

Underground Electrical Distribution at Morton's Fairport Mine

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ABSTRACT

Alternating current was selected as the energy source for the Fairport Mine based primarily on economy, safety, reliability and voltage regulation. System voltages chosen were 4160 volts for distribution and 480 volts for utilization.

The system was designed with the same criteria of safety, reliability and voltage regulation, tempered, in part, by economy. Special attention was given to voltage regulation at the mine face.

From a preliminary layout, the system constants were placed on an alternating current calculating board and short circuit, operating, and starting conditions were checked. The minor adjustments indicated were made and this is the system now in operation at Fairport.

This design was based on a minimum operating voltage of 90 percent of rated and a minimum starting voltage of 80 percent of rated at the mine face under the worst possible anticipated conditions of load, starting and trail cable length. The heart of this design is an Induction Voltage Regulator, located in the 4160 volt Feeders to the mine face area, which compensates for voltage drop out to the portable substation transformers under all conditions from light to heavy loading.

A portion of the paper is devoted to a qualitative outline of the system and its components and also covers the aspects of safety, corrosion resistance, general construction methods and special design, control, signal, alarm and communication features.

The actual operating characteristics and maintenance experience agree remarkably well with those anticipated. A modern alternating current underground distribution system can give excellent operating results if careful study, tempered by experience, is applied to the basic design.

INTRODUCTION

Alternating Current was selected as the energy source for all underground electrical equipment at the Fairport Salt Mine. The principal areas of comparison leading to this choice, rather than Direct Current are:

1. Economy
2. Safety
3. Reliability and Maintenance
4. Voltage Regulation
5. Miscellaneous considerations

Let us briefly expand each of these items.

Economy

1. The cost of Alternating Current motors, controls and equipment is considerably less than for their Direct Current counterparts.
2. The Transformers required for step-down to operating voltages for Alternating Current is more than balanced by the costly rectifying or conversion equipment required for Direct Current systems. A comparison of efficiency between the equipment for the two systems will reveal a savings in operating cost through lower losses in transformers than in either conversion method.
3. High voltage power transmission to the Mine Face Area with smaller current values allows the use of reduced size cables for an Alternating Current system with an accompanying reduction in cost. Reduced power losses in the cables are another savings due to smaller currents.
4. Squirrel-cage type Alternating Current motors with their rugged rotors are far more economically maintained than Direct Current Motors which have wound armatures, commutators, and brushes. The simple Alternating Current starter with few components requires far less maintenance than the accelerating resistors and relays required for Direct Current starters. The Direct Current conversion equipment maintenance cost is eliminated.

Safety

1. Use of resistance grounded transformers on Alternating Current systems limits the magnitude of line to ground fault currents which reduces line to ground or machine to ground voltage on faults to a safe level for personnel. The low fault current plus rapid fault clearing also limits damage to equipment. This protection is also afforded to trail cables, minimizing their hazard and damage on faults. The Direct Current distribution system with grounded return path does not lend itself well to a current limiting scheme.
2. The relative complexity of Direct Current controls presents a hazard in itself which can be reduced by the inherent simplicity of alternating current controls.
3. A 480/277 volt neutral grounded Alternating Current system results in only 277 volts from phase to ground which is comparable to a 250 volt Direct Current System.

Reliability

1. The transformer, which is extremely rugged, simple and has no moving parts is inherently reliable and maintenance free. It has the ability to carry moderate overloads for long lengths of time and large overloads of short duration with a relatively small loss of useful life. Most types of direct current conversion equipment are relatively complex, some types have moving parts and all are limited in overload capabilities. In comparison, they require more supervision, inspection and maintenance.
2. The simplicity and ruggedness of the alternating current squirrel cage motor produces maximum trouble-free service when properly applied. In contrast, the direct current motor with wound armature, commutator bars, brushes and brush holders is by far more likely to produce troubles throughout its life. For similar reasons, direct current controllers, with inherently more moving parts and devices plus resistors, require more maintenance than their alternating current counterpart.
3. The simplicity of safety grounding and fault tripping on alternating current systems is an extremely reliable feature which cannot be easily duplicated on direct current systems.
4. Inherent maximum torque limitations of alternating current motors limit the torque transmitted to gears and cutter heads, minimizing mechanical maintenance.

Voltage Regulation

Both alternating current motors and controls require better voltage regulation than similar direct current equipment. The added elements of power factor, line reactance, high motor

starting currents, and high contactor drop-out voltages for alternating current systems contrasts sharply with regulation of direct current systems which are subject only to line resistance and relatively low motor starting currents. These effects can be overcome or minimized by choice of a high utilization voltage such as 480 volts -- 3-phase, power factor correction, and use of a voltage regulator which would add to the initial system cost.

Miscellaneous Considerations

Other factors in favor of an alternating current system are:

1. Simplicity and ease of control.
2. Lower weight and smaller size of motors and equipment.
3. Flexibility.
 - a. Ease of transformation for power and lighting voltages.
 - b. Ease of adapting motor starters within starter rating without involving major changes such as resistors.
 - c. Ease of advancing the location of the transformation as compared with moving conversion equipment.

