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LA-UR -89-3291

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LA-UR--89-3291

DE90 002448

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SUBMITTED TO proceedings of the 13th IEEE Symposium on Fusion Engineering
Knoxville, TX
October 2-6, 1989

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ABSTRACT

This paper gives the mechanical design and electrical parameters of a pneumatically operated transfer switch. This design is used to switch 3-second 50-kA current pulses, and is easily capable of 75 kA operation (2×10^{10} I^2t); with water-cooled versions capable of 20 kA continuously. Although the switch is not specifically designed to make or break 50 kA, it is provided with auxiliary Elkonite arcing contacts (which make first and break last). The arcing contacts have proven their value in protecting the main electrodes even under repetitive (50 kA) fault conditions. Included in this presentation will be the results of extensive life testing and associated criteria.

INTRODUCTION

This switch was developed in response to our need to provide 50 kA current pulses to vacuum interrupter switchgear. The switches open (supply is off) isolating the 50kA current source to permit the switchgear to be tested at 50 kV potentials. Borrowing on experience gained from high power dc circuit breaker and high current contact methodology, a switch was fabricated as shown in Fig. 1. Although this switch's application is not to make or break current, auxiliary arcing electrodes are provided (as large dc circuit breakers). This design feature protects the main current carrying electrodes in event of a control logic fault. To facilitate the low contact resistance with minimal alignment problems, Multilam contact louvers are used. This switch was not initially optimized for fast switching, but for reliable voltage hold off and low contact resistance.

FABRICATION

Ruggedly designed, the switch is manufactured using 1" thick Lexan plate for the pressure enclosure and 2" thick brass blocks for electrodes. Lexan is a good choice as an enclosure as it provides a means for internal visual inspection, machines easily without pressure fractures, has outstanding strength, does not craze from UV exposure (from electrical switching), and does not track easily.

Seams and electrode feed-thrus are sealed with silicon RTV to permit a pressurization capability above 50 psi. A flat gasket is used with the lid to permit disassembly and cleaning of the internal mechanisms. Brass was chosen as an electrode material for ease of manufacture and cost effectiveness. The brass electrodes are silver plated on all contact surfaces to inhibit oxidation. Dovetailed grooves in the fixed electrodes are required to hold the Multilam contact louvers. Auxiliary arcing electrodes of copper tungsten Elkonite is a material specifically engineered for this application.

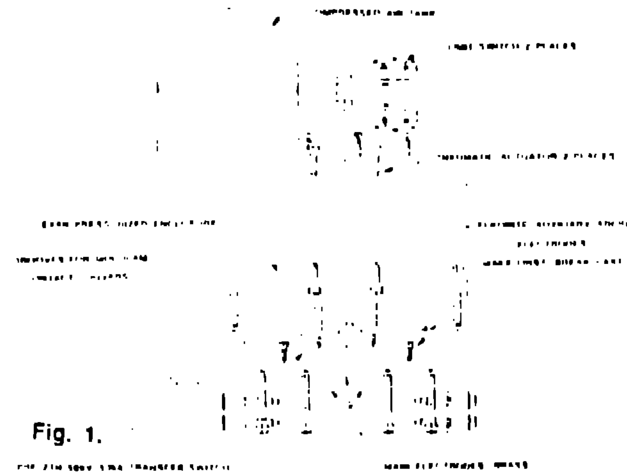
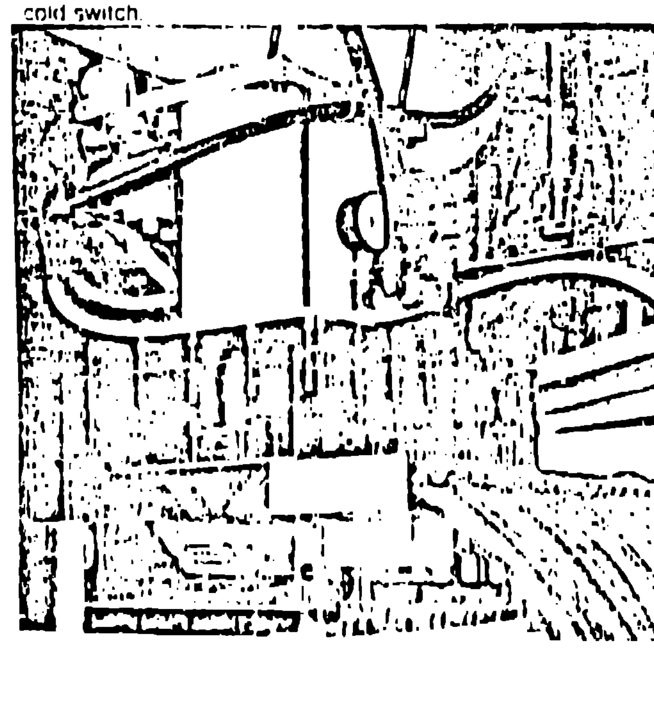


Fig. 1.

