A SUGGESTIVE CODE FOR THE ELECTRICAL OPERATION OF MINES IN THE SOUTHERN APPALACHIAN DISTRICT.

BY

ERNEST CHARLES JONES

A THESIS SUBMITTED FOR
THE DEGREE OF BACHELOR OF SCIENCE
ELECTRICAL ENGINEERING COURSE

University of Tennessee.
1922

TABLE OF CONTENTS.

INTRODUCTION.

It has been suggested that a standard code for the electrical operation of mines in this Southern Appalachian District would be a great benefit to the mine operators. The cost of mining a ton of coal varies by a large per cent in different mines. There are gounds for a reasonable difference but there is no excuse for a wide variation. Local conditions will exert the main influence on the cost of mining.

With this problem in view, it is necessary to investigate and see where the lack of efficiency occurs. The primary purpose of this thesis is to find where losses occur in the electrical equipment of a mine, and to suggest a method for decreasing these losses to a minimum.

ELECTRIC MINING SIGNALS.

There are only two forms of signals employed now in mines:

1. Those for signalling from any portion of the traction system.

2. Those for working the cages in the shaft.

There are three different methods used in this vicinity.

1. Bell.

2. Light flashing.

3. Telephone.

In order to determine just which system should be adopted, it would be essential to make a complete study of the local conditions. The amount of traffic on the railroad system would exert and influence on the type that should be selected. The distance between hooking-on stations would be a factor that would enter.

The ideal system would be furnished by the telephone, but the initial cost is so great that its use would be rendered practically impossible. The first cost of a flashlighting would be excessive also. The concensus of opinion of engineers in this district is that the bell service is the most efficient and economical for traction signals.

(See Figure No. 1 for a design of a bell system.)

Specifications.

There should be a bell located at the end of each branch road of the traction system. At the exit of the bank there should be a control switch which can be operated by the train crew. The battery and centimeter should be located in a

Figure # 1.

