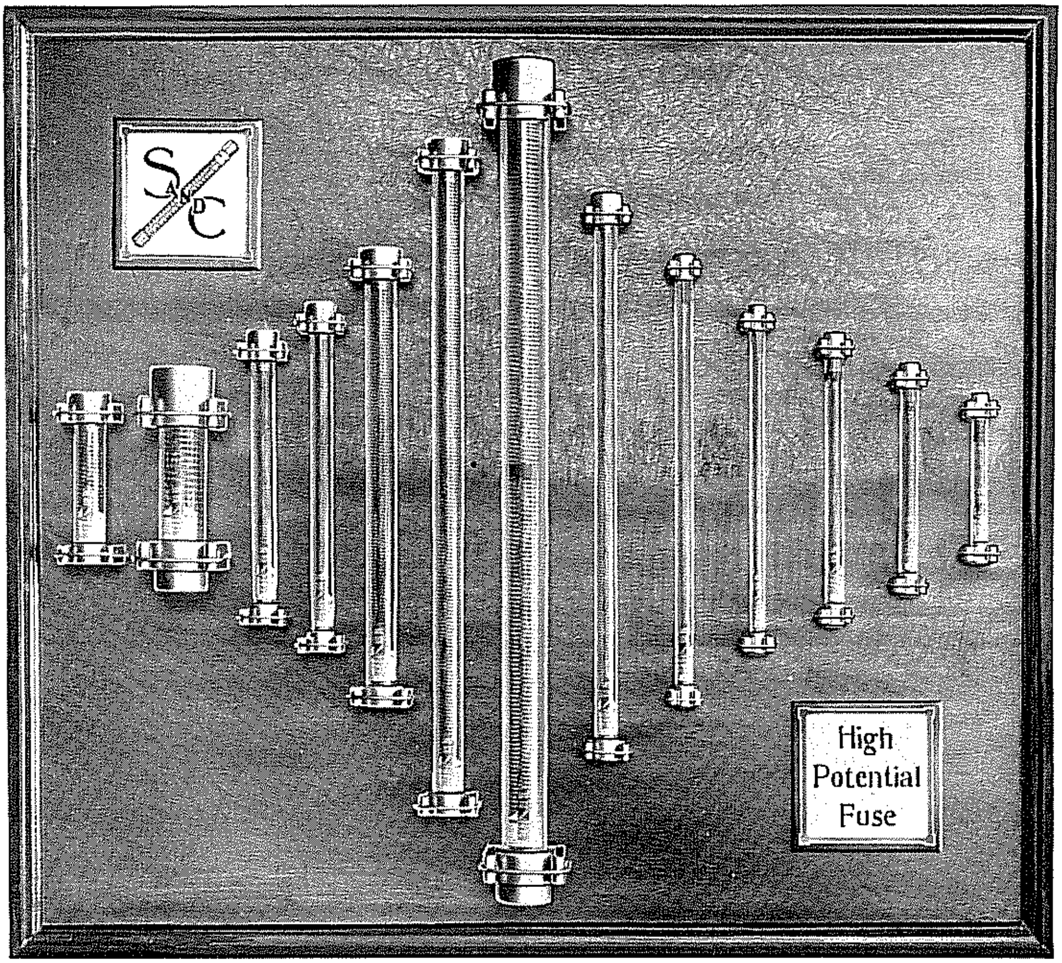
The S & C HIGH POTENTIAL FUSE

SCHWEITZER & CONRAD INC.



The S & C Fuse

2,200 to 132,000 Volts

½ to 400 Amperes

The Standard of High Voltage Fuse Protection not only in the United States but all over The World.

SCHWEITZER CONRAD, INC.

4435 RAVENSWOOD AVENUE CHICAGO, ILLINOIS U.S.A.

Bulletin 200A

The S&C Fuse

And Its Relation to Electric Power Systems

Electric Power Systems

The extension and interconnection of high voltage power systems have contributed largely to national prosperity by making available an abundance of electricity for power, lighting, and heating purposes in all communities, even those situated great distances from generating stations.