Test Results & Parameters

Static breakdown voltage tests with air indicate a maximum usable voltage of about 65 kV as shown in Fig. 2. Although this curve is not ideally linear, this may be due to the unusual geometries causing field enhancement at higher voltages. Contact resistance measures 6 $\mu\Omega$ and repetitive operation indicates this low loss. Electrode temperature after a full day of operation (1 shot/10 minutes) with I^2T of 3.5×10^{9} reaches about 30°C. After the initial success using this switch (Photo 1) as an isolation device between a 50 kA battery bank and a dc vacuum interrupter, the Los Alamos design team chose to further characterize this switch. Testing to over 50,000 operations was to determine its suitability to replace commercial vacuum contacters as cold switches. Table 1 gives a brief summery indicating this switches suitability as a cold switch.



* Work performed under the auspices of the US DOE

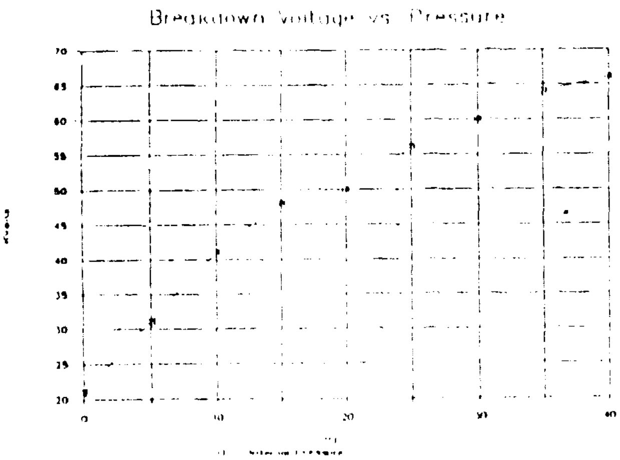


Fig. 2.

TABLE 1

ITEM	VALUE	COMPARISON TO VACUUM CONTACTOR
Switch R	6 $\mu\Omega$	1/10 of contactor (60 - 110 $\mu\Omega$)
Opening Time	40mS	Similar to contactor
Closing Time	45mS	Slightly slower
Maximum Current	75kA pulse 20kA CW (water cooled)	Better
Maximum Voltage	65kV	Better
Life	Tested to 65,000	Better
Operating Temperature	30°C	Better (160°C)

Life testing was to determine unusual or unforeseen failure modes along with any degradation of performance. Minor design modifications were needed in the pressure tanks' mounting fixture and the couplings used with the air pistons. Switch resistance increased from 6 $\mu\Omega$ to about 12 $\mu\Omega$ after 65,000 operations. This slight change is inconsequential to the switch's operation. The Multilam contact louvers began to develop fatigue cracks after 30,000 cycles, and roughly 13% were cracked at one end by 50,000 cycles. This again is inconsequential as there is a 200% safety factor for the required number of louvers at 50 kA operation. It was also comforting to note that switch timing did not vary, a constant concern of spring loaded, mechanically actuated devices. A twenty shot overlay of switch closing time (Fig. 3) after the 65,000 cycle test, indicates a delay of about 42 mS with 4.5 mS peak peak jitter. The opening time, a 20 shot overlay, at end of life, shows a well defined contact parting at 40 mS with little jitter (Fig. 4). This switch is shown in Fig. 5, ready for its final test, a destructive test to repeatedly make and break load current. Earlier test results from dc vacuum interrupter testing had indicated this switch does not damage easily. Repetitive opening under 50 kA load caused no damage to the main electrodes. After repair of the control room timing chasis, inspection of the switch showed the damage localized on the auxiliary arc electrodes. The inductively induced arcing did not cause the arc to migrate to the main electrodes. Repetitive switching (make and break) at the 10 kA and 20 kA levels showed no burning on the Multilam louvers. At the 30 kA level (20 test cycles) there was a sufficient voltage drop through the auxiliary arc electrodes to cause burning of louvers on closing (Fig. 6). The contact bounce compounds this situation, parting at 50kA (clean opening) caused little damage. Before final disassembly, even though the switch was heavily contaminated with metallic ash, the switch still held off 65 kV! Note the lack of track marks in Fig. 6., but our fingerprints are clearly visible (from disassembly) on the sides.

