary?

This is a very important question to answer directly and

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authoritatively with the customer. In recent years many examples of contactors or vacuum interrupters being passed off as contactors have been applied on inductive loads which have caused motor failures. Motor failures have been the result of insulation failure occurring on the ends of the motor winding and were probably the direct result of voltage switching surges generated by the switching device.

All switching devices will create some degree of voltage surge whether they are in air, vacuum, oil or SF6 mediums. Each of these mediums has different characteristics, but because vacuum is such a good switching medium, it can create unacceptable voltage spikes. The control of these voltage spikes is determined by the material used on the contact face to determine voltage control. Joslyn's USAVAC design has taken into account the specific requirements of inductive load switching. The contactor is specifically designed for motor load applications. The motor is probably the most vulnerable piece of equipment to be switched on an electrical system. BIL levels for motors are typically only 19kV.

Referring to the diagram, Figure 2, you can see how arcing is transferred from the higher vapor melting point materials to lower vapor point materials to obtain arc control to extremely low current levels. This is published as a maximum figure of .9 of an amp and an average .55 of an amp. We have found that our competition is somewhat reluctant to disclose this information.

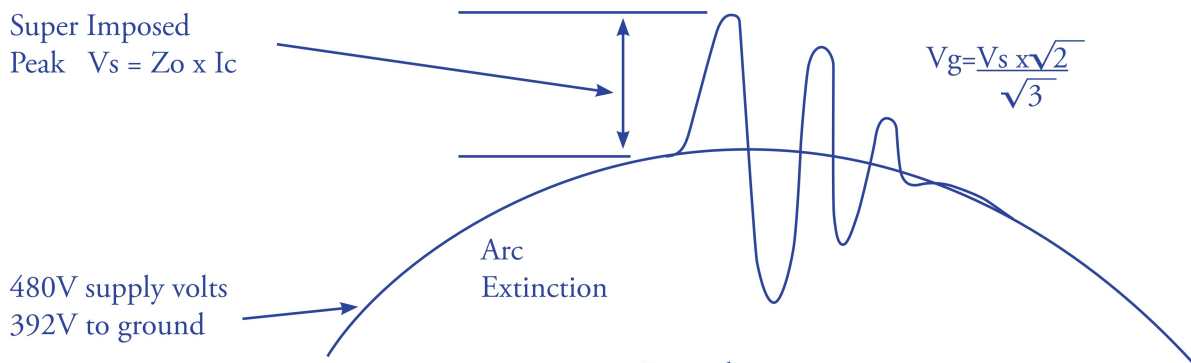
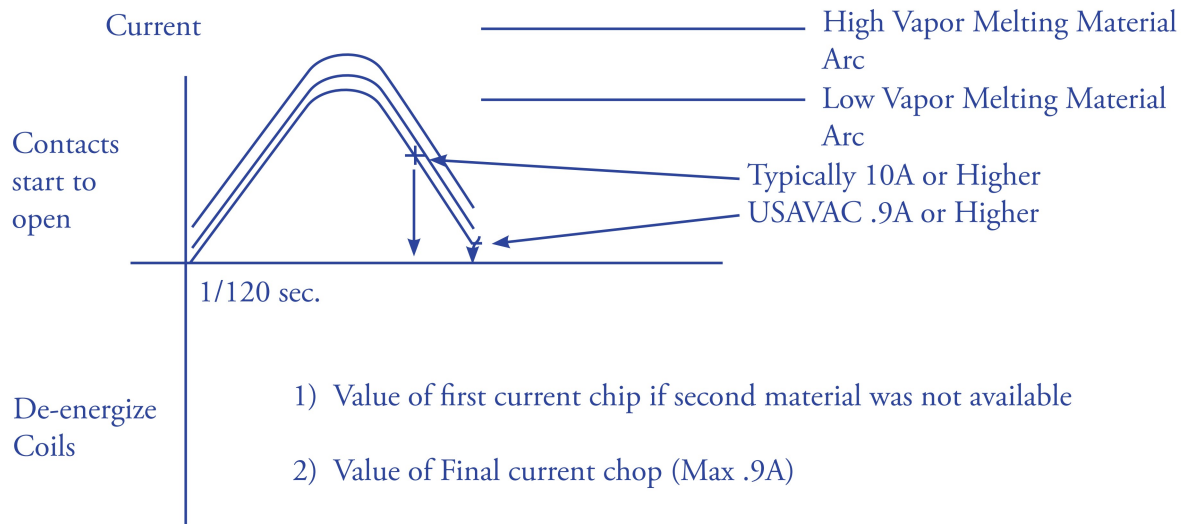
The point of which the current goes out is in fact known as the current chop level and this creates an instant decay of current to zero inducing the voltage to peak onto the RMS system.