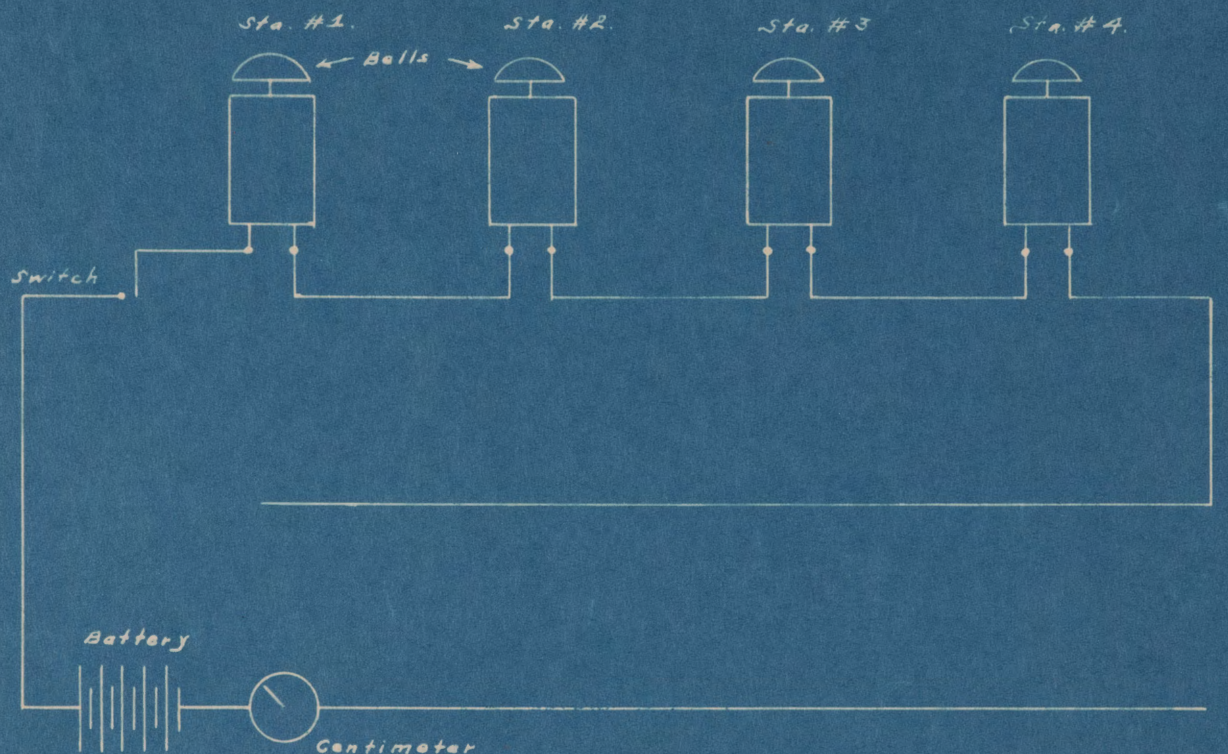


Diagram of a three wire engine-road Signal. The bells are located at each Branch road, and they are connected in series.

Drawn by E. C. Jones.

dry shelter, preferably in the central station on the surface. Number sixteen Brown and Sharp gauge wire should be used as the conductor. All joints should be soldered, except where screw connections are present.

The conductors should be supported in the tramways by means of insulators of some standard make. (See Diagram No. 2 for method of suspension.) (A) is a conical shaped wooden peg which is to driven into the roof of the tramway. The size of the peg can be determined by the character of the earth into which it is to be driven. The peg should be dipped into creosote before it is driven into the earth. (B) is a cross-arm on which the pins should be placed. (C) is an insulator which holds the wire in place.

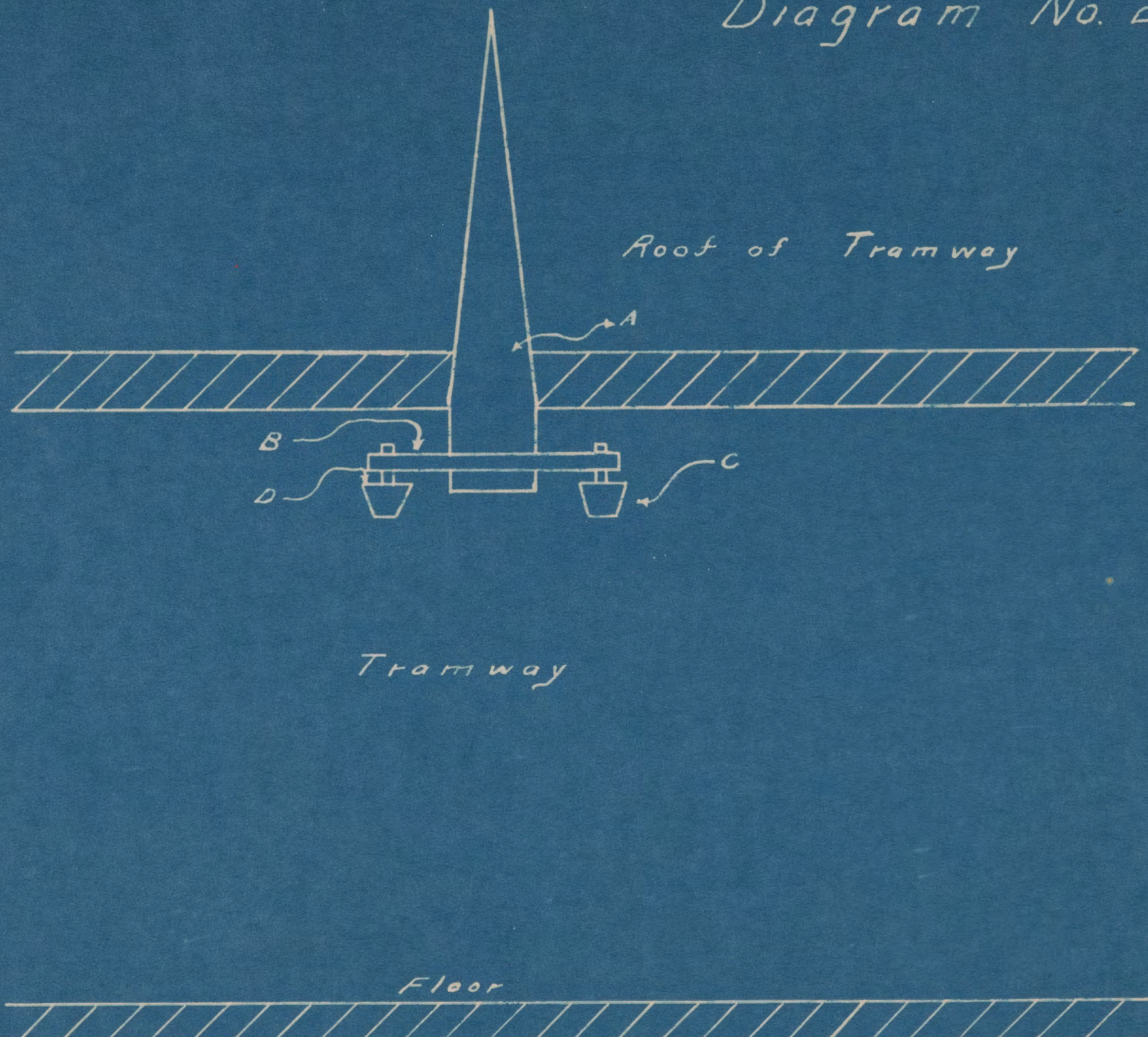
The bells may be connected in series or in parallel. The parallel system requires the largest individual cells; the series system requires the largest number of cells in the battery. The parallel system requires that the bells should be exactly alike in construction and especially that the resistance of the bell coils shall be exactly the same. In the parallel system, if one of the bells has a lower resistance than the others do, the others will be affected, especially if the battery is weak.

