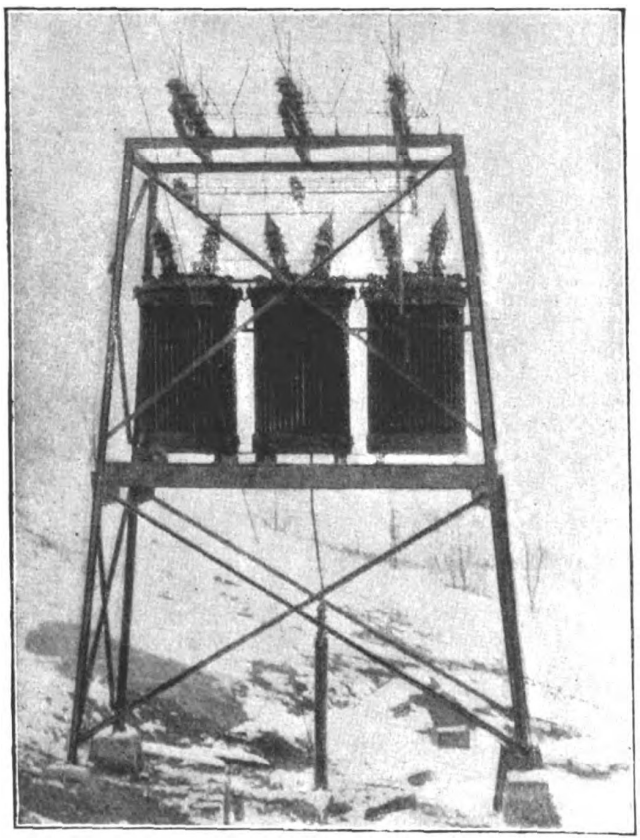


HORN-GAP ARRESTERS PROTECT BANK OF 50 KVA. 22,000/2,200 VOLT TRANSFORMERS

The 2,200-volt alternating current passes through a borehole to a rotary converter installed inside the mine.

improperly or inadequately bonded track is to measure the voltage drop on 1,000 joints of track, using suitable portable resistance or other equipment which will draw sufficient current to cause an appreciable voltage drop on the section of track being tested.

The method employed by the Consolidation Coal Co. in making this test is to use a haulage locomotive to draw the desired current. Either a loaded trip can be coupled to this machine or the brakes can be set so that the desired current will be consumed. Simultaneous voltage and current readings are taken. If a voltage drop on the track is discovered arising from other loads in the mine such as mining machines, pumps and the like, this voltage reading is deducted from that taken while the locomotive is in motion.

Rotary Converter Must Be Well Protected

Three causes of serious burnouts of rotary converter armatures have been: Failure of overspeed devices, bearing burnouts and operation on single phase. To lessen the likelihood of failure of overspeed devices weekly tests should be made upon them. Of course, these devices are required only at installations where two or more rotary converters operate simultaneously. The necessary test can be easily made by tripping the oil circuit breaker on the alternating-current side of the machine and letting it continue to run from the direct-current side, weakening the field if necessary to cause overspeeding.

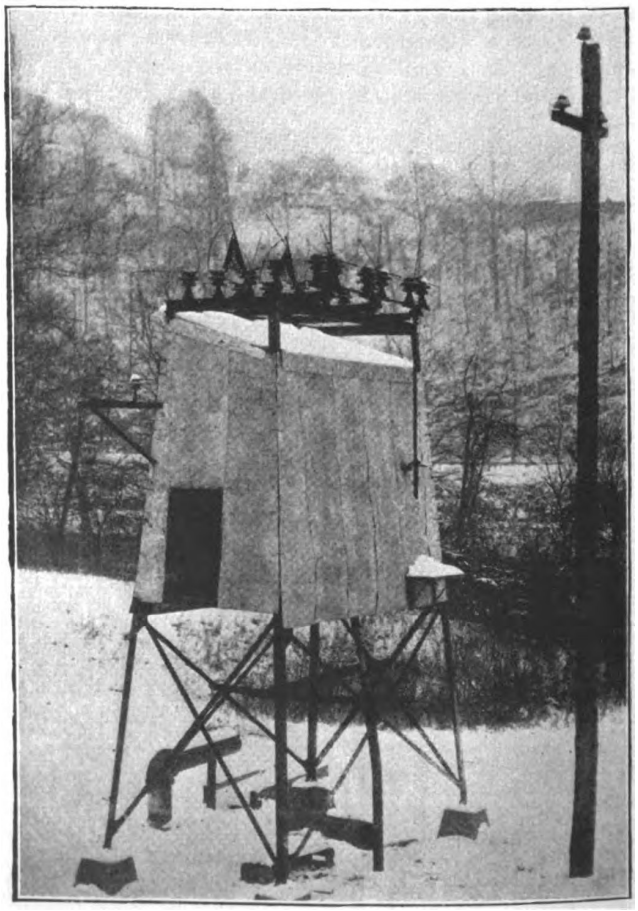
Such devices usually are arranged to operate at 15 per cent above normal. If the overspeed device fails to trip the direct-current circuit breakers at the proper speed, the necessary adjustments should be made either upon the overspeed switch of the rotary converter or upon the direct-current circuit breaker.