These interconnections have effected considerable savings in generation and distribution costs, by obtaining the advantages accruing from diversity of loads and making possible the construction of large and efficient generating stations at locations where electric production costs are a minimum.

A Problem in the Transmission and Distribution of Power

Continuous, uninterrupted service on these transmission and distribution systems is, however, more difficult to maintain because the failure of any transformer will cause a service interruption to other parts of the system unless means are provided for the rapid and effective isolation of the defective transformer.

A transformer failure may result from an overload, a short circuit, or a voltage surge, and its rapid and effective isolation necessitates the application of protective equipment which will successfully interrupt both overload and short-circuit currents.

The Disconnecting of Defective Equipment

The automatic isolation of defective equipment is accomplished either by oil circuit breakers or fuses. Oil circuit breakers, on account of their high initial cost and the large installation space required, are, in numerous cases, not justified from an economic standpoint, and for this reason fuses—and particularly the S & C Fuse—have found an ever-increasing field of usefulness.

High Voltage Arcs

Interrupting a high voltage circuit under load is certain to be accompanied by an arc which must be disposed of in some manner before it reaches destructive proportions.

A brief consideration of the characteristics of a high voltage arc will show the fundamental features which high voltage circuit interrupting equipment must possess in order to clear the circuit during both overload and short circuit conditions.

Fig. 1 shows in graphic form the relation existing between the line voltage, the current, and the arc voltage, during the opening but before the final clearing of a high voltage *non-inductive* circuit.

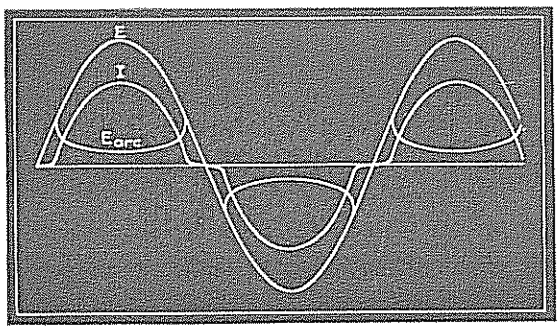


Fig. 1—Non-Inductive Circuit. E-Line Voltage; I-Current; E_{arc}-Arc Voltage

Immediately upon the opening of the circuit, a voltage appears across the gaseous gap (*i. e.* the arc voltage) which is in phase with the current. During the latter portion of each half cycle the arc becomes unstable and its resistance increases rapidly, causing the current to diminish to zero a small interval of time before the line voltage becomes zero. The arc is re-established during the following one-half cycle, as shown in Fig. 1, unless a gap has been established having a flash-over value greater than the highest instantaneous value of the line voltage.

The S&C Fuse

And the Requirements for Interrupting High Voltage Circuits

Fig. 2 shows in graphic form the relation existing between the line voltage, the current, and the arc voltage during the opening but before the final clearing of a high voltage

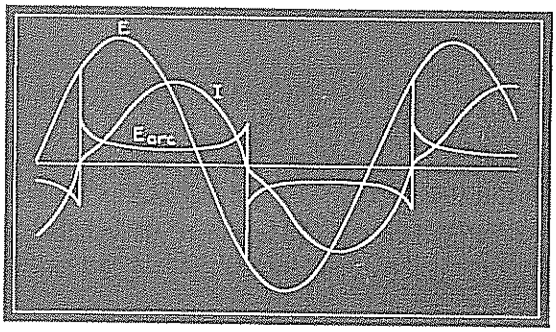


Fig. 2—Inductive Circuit—60° displacement between current and voltage. E-Line Voltage; I-Current; E_{arc}-Arc Voltage

inductive circuit. This graph shows that there is always a voltage available for the instantaneous re-establishment of the arc at the instant the current is zero. The voltage which causes the re-establishment of the arc increases with the inductance in the circuit, and becomes a maximum when a 90° phase displacement exists between the line voltage and the current. *Inductance, therefore, greatly increases the difficulty of interrupting the circuit.*

Fundamental Requirements for the Interruption of a High Voltage Circuit

From Figures 1 and 2 it is evident that a fundamental requirement for the successful interruption of a high voltage circuit is the establishment, at the proper instant, of a positive gap, over which the arc cannot be re-established. It will also be apparent that such a gap must be established in a minimum of time to prevent destruction of the circuit interrupting equipment due to the thermal effect of the arc.