In this type of work the battery is in continuous service. There are three forms of batteries used:

1. Leclanche.
2. Mercury Bichromate.
3. Dry Cell.

The dry cell is the used in the best practise. They are easily replaced and the cost of attendance is less than that

Diagram No. 2.



Drawn by — E. C. Jones.

for any other cell and this labor that is saved more than pays for the additional material used.

Bells for mining signals are of two forms:

1. Those that are used in explosive atmospheres.

2. Those that are used in normal atmosphere.

A well constructed bell will serve the purpose in ordinary atmosphere, but in an explosive mine the bell armature must be housed, so as to prevent explosion.

Wires for engine-road signals should be kept well away from cable carrying currents for lights or power service. When possible, signal wires should be placed on the opposite side of the road to the cables for power service.

ELECTRIC LIGHTING FOR MINES.

Several types of lamps are used in mines but the incandescent is the most practical and economical.

Electric lighting is very poor in the mines of this district. In some mines there are not over three or four lights and they are located near the entrance. In a large majority of the mines they use carbide lamps. These lamps are worn on the hats of the miners. This type of lamp is constantly going out and it has to be replenished with carbide frequently. The Mazda lamp is simple in construction and does not require daily attention, whereas a carbide lamp does. An incandescent lamp can be replaced for a price less than that of the carbide lamp. The efficiency of an incandescent is higher than a carbide lamp.

The best incandescent bulb on the market that can be used at standard voltage is the Mazda lamp with an Edison base.

There should be a separate line in the bank for lighting purposes only and it should be so located that it could not be touched by any passing traffic. The conductors should be supported in the same manner that the signal conductors are (See Diagram No. 2). Number fourteen Brown and Shapr gauge wire should be used.

Lights should be located at each branch from the main tramway. Local conditions would determine the location of lights at other places in the bank.

Storage batteries should never be used in any remote corner, that light may be desired; an extension should be made. It costs extra to charge these batteries.

In an explosive mine some sort of enclosed socket should be used.

The main tramway lights should be controlled on the surface; in this case switch sockets would not be necessary along the main tramway. There should be a controlled switch for the branch-road lights somewhere near the main tramway light that is located at the entrance of that particular branch-road.