To prevent bearing burnouts use an oil of proper grade, which should be changed often enough to suit the operating conditions. Bearing thermostat relays are considered a good investment. To prevent the possibility that the rotary converter will run on single phase owing to line trouble, and that it may continue to run for a length of time sufficient to overheat the armature, inverse time or thermal relays should be installed.

Four Lightning and Surge Arresters

To protect the insulation of machinery and transmission lines from damage by lightning, arresters must be provided. These should be capable of conducting to the ground the excessive energy arising from lightning or surges. Space will not permit a complete description of all types of these devices, but a brief delineation will be given of some of the best-known varieties now in use. These include the electrolytic, oxide-film, horn-gap and liquid-rheostat types.

Electrolytic lightning arresters consist of a series of aluminum trays stacked up inside an iron tank. Each tray is partly filled with the electrolyte, the remaining space being filled with oil to prevent evaporation. One cell is provided for each 250 to 280 volts of normal line potential. Each single-phase set of trays is con-



STEEL TOWER CONTAINING TRANSFORMERS PROTECTED BY HORN-GAP SWITCH AND LIGHTNING ARRESTER

The transformers are of the indoor type and consequently are covered by sheet iron at the sides and above. The secondaries of the transformers are connected to a three-conductor lead-covered steel-armored cable leading through a borehole to a pump inside the mine, the discharge pipe of which can be seen under the tower.

nected to a line wire through an air gap. This gap should be shorted every few days, causing the arresters to discharge and build up an insulating film on each tray. When high voltage occurs on the line the air gap is jumped and the current breaks through the insulating film on the trays. When normal potential is restored, the insulating film prevents further discharge of current.

Arresters should be thoroughly overhauled once each year. Experience shows that a certain amount of rust accumulates on the inside of the iron tanks even though they be filled with oil. Some of this rust has been found in the trays. The Consolidation Coal Co., when it made its spring overhauling, painted the inside of the tanks with shellac. It is hoped that this will prevent further rusting.

Horn-Gap Arresters Cheap But Efficient

The cheapest form of lightning arrester is the horn gap, yet the results it gives are quite satisfactory. The arresters consist of an air horn gap connected to the ground. A suitable resistance in series with the air gap often is provided. This allows current to be discharged to the ground when high voltages come upon the line. When normal line voltage is restored the resistance is sufficient to help cut down the flow of current. The discharge is interrupted also by the arc following up the horns of the air gap.

An auxiliary air horn gap often is provided which allows discharge to go to the ground in case the resistance becomes broken or in case of insufficient capacity of the resistance elements. The air gaps connected to the lines should be made small. In fact they should be just large enough to prevent discharges from being too numerous. Frequent inspections should be made of the resistance elements.

The Bennett surge arrester consists of a tank filled with water with a tube extending from the top down through the middle to a point near the bottom. An electrode extends through the cover and makes contact with the surface of the water within the tube. The line wire connects to an air gap in series with the top electrode.