An arc in reality is a conductor, which automatically adjusts its cross section so as to maintain a constant current density. An arc may develop considerable physical proportions during a short-circuit, and this necessitates some reliable means for rapidly quenching the arc. Immediately following the interrupting of a short-circuit in modern systems, the system voltage often reaches several times its normal value due to the sudden release of the stored energy of the system, which phenomenon increases the chances for the failure of the circuit-interrupting equipment.

Methods Employed for Interrupting High Voltage Circuits

Several methods for interrupting high voltage circuits have been applied by manufacturers. In expulsion fuses, for instance, sufficient vaporization of the fuse element must take place to expel conducting vapors and metals from the fuse tube. Other manufacturers place the fuse element in a tube filled with powdered or granular materials and depend upon this material to absorb the vaporized fuse metal, and to extinguish the arc. In the case of an oil circuit breaker or an S & C Fuse, the gap is formed in the circuit by mechanical means which are entirely independent of vapor pressure, and the arc is quenched by drawing it through a dielectric liquid.

Why Some Kinds of Fuses Fail

Experience with the various methods of circuit interruption has shown that the expulsion type of fuse fails when the current is raised to a value which is only sufficient to melt the reduced section of the element, because the melting of this reduced section does not establish a sufficient gap to prevent the re-establishment of the circuit. Both the expulsion and powder-filled fuses fail during heavy short-circuits because of enormous pressures causing destruction of the fuse tube, or because of the ionization of a sufficient quantity of fuse element vapor through which the arc is re-established and maintained.

The S&C Fuse

And the Fundamentals of High Voltage Fuse Design

Requirements for a Successful Fuse

During failure of equipment, the current may vary between the limits of an overload and a short-circuit of considerable magnitude. Also the phase relationship between the current and voltage during equipment failure, and the point on the voltage wave at which the short circuit occurs, will be subject to wide variations. When these self-evident facts are considered together with the conditions outlined in foregoing paragraphs, it will be apparent that the fundamental requirements of a high voltage fuse are:

(1) The fuse element should be of minimum section and length so as to reduce the quantity of ionized vapor to a minimum.

(2) The fuse element vapor must be vented to prevent destruction of the fuse tube.

(3) The arc must be drawn out and quenched, setting up a gap having a flash-over voltage greater than the maximum normal or transient value of the line voltage.

Principles of the S & C Fuse

An examination of the illustration on the opposite page will show that the following features which are so necessary for the interruption of high voltage circuits, have been incorporated in the design of the S & C Fuse.

(1) The fuse element is of minimum section and length, resulting in uniform time-current characteristics and in a minimum of ionized vapor when the fuse is blown.

(2) The fuse element is shielded by the brass ferrule, completely protecting it from corona, which makes possible the manufacture of successful fuses for 2.2 Kv. to 132 Kv. having an ampere rating as low as one-half ampere.

(3) A vent cap is provided for releasing the pressure when the fuse is blown under short-circuit conditions. The entire assembly is enclosed in a glass tube which will withstand a hydraulic test pressure of 1000 lbs. per square inch.

(4) A positive gap is introduced into the circuit by the rapid retraction of the moving arcing terminal through a high dielectric liquid, this gap being formed regardless of whether the fuse element is blown during either overload or short-circuit conditions.

(5) The arc is drawn down through and quenched by a high dielectric arc-extinguishing liquid.