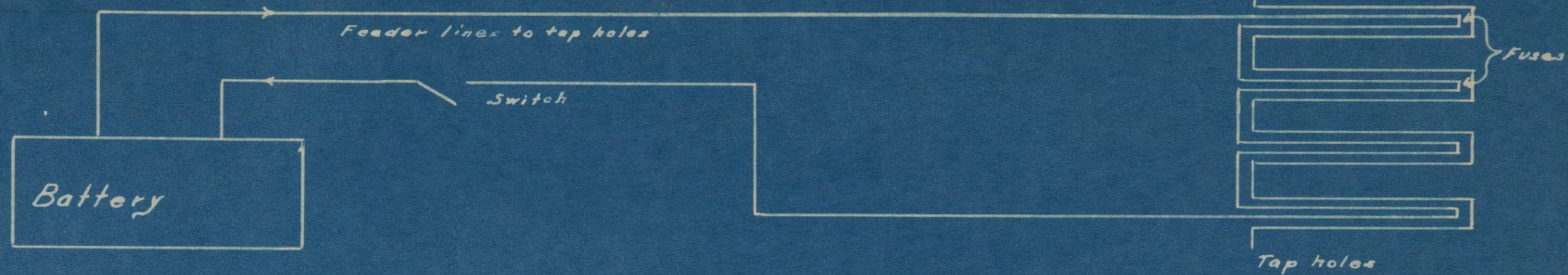
SHOT FIRING.

All shot firing should be done by electricity in case there are experienced hands available to do it. This work is exceptionally dangerous if the proper precautions are not taken.

Electric fuses should be imbedded in the explosive charge. The fuse should be put in series with a battery of dry cells and there must be a switch in the line located in out-of-danger zone. A stick should separate the wire and the tap-hole. Low tension fuses should be used. The cable should never be connected with the firing battery, until it has been first connected to the fuses.

Fuses may be connected in series or in parallel. The series connection is used in best practice. (See Diagram No. 3 for wiring diagrams.)

Diagram III



Series Arrangement for Shot-Firing

Parallel Arrangement for Shot Firing

Drawn By — E. C. Jones.

THE GENERATION OF ELECTRICITY.

The local conditions determine the source of electricity for a mine or group of mines. If power could be purchased at a comparatively low rate from some public utility company, this opportunity would be commercially attractive, if there is an insufficient supply of oil. A large quantity of water is essential in a steam plant. The size of the mine would influence the installation of an electrical generating plant.

It will be understood that the most economical method of the distribution of power about a mine, or to any group of mines, is by generating electricity at some convenient point, as central as possible, where a plentiful supply of water is available, and where coal can be had cheaply and conveniently. The energy can be transmitted by means of conductors to the motors. Electrical energy can be transferred cheaply and easily without a great loss of efficiency.

There are very few places in this section where an ample water supply is convenient.

Most mines in this section purchase their power from some public utility company. They receive an alternating current at a sub-station at a high voltage and a low current. The voltage should be stepped down to two hundred and fifty volts direct current through a rotary converter. The sub-station should be located near the bank; a long transmission of direct current is not economical or practical. When purchasing power in this way it is essential to note that the utility company from which the power is bought meets their contract. Sometimes the voltage will fall below that required by contract, and this decrease in voltage will in turn cause a rise in current. This increase in current will overheat and burn up the armatures of the bank motors. Special care should be taken with reference to this matter, or the whole electrical system will be damaged.

DISTRIBUTION OF POWER BY ELECTRICITY.

There is fall of pressure in every machine that uses current. There is also a drop in pressure in every transmission line.

The drop in the transmission line is measured by the product of the current and resistance. The voltage drop in any line should not exceed five per cent of the total voltage maintained. This is a very important matter in connection with the use and selection of apparatus and the size of cables required. In short, all drops in pressure should be reduced to a minimum. There is considerable economy in use of the proper size cable.

Having the following formulae it is an easy matter to determine the proper size cable.

(1) $E = IR.$

Where E = voltage in line.

" I = current in line.

" R = resistance of conductor.

(2) $R = \frac{pl}{a}$

Where R = resistance.

" p = specific resistance.

" l = represent length of conductor.

" a = the cross-sectional area.

Example.

Load = 200 Amps.; volts = 250; length = 1000 ft.

(1) $E = IR.$ $E/I = R = 1.25$ Ohms.

(2) $R = \frac{pl}{a}$

$$1.25 = \frac{9.529 \times 1000 \times 2}{a}$$

$$a = \frac{9.529 \times 2000}{1.25} = 15{,}240 \text{ cir. mil.}$$

15, 240 cir. mills requires #8 Brown and Sharp gauge wire.

ELECTRIC TRACTION.