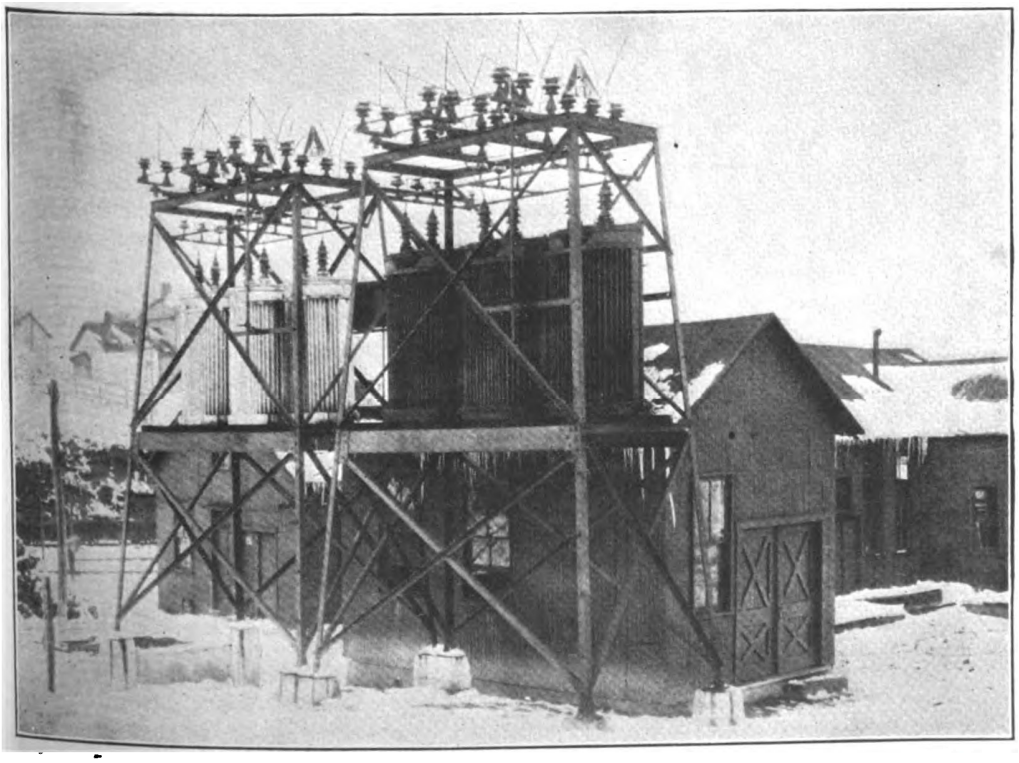
In case of high voltage on the line, due either to a switching surge or to lightning, the current jumps across the air gap and discharges into the water in the tank. As a result steam is generated, and the level of the liquid in the middle tube is forced down until the water is separated from the top electrode a sufficient distance to extinguish the arc.

Discharge is interrupted also by an arc following up the horns of the air gap connected to the line wire. The conductivity of the water should be sufficient to draw enough current to cause an arc to travel up the air gap horns a distance of three or four inches when they are "shorted" with normal line voltage. If necessary a small quantity of salt may be added to the water. The width of the horn gaps should be adjusted to the lowest value that will prevent slight surges from causing a discharge but should be made such as will allow all dangerous surges to arc over.

Provision must be made to prevent the water from freezing in cold weather, and to this end heating coils can be furnished with these arresters. It is necessary that suitable voltage be provided for the energizing of these coils. In some instances additional transformers must be installed to supply energy of the correct potential to the heating coils.

Protect Oil Circuit Breaker Bushings

At the Hutchinson central substation of the Consolidation Coal Co. much trouble has been experienced from the breakage of oil circuit breaker bushings during line disturbances on its four main circuits. When a "short" would occur on one line and the oil circuit breaker would trip out, a switching surge on the common high-tension bus would cause a bushing failure on the bus side of one of the oil circuit breakers connected



Two Banks of Transformers

Both have horn-gap lightning arresters. One bank of transformers steps the current down for use of rotary converters, the other bank reduces the voltage of the current to supply a 2,200-volt service. The transformers are of the outdoor type.

to the common bus. This would sometimes happen to the breaker that opened and sometimes to one adjoining it. After a careful study of the causes of the bushing failures, it was decided to try out Bennett surge arresters. These were connected to the common 22,000-volt bus to which the four oil circuit breakers are connected.

A short time after these arresters were installed another bushing failed on the bus side of one of the oil circuit breakers. The connections were traced out and it was found that this bushing was connected to a high-tension bus which was in turn connected to a Bennett surge arrester element having a weak salt solution. This arrester element was directly under the 22,000-volt buses, and the solution had been left weak while the arresters were being tried out, as it was feared that this element might draw such a heavy arc that it would hold on long enough to be carried into the 22,000-volt buses.

After this bushing failure the strength of the solution was increased. Since that time there have been no more bushing failures, although several highly electrical storms have occurred accompanied by heavy line disturbances. The arresters were installed Feb. 20, 1921, and the first bushing failure occurred about April 16, 1921. Although during the present trial period heavy line disturbances have been experienced, the test has not been of sufficient duration to prove that the devices installed are adequate to prevent further bushing failures. The arresters are placed inside a brick building, where there is little danger that the water will freeze. It is the intention, however, to install electric heating elements before next winter.