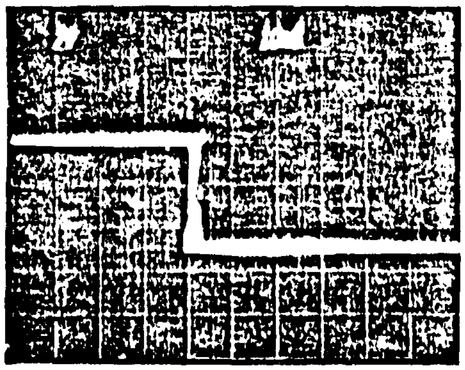


Fig. 3.

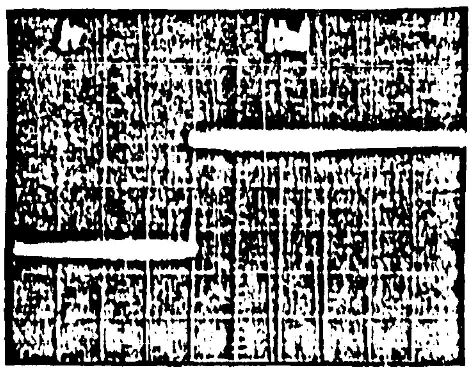


Fig. 4.

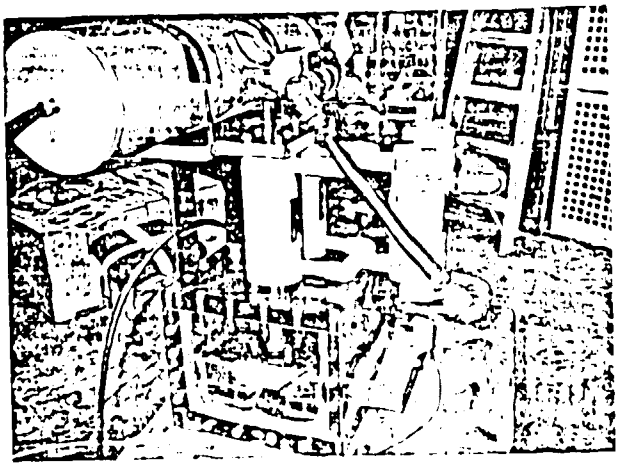


Fig. 5.

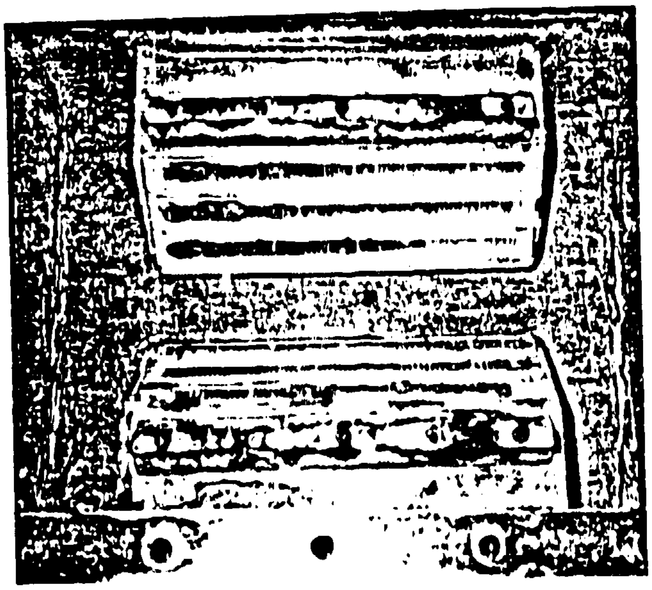


Fig. 6.

Mechanical stress tests were performed on the contact flanges. The switch was supported by its flanges during most of the cycling. As no pressure leaks developed or electrode misalignment, it was determined the switch is capable to mount in line with the elevated buswork. This not only saves valuable floor space, but avoids costly cable drops.

CONCLUSION

Los Alamos has designed, tested, and fabricated a high power cold switch of outstanding performance. This switch has a very significant impact on system reliability, circuit loss, cost, required floor space, and control simplification. Further development of downsized units (smaller units for reduced currents) may permit us to quickly switch power supplies for plasma current ramp down and other control functions.