Electric traction furnishes the most complex problem in the whole field of mining operation. It is here that the heaviest load is drawn and also the most losses occur. Every mine operator should give this problem a careful study.

A four naught trolley should be used. It should be supported every twelve or fifteen feet with some form of standard insulator. The support of the trolley can be made more stable by means of a log screw, working in a block of wood, driven into the ceiling of the tramway for such purpose. (See discussion and Diagram 2 on supporting of signal conductors for details.)

Bonds and Bonding.

The trolley supplies the circuit with current from the source and the return portion of the circuit consists of rails. Often the only connection between the rails is affected by means of fish-plates which are highly corroded. With these poor joints the resistance in the return circuit would run exceedingly high. Any addition of copper in the feeder lines would not improve conditions. A good copper connection between the rails would solve the problem. These copper connections are called bonds. Several types of bonds have come into use:

(a) Compressed terminal bonds.

(b) Soldered or brazed bonds.

(c) Electrically welded bonds.

(d) Amalgam bonds.

The first type mentioned is used in best practice. It is installed by forcing the head into a recently reamed hole into the web of the rail by means of a heavy screw clamp which causes it to expand and spread out under the pressure applied. In this way it makes an intimate contact with the inner surface of the hole. Care must be taken not to drill the holes too large. No lubricant should be used that will leave an insulating film on the inside of the hole.

Nothing less than a four naught Brown and Sharp gauge bond should be used. The bonds should be placed on the bottom of the flange. A compressed flexible bond should be used. Good contact should be obtained in their installation. When the bonds are placed on the bottom side of the rail there is no danger of a mille or any passing traffic loosening it. The bond resistance of a well bonded track using four naught Brown and Sharp gauge bonds will range from five to seven per cent of the resistance of the return tract. With a few missing bonds or with poor contact between bonds and rails this resistance may be increased many times. It is to the interest of the operating company to keep this resistance at a mimimum value since the voltage at the car varies inversely and the losses vary directly with the resistance. It is necessary, therefore, to make frequent tests of the resistance of rail bonds and the standard has been arbitrarily set that the resistance of a bond shall be less than that of three feet of rail.

The comparison of the resistance of the bond with that of three feet of rail may be readily made by making use of the current flowing in the rail. Two contacts (a) and (b) (Fig. IV) consisting of hardened steel knife edges or points connected to a millivoltmeter (V) are applied to the head of the rail at a distance apart corresponding to the length of the bond. A third contact (c) is permanently spaced three feet distant from one of the former contacts (b). If another millivoltmeter (V) be con-

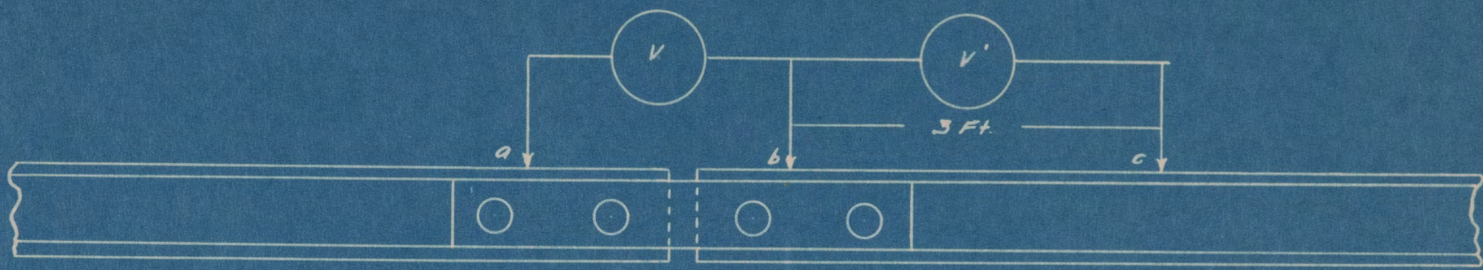


Diagram No. IV.

Drawn By - E. C. Jones.

nected between (b) and (c) and read simultaneously with the meter connected to (a) and (b) the readings are proportional to the resistance of a three feet section of rail and that of the bond, respectively. The bond may be pronounced in satisfactory condition if

V is less than V'

while if (V) be too great its departure from the required value may be recorded as

$$\frac{100\ (V-V')}{V'} \text{ per cent.}$$

Care must be exercised in making these tests, not to damage the millivoltmeter by attempting to measure an open bond. It is always well to try the bond on a meter with a fifteen volt scale, first, and if the drop of potential is found to be within the range of the millivoltmeter to make the final reading with the latter instrument.