Compared With an Oil Circuit Breaker

In fact, the operation of an S & C Fuse immediately following the melting of the fuse element is similar to the operation of the most expensive oil circuit breakers, but in addition has the following advantages:

(1) The arc is quenched in a liquid which, not only is non-inflammable, but also, is one of the most effective fire extinguishers. The vapors of this liquid will not support combustion nor endanger adjacent equipment.

(2) The moving arcing terminal of an S & C Fuse possesses practically no inertia and under short-circuit conditions clears the circuit in ½ to 1½ cycles, whereas, an oil circuit breaker will require from 6 to 60 cycles to clear the circuit after the trip coil has been energized.

(3) When an S & C Fuse is blown under short-circuit, the replacing of the fuse completes the necessary maintenance, whereas, under similar conditions an oil circuit breaker would require dismantling, inspection of contacts, and probable replacement of oil, resulting in a maintenance expense many times greater than the refill cost of a set of S & C Fuses.

The S&C Fuse

Has Numerous Advantageous Features

Rapid Operation

The time required by an S & C Fuse to clear a short-circuit on a 60-cycle system is from ½ to 1½ cycles, or from 1/120 to 1/40 second.

During overloads, the time required to melt the fuse element will depend upon the current volume but when the fuse element is melted, the clearing of the circuit is just as rapid as on short-circuits. In other words, *the speed with which the circuit is actually interrupted after the fuse element is melted is not dependent upon the value of the current at the instant the fuse is blown.*

This speed of the S & C Fuse is of decided advantage under two of the most common conditions. In the case of a short-circuit, the S & C Fuse will clear so rapidly that the disturbance is localized. In case of insulation failure, the S & C Fuse often clears the circuit before a complete breakdown of the insulation occurs. The damaged equipment is, therefore, disconnected before either the equipment or the system is subjected to the effects of a short-circuit.

S & C Fuses Do Not Endanger Nearby Apparatus

Ordinary fuses frequently communicate an arc to adjacent equipment and busses because they expel conducting vapor. That an S & C Fuse does not expel conducting vapor, has been conclusively proven in nineteen tests during which a piece of dry cotton was suspended six inches directly above each fuse. The fuses were blown during short-circuit and in only one case the cotton was ignited by the action of the fuse. However, the flame was so rapidly extinguished by the fuse liquid vapor that the burning of the cotton could barely be detected.

S & C Fuse Liquid Will Not Burn or Freeze

The liquid used in the S & C Fuse is non-inflammable; in fact, it is the best electric fire extinguisher obtainable. Also, this liquid will not freeze in any climate in which it might be used, the freezing point being 65° below zero F.

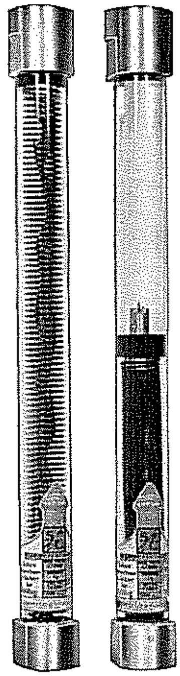


Fig. 9 *Fig. 10*

Blown Fuse Distinguishable at a Distance

The S & C Fuse when blown is distinguishable at a distance (see Fig. 10). This not only saves time and expense, but eliminates the danger attending the removal and testing of fuses to determine whether they are blown.

Return Blown Fuses to the Factory for Refilling

Blown fuses returned to the factory for refilling are first disassembled; all obsolete or damaged parts are discarded and the remaining parts which meet the mechanical and electrical requirements are thoroughly cleaned. The fuses are then assembled, just as new fuses are assembled, and the latest improvements are always incorporated when S & C Fuses are thus reconstructed.

This refilling, which is actually reconstructing, therefore, wipes out all depreciation or obsolescence which might be charged against fuses regardless of when they were originally purchased.

Although extreme care and special processes requiring special equipment are necessary to do the work properly, the cost of refilling is not high. When it is understood that the refill charge covers complete rejuvenation of the fuses, and therefore disposes of depreciation and obsolescence, the charge is found to be remarkably low.