This voltage can be calculated and is simply the product of the surge impedance of the circuit times the value of current at which the arc condensed or was extinguished. "The current chop".

In practice the customers may have difficulty in establishing surge impedance values although these typically for explanation purposes you should use a 2000 ohm figure and multiply this by .9 of an amp. In the case of the USAVAC device, to obtain a 1.8kV peak on top of the RMS voltage supply. Thus by then multiplying that same surge impedance by a 10 amp current chop value, which is not uncommon for a circuit breaker type interrupter design you could see the induced voltage would be 20kV on top of the RMS supply

voltage. The last figure would be unacceptable without the need for additional surge suppression equipment.

ARC CONTROL (FIG 2)



$$Z_o = \text{Surge Impedance} = \frac{L}{C} \sqrt{\text{ohms}}$$

$I_c = \text{Current Chip (A)}$

Example

If $Z_o = 2000 \text{ ohms}$ and $I_c = .9A$

Then $V_s = 2000 \times .9 = 1.8kV$

But If

$I_c = 10A$

$V_s = 2000 \times 10A = 20kV$

Properly designed vacuum contactors which have been in operation for many years have been applied to motor loads successfully without failures.

As a final response to the customer, you should clarify that properly designed vacuum contactors which have been in operation for many years have been applied to motor loads successfully without failures and that many thousands of these starters are in the United States and other parts of the world.

There has been in the past, examples of misapplication where vacuum devices that have high current chop values have been applied on inductive load circuits without the use of additional surge suppression equipment and that these instances are examples of bad application and not poor design. Finally, Joslyn is well aware of these characteristics, having had some twenty years experience in producing and designing vacuum interrupters .

Question: Why is the vacuum contactor a better performer when switching capacitors?

Certain basic principles must be attained in all devices vacuum or otherwise, to switch capacitors. Considerations “important” is both the contactor design and application.

1. That concern is preventing restrikes from charged capacitor banks. This causes high over voltages and is damaging, usually critical to both the contactor and the capacitor. (The contactor usually disappears; the capacitor tank swells.)

It is caused by the contactor contacts not being open far enough at current zero. It is critical to have the contacts moving fast when opening time such that after the first zero point, the contacts are far enough apart and the dielectric strength good enough to prevent a discharge from the energized capacitor. In a vacuum medium the environment is pure and constant with life; therefore the only consideration is the speed of contacts. However, with an air magnetic device although the speed may be fast enough, the environment varies depending in the cleanliness of the contact chamber. This gives different degrees of performance, thus with usage it always gets worse, whereas in the vacuum device, it remains constant. It should be remembered that restrikes occurring on capacitor banks are not uncommon with air magnetic application. They cannot however, be guaranteed never occur even with a vacuum contactor. It is however, far less likely to occur in the vacuum device.

The Joslyn Clark vacuum contactor can be assembled and dismantled without the use of tools.

2. In application, the closing of a contactor onto an energized bank or back to back switching also causes high surges. Usually reactors are applied to limit these surges and both NEMA and ANSI have standards set for calculating these values. In general, the lower value the longer the life of the switching device. For the USAVAC we recommend 9KA as a maximum peak value.

You need not concern yourself about the calculation. The people in the capacitor switching business understand these requirements. You should only be aware of them. NEMA recommends a derating of NEMA rated contactors for capacitor tolerance and harmonic considerations. This derating is 80% of the inductive motor rating contactor.