Cross Bonding.

Thus far the bonding of rail ends alone have been considered. It is sometimes necessary to provide against the greatly increased resistance of the return circuit due to a possible open bond by connecting the rails together electrically by cross bonds. They should be made of four naught Brown and Sharp gauge wire (flexible) soldered to the bonds on opposite rails. Cross bonding should occur every seventy-five feet.

Tracks should be tested every six months for defective bonds.

Electric Locomotive.

The electric locomotive should be rated at two hundred and fifty volts. The current that the motor will draw depends mostly on the weight of the locomotive. The main trouble with the locomotive is motor trouble. The direct current motor is given to sparking. This can be eliminated by using interpoles, carbon brushes, or shifting the brushes in the direction of rotation.

The speed of the motor is obtained by varying the resistance in the field by means of a rheostat. The handle on this rheostat must be mechanically efficient or sparking will occur between the resistance terminals and the handle. An oil switch circuit breaker should be in the line to take care of overloads.

OTHER ELECTRICAL MACHINERY.

(a) Fans:

Every mine has to have ventilation; this is essential. This fan motor (A. C.) should be located on the surface under cover. The bearings of this machine should be kept oiled.

Precaution should be taken against sparking. This can be done by the methods suggested under Electric Traction.

Sometimes more ventilation is necessary than at others, so it would be best to have a variable speed motor for this purpose. Some control of the field would solve the problem.

(b) Pumps:

Some mines are troubled with water, and hence it is necessary to use a motor driven pump. This should be an A. C. motor and of such a rating to take care of the pump. The same precaution should be taken in regard to this motor as for the fan motor.

(c) Cutting Machinery:

Cutting machines should be driven by D. C. Short motors. The same precaution should be taken against them as for any other D. C. motor. The cutting machines are used in the pit but it is not necessary to run a separate line in the bank, for this pur - pose only; they can be operated on the same circuit as the locomotive.

LIBERTY MINE

The Liberty Mine is owned by the Liberty Coal and Coke Company and it is located at Gensen, Ky. This mine is nestled in the hills of Southern Kentucky about four miles from Pineville. The Southern Railroad passes within a quarter of a mile of the coal tipple; hence this mine has good freight accommodations. When the mine is working in full blast, about three hundred and fifty men are in the employee of the company.

This mine generates its own power. It is a direct current generating unit and a pressure of two hundred and fifty volts is maintained. This power house supplies two mines, Barker No. Two and The Liberty.

In the engine room there are two direct current generators:

(One)D. C. Generator built by Western Electric Co.

Rating; 150 K. W.
250 Volts.
600 Amps.
225 R. P. M.
230 No load voltage.

This generator is driven by a reciprocating steam engine.

(Two) D. C. Generator built by Westinghouse.

Rating: 200 K. W.
250 Volts.
300 Amps.
200 R. P. M.

This generator is also driven by a reciprocating steam engine.

In the boiler room there are two one hundred and fifty horse power boilers.

This mine does not have a separate line running into the mine for lighting purposes only. Wherever a light is desired it is their practice to take it from the traction circuit. Their lighting facilities are inadequate. They have only three or four permanent incandescent lights along the tramways. All the mines use lamps which are worn on their hats and they go out frequently. They are carbide lamps. The smell of this carbide is very noticeable in the pit.

They have the bell system for signalling and it seems to work very efficiently. The operating and upkeep cost is low. The mine is not gaseous so it is not necessary to have a protective covering on the bells.

They used Westinghouse six ton locomotives. The locomotives take the empty cars to the room where the cutting machines are workingand then they make a return trip with a few loaded cars. These cars are taken out to the tipple where they are weighed and then their contents are dumped into the tipple bin. In turn feight cars take the coal from this bin by merely opening a trap-door. Coal cars cannot be placed right at the hands of the men loading the cars. A temporary track is laid and the chain of cars are drawn by a mule to the position where the mine loaders are working.