Oxide-film arresters consist of stacks of flat wafer-shaped elements, each of which were rated at 300 volts. Each element consists of an annular porcelain ring filled with lead oxide. A metal plate is clamped to each side of the ring, its inner surface coming in contact with the lead oxide, while its outer surface is coated with an insulating material. In series with each stack of elements is a sphere air gap connected to the line.

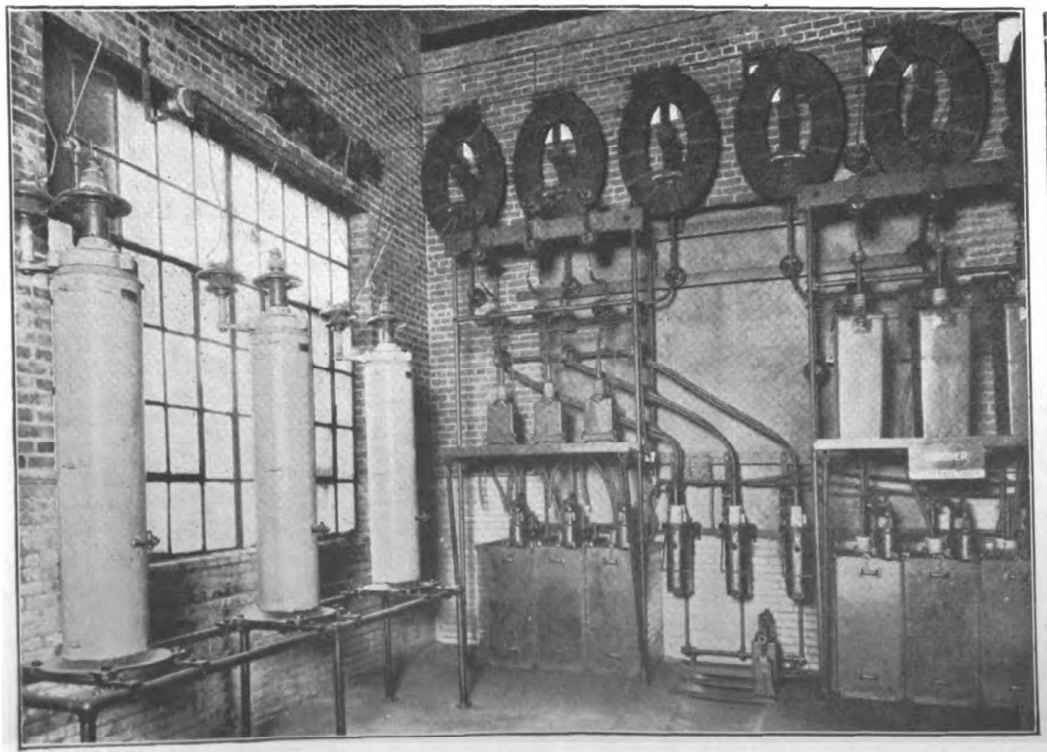
When high voltage breaks down the sphere gaps, the stacks of wafer-shaped elements have full line voltage impressed upon them. The insulating coating on the metal disks is punctured and current flows through the lead oxide. Red lead and litharge are formed and deposited on the surface of the metal plates. As red lead and litharge possess insulating qualities, the discharge is arrested by the time normal line voltage is restored. New punctures are made upon the next discharge. The arresters are fit for service so long as the surfaces of the disks have not, everywhere, been punctured.

The manufacturers state that this type of arrester has been in constant service for six years without any noticeable change in its effectiveness. It will be necessary, of course, to renew the disks in time, and a testing device is furnished with these arresters.

Relative Advantages of Four Arrester Types

The approximate relative prices of the above-mentioned lightning arresters for 22,000-volt three-phase service, which is the standard in the Fairmont fields, are as follows: Electrolytic, 100; oxide film, 95½; Bennett liquid type, 63; air horn gap with choke coils, 12.

As the oxide-film arrester requires practically no attention it would seem that it could be used in more installations than can the electrolytic type. These, however, should be tested after each lightning season. This is a simple operation, requiring but little time. The oxide-film arrester should require less attention than the Bennett liquid type, which is subject to freezing. It is also necessary to inspect the water level of the latter type occasionally. A film of oil is kept on the surface of the water to prevent evaporation, but as steam is generated each time the arrester discharges, the water level is bound to fall even though slowly.



High-Tension Room

On the left will be seen three Bennett Surge Arresters, manufactured by the Electro Service Co., of Marietta, Ga. The arrester farthest in the rear ground is directly under the 22,000-volt bus. Oil circuit breakers with current transformers for two outgoing circuits are to be seen in the rear of the room.