Question: How do I measure contact life erosion?

The interrupters are well protected from mechanical damage.

The Joslyn Clark vacuum contactor can be assembled and dismantled without the use of tools. Likewise, the contactor can be checked and maintained without the use of any special tools. To check for contact wear you need a standard feeler gauge. The check can be done by either mechanically closing the device or electrically closing the device and is detailed in the following procedure.

CONTACT WEAR

The interrupters are well protected from mechanical damage. The phase assembly has anti-torque and over-compression features that prevent possible damage to the flexible bellows at any time in the interrupter's life.

The remaining electrical life can be checked by measuring overtravel. This can be done electrically or mechanically without dismantling or requiring the use of special tools (a wire gauge can be used).

You must insure that the power supply is isolated preferably with a visible disconnect.

A general inspection of the contactor should also be made manually operate the contactor, check for freedom of movement and general cleanliness. Do not attempt to adjust or rest parts.

The need to replace contacts, arc chutes be cleaned and reset contacts, has been eliminated. This, in practical terms, is expensive both in parts costs and labor. The need to adjust or reset factory settings is also eliminated. The Joslyn contactors are self-adjusting throughout their life.

Contractors however work with a variety of other power devices that is, isolators, fuses, power stabs, and preventative maintenance is an important exercise to be undertaken to enhance the life of the equipment. Prudent engineers will implement such programs and at this time the vacuum can be checked by either a hi-pot or resistance test.

INTERRUPTERS

The interrupters can be checked for dielectric strength by the use of a Hi-Potential test set. A micro-ohmmeter will also provide data on contact resistance.

CONTACT RESISTANCE

With the switch closed, the resistance across the terminals should be less than 200 micro ohms. If higher contact resistance values are measured then the high potential test should be performed.

HIGH POTENTIAL TEST

The following test should be performed using a 50/60 hertz test set, where the voltage is continuously variable up to, say, 30kV RMS. X-radiation at this level is negligible; however, personnel should not be closer than 6 feet to the interrupter under test to avoid electrical high voltage shock hazards. The contactor should be free of dust and other contaminants before conducting this test.

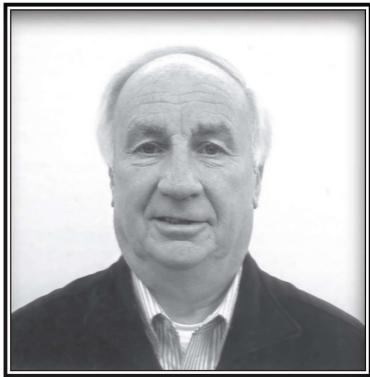
Connect output leads of test set across the interrupter terminals with the contactor in the OPEN position. Slowly raise the voltage from zero to 10kV RMS and hold for 15 seconds. During this time any discharges or test set trippings should be ignored unless it becomes impossible to reach test voltage and hold for 15-second period. The leakage current should not exceed 5 milliamps during the test.

Question: How do I adjust the contact?

The Joslyn Clark maintenance manuals describe how to unpack, install, and maintain the device. It also lists recommended spare parts with quantities based on routine wear and breakdown situations. The contactors, however, should not be readjusted. They are self-adjusting.

Question: What happens when the contactor welds?

Under normal conditions and operating within the ratings listed, the contactor will not weld. Contact bounce and contact oxidation have been eliminated in the designs; both of the above are principle causes of a contactor welding.



John Lett became involved with vacuum power switching in the early 1960s, soon after completing his engineering studies at Aston University in his native UK. Working on Low and Medium Voltage Contactor and Motor Control Center designs, Lett's work in Engineering, Sales and Product Management developed competitive vacuum designs and expanded their acceptance in European markets. In 1978, he moved to the United States to continue this work in North America, where at the time few manufacturers of vacuum power products existed.

Vacuum designs are extensively used today, and at medium voltage almost exclusively used in power switching for motors, transformers and capacitors.

Lett retired from JCC/Danaher in 2009, but still works as a consultant for the company. He considers the next step for vacuum products to be utilized in the 10-15 Kv ranges as new motor designs are developed.