This mine is not troubled with water and hence no pumps are used. The fans are run by electric motors but they only have one speed. The current used by the cutting machines obtained from the traction circuit-a mere extension is made. The cutting machine motors give very little trouble.

The cables running in this bank are supported by log screws working in a block of wood which is used as a peg. The lines are well suspended. Size four naught trolley is used and a forty pound rail forms the return.

In this mine the bonding was in good condition. I took several readings along the tramway and such conclusions were drawn. It was impossible to get anything definite information on bonding because the motors were continuously varying the current on the line, but by using best judgement was able to get a fair estimate of the voltage drop. Compressed bonds were used. They are placed on the inside of the rails. The rails are cross bonded every hundred feet.

The electrical apparatus in this bank is in charge of a regular force, and a thorough inspection is made frequently. This mine is pointed out to be the best electrically equipped mine in this section.

EXCELSIOR MINE.

This mine is owned by the Low Ash Mining Co., and it is located at Elcelsior, Ky., about four miles north of Middlesboro. This mine is also located convenient to the Southern Railroad, a spur branch runs immediately under the tipple.

There is a camp at this mine and the miners buy power from the company. Each household has a meter and each customer is charged according to a certain rate.

On the surface there is an alternating current for the pump, cutting machines, and lights. The alternating incoming voltage is twenty-three hundred and it is stepped down to one hundred and ten volts.

On the surface there is also a house where the fan is located. This fan is driven by a vertical steam engine. The speed of this steam engine can be controlled easily to get a wide variation. The oil switch circuit breaker is also located in this house.

This mine generates its own power for traction purposes. They have a Goodman direct current generator installed. It is driven by a reciprocating steam by means of a belt transmission.

Generator Rating:

Multipoles - 6 poles.

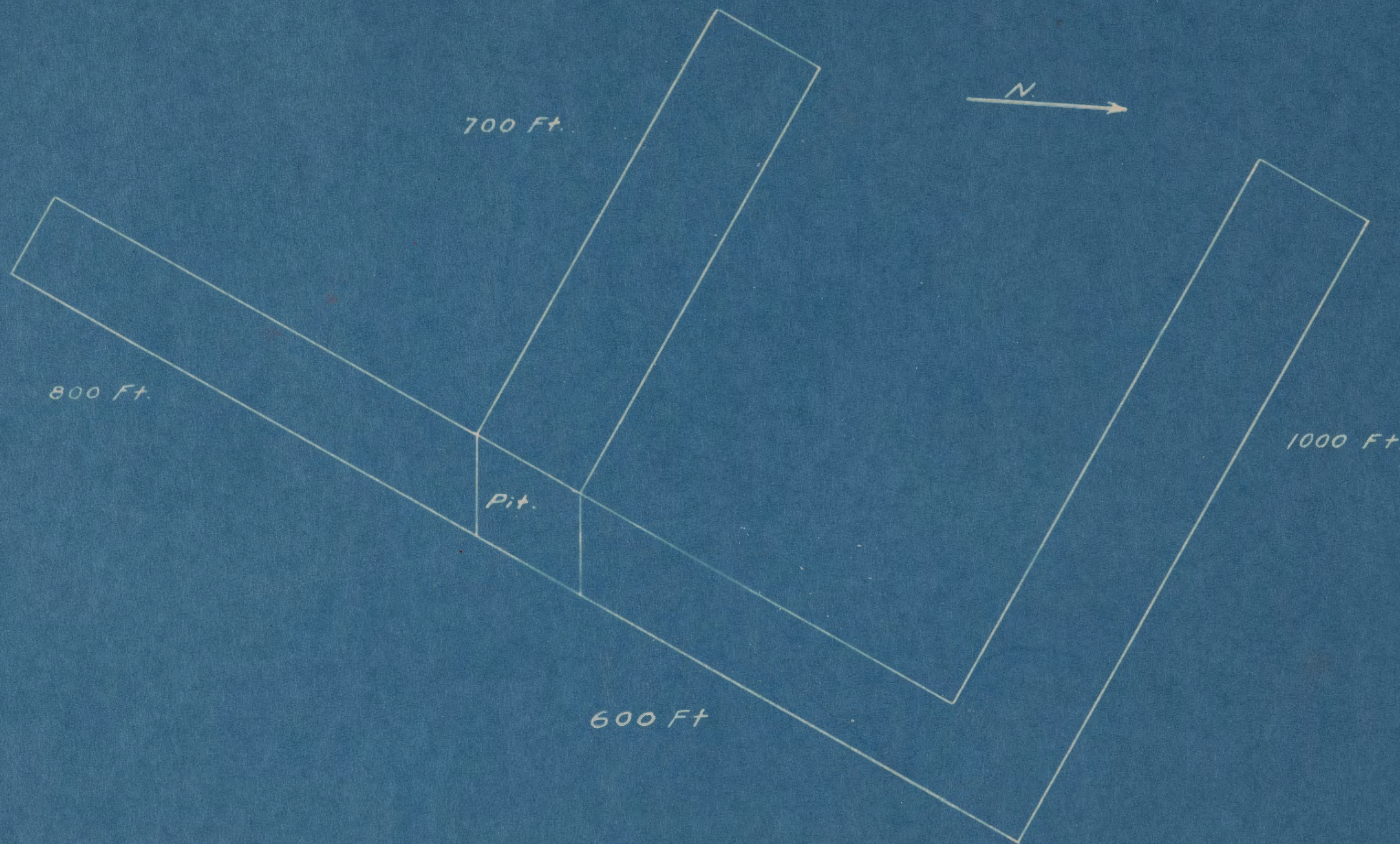
75 - K. W.