The above comparisons show why the choice was an alternating current system employing 4160 volts -- 3-phase for distribution and 480 volts -- 3-phase for utilization. There are no track haulage requirements at Fairport Mine. The salt is loaded by machine into large non-highway type diesel trucks at the mine face and brought to the crushing and screening area at the production shaft. There, it is dumped into a hopper and proceeds through initial crushing and screening below ground transported on belt conveyors to the production shaft skip loading hopper. There it is automatically loaded into skips and hoisted above ground where it is finish processed, stored, and shipped from the plant by truck, rail, and boat.

The design of the underground electrical distribution system at Fairport was based on the criteria of safety, reliability, and optimum voltage regulation. Economic considerations were weighed in the choice of equipment and methods but, in general, this was not given the primary control it is usually afforded.

Safety considerations covered both personnel and equipment. Reliability was considered not only in relation to normal maintenance and repair but also to operating ability in a salt contaminated atmosphere with its inherent corrosion problems. Voltage regulation was a primary factor in the choice of size and rating of all electrical distribution equipment.

The excellent electrical operating experience of this mine to date is not a fortunate accident. The characteristics of all proposed electrical loads were gathered, tabulated, and incorporated into a preliminary layout from which tentative sizes and ratings of equipment were calculated. This layout was reduced to the proper data and placed on an alternating current calculating board where the probable operating, motor starting, and short circuit conditions were checked against design criteria. The minor adjustments indicated as necessary were made in the design and this is the system now in operation at Fairport.

This design was based on a minimum operating voltage of 90 percent of rated and a minimum starting voltage of 80 percent of rated at the mine face for the worst possible anticipated combination of mining machinery operating at one time at the end of 1100 feet of 480 volt trail cable. These conditions are rarely found and consequently the actual running and starting voltages are appreciably higher at this operating distance. In practice, it has been found possible to operate at these values at distances in excess of 1500 feet of 480 volt trail cable.

The heart of this underground distribution system is a step-type induction voltage regulator located in the 4160 volt feeders to the mine face area. The regulator is controlled by the magnitude of load current which causes it to adjust to the voltage to compensate for voltage drop in the feeder. This holds the primary voltage at protable substation transformers nearly constant at their rated voltage for heavy and light load conditions. It also prevents over voltage on the transformers at light load which might cause equipment failure or damage.

Those interested in a more than qualitative description of the underground distribution system under discussion are referred to the single line diagrams at the end of this article for more information as to size, rating, and system configuration.

OUTLINE OF UNDERGROUND FEEDERS AND DISTRIBUTION

4160 Volts

The underground electrical distribution system begins with two 4160 volt, 3-phase primary feeders from the above ground main switchgear to the main underground substation and switching station. 4160 volt feeders are brought from this substation to the mine fan and to portable substations at the mine-face area. The feeders to the portable substations are run via the voltage regulator and portable 4160 volt switch houses.

480 Volts

480 volt, 3-phase feeders are run from the main underground substation transformer low-voltage switchgear to motor control centers, and 480 volt branch circuits from the motor control centers to the motors, welding receptacles and other loads in the permanent underground crushing and screening area.

480 volt, 3-phase mine power feeder cables are run from the portable substation transformer low-voltage feeder breakers to the mobile mining machinery and portable distribution panels at the mine-face area. Portable cord 480 volt, 3-phase branch circuits are run from the portable distribution panels to portable fans and power tools.

LIGHTING

The crushing and screening area lighting consists of 480/277 volt, 3-phase, 4-wire lighting feeders from the main underground substation low-voltage switchgear, via a main lighting distribution panel, to lighting panels in the area. Branch circuits are run from the lighting panels to the overhead 8-foot powergroove fluorescent fixtures. Local floodlighting for critical areas and 120 volt receptacles in the crushing and screening area are fed from 120/208 volt, 3-phase, 4-wire lighting transformers and panels in each of the motor control centers. Local floodlighting in the mine-face area is fed with portable cord branch circuits from 120 volt, 1-phase lighting transformers and panels in each of the portable distribution panels. 120 volt receptacles are located on each portable distribution panel for power tools. Additional lighting in the mine-face area is provided by the headlights on the various mobile mining machines.

SAFETY FEATURES

Ground Monitoring System

The 4160 volt and 480 volt portable cables are provided with ground monitoring from the portable 4160 volt switch houses, through the 300 KVA portable substations, and out to the mobile mining equipment and portable distribution panels at the mine-face. This system offers a high degree of personnel safety in the areas where portable cables are used. All portable cables with plug terminations in the mine are protected by this system. An alternating current of extremely low potential is circulated over a cable pilot wire to the connected equipment frame and back through the ground conductor to the monitoring relay. Any opening in the ground or pilot wire interrupts this current allowing relay contacts to close, tripping the circuit breaker. This offers protection in the event of cable damage opening either the ground or pilot wire, loss of wire connection at equipment, or disconnecting of cable plugs before the circuit is de-energized.