275 - Volts.

275 - Amperes.

This is a shaft mine and the main tramway is fifty feet below the surface. The main tramway is about 1200 feet long. (For the various branches and general location see figure number eight.)

Diagram No. V.



Drawn By - E. C. Jones

In connection with this shaft they have a haulage system. The cars are carried on a haulage elevator from the bottom of the pit to the top of the tipple by means of a windlass driven by a steam engine. They have a clapper bell for signalling on the haulage system.

In the boiler room they have a hundred and twenty-five horse power boiler. They maintain about an hundred and seven pounds steam pressure. (None of these steam engines have been indicated since they have been installed, which means a long period.)

They have no method of signalling in this bank for traction service. One of the hands has to walk several hundred feet to get in connection with the locomotive.

They have no separate lighting circuit running into the pit. The men use carbide lamps on their hats altogether.

This mine was just starting up when the visit was made and hence the writer was unable to make any tests on the bonding.

On the whole this mine is in a run-down condition and it was pointed out to be one of the poorest in that vicinity.

CONCLUSIONS.

From the trips made I can readily see the chance for improving the electrical field for mining in this Southern Appalachian District. Most of the losses occur in the transmission lines or in the bonds. Poor workmanship was exhibited in many cases. Electrical joints were poorly made, if any at all. A large portion of the apparatus gives the appearance that it was just set up as a temporary job.

Aside from any technical point the labor in the mines visited was not handled as efficiently as it might have been. Time is wasted by men waiting on cars. This proved to be the most noticeable occasion where money is actually lost. The reason for this is a lack of efficient signals. As an example: At the Excelsior Mine, one of the employees has to walk several hundred to notify a locomotive that a load is waiting at the other end of the line.

In a mine it is essential to keep every individual unit in working order. Every unit is dependent on the other to keep the system going. For instance, if the cutting machines fail to operate properly the whole mine ceases operation; if the fans cease to function, the miners are unable to work in the bank. it is for this reason that every machine must operate normally at all times. In order to do this, it is absolutely essential to have an efficiency department kept busy on the job at all times.

APPENDIX.

BIBLIOGRAPHY.

1. Electricity in Minihg - - - - - - - -Sidney E. Walker.

2. Electric Railway Engineering- - - -Harding.

3. Increasing Coal Efficiency- - - - -Charles E. Stuart.

APPROVAL

The foregoing thesis is hereby approved as a creditable study of an engineering subject, carried out and presented in a manner sufficiently satisfactory to warrant its acceptance as a prerequisite to the degree for which it has been submitted. It is to be understood that by this approval the undersigned does not necessarily endorse or approve any statement made, opinions expressed, or conclusions drawn therein, but approves the thesis only for the purpose for which it is submitted.

Name W. R. Woolrich

Title Assoc. Prof. Mech. Eng.