Each portable plug and receptacle has a long ground pin, medium length phase pins, and short monitor pins with long throw threads on the plug locking device so that exposing the phase pins, while they are still energized is impossible. This arrangement causes the short pins to withdraw, opening the monitor circuit and tripping the circuit breaker when the locking device is unscrewed, before the phase and ground pins are completely withdrawn or exposed. It is also

impossible for the circuit to be energized until the plug is properly inserted into its receptacle, completing the ground monitoring circuit.

A test pushbutton which opens the monitor wire is provided at each portable substation, mobile mining machine, and portable distribution panel for testing this system at the end of each work period when the men leave the area.

Grounding System

The mine and plant ground consists of over 40 ground rods located in groups over the entire property and inter-connected with each other and with all building steel. This serves as a solid ground for all above ground equipment, and, provides an excellent ground bed for extending a ground down into the mine.

The power company substation grounding system is separate from the mine and plant grounding system to cut down the effects of lightning and switching surges on the high-voltage incoming service.

Lightning arrestors are provided on both the outdoor substation 33 KV and 4160 volt bus, connected to the power company ground. Lightning arrestors are also provided at the main 4160 volt switchgear above ground and the primary of each underground portable substation, connected to the mine and plant ground.

Ground conductors tied into the plant ground, are brought down into the mine in each of the two 4160 volt mine feeder cables run in the Access Shaft. Two additional separate ground wires, tied into the plant ground are brought down in the mine; one each in the Production and Access Shafts, and tied into the ground brought down in the two mine feeder cables, at the bottom.

In the permanent underground crushing and screening area, the plant ground brought down the shaft is tied into the grounding for the solidly grounded 480 volt permanent machinery distribution system, consisting of a main ground loop with taps of smaller sized wire to each motor control center, power or lighting panel, control panel, motor and transformer. The structural framework of the conveyors, crushers, and screens are also grounded at frequent intervals. Each conduit provides another path to ground since they are grounded at their origin plus the various points where they are attached to the structural framework which is also grounded. Thus, parallel ground paths are provided for each piece of electrical equipment, both through ground wires and the aluminum conduit. This insures both continuity of the ground system and a low resistance path to ground, which is highly desirable from a safety standpoint.

In the tunnels in the mine-face area, grounding is provided for equipment and machinery through the ground conductors in the portable cables which are connected to each piece of equipment. Both the 4160 volt system throughout the plant and mine, and the 480 volt system in this area are resistance grounded as explained later.

The main (above-ground) 3000 KVA power company transformer bank is equipped with a 96-ohm neutral grounding resistor which limits the 4160 volt system line-to-ground fault current to 25 amperes throughout the plant and mine.

Each 300 KVA, 480 volt, portable substation is equipped with a 17-ohm neutral grounding resistor which limits the 480 volt system line-to-ground fault current to less than 17 amperes for the circuits fed from these substations.

Overload and Fault Protection

Each 4160 volt feeder breaker in the above-ground main switchgear is of the metal-clad, air-circuit-breaker type, equipped with a highly sensitive ground-fault relay in addition to the normal relays for overcurrent and instantaneous line-to-line fault protection. Each breaker is electrically operated for close and trip, with batteries supplying the operating energy.

Each 4160 volt portable switch house contains two oil circuit breakers, manually operated with stored-energy capacitor tripping used in conjunction with the overcurrent, instantaneous, highly-sensitive ground fault, and ground monitor relays provided for each breaker.

The 4160 volt mine fan starter is equipped with current-limiting fuses for over-current and line-to-line fault protection plus a highly sensitive ground fault relay working in conjunction with the starter contactor for ground fault protection.

The 480 volt main underground substation feeder breakers are manually operated with the exception of the lighting main breaker which is electrically operated. Each breaker contains magnetic overcurrent and instantaneous fault tripping elements. No additional ground fault protection is required on this system as it is solidly, not resistance grounded, and ground faults will be of sufficient magnitude to trip the elements provided.

The 480 volt motor control center starters, 480/277 volt lighting distribution and lighting panels, and 120/208 volt lighting panels, are all equipped with current-limiting slow-blow fuses for overcurrent and fault protection.

The 480 volt portable substation feeder breakers are manually operated with thermal and magnetic trips for overcurrent and instantaneous fault protection plus a shunt trip attachment on each breaker for use with the highly sensitive ground-fault relays and the ground monitor relays provided.

Current-limiting slow-blow fuses are provided for all 480 volt and 120 volt circuits fed from the portable distribution panels, for overcurrent and instantaneous fault protection. Ground-fault protection is provided for the 480 volt circuits by the back-up feeder breaker at the portable substation, whereas the 120 volt circuits do not require this protection, as they are solidly grounded.

Relay Co-ordination

At present, the 4160 volt breakers and 480 volt substation feeder breakers are all supplied with long-time and instantaneous tripping elements, all properly sized and adjusted within the limits of good practice, which comprises a "fully rated system."

However, the W. W. Clark Corporation has made a relay co-ordination study for the system, based on replacing the 480 volt breaker trip elements with long-time and short-time tripping elements, all properly sized and adjusted in accordance with this study. This system study has established the proper settings for all breaker relay and trip elements, both high and low voltage, so that a small time delay is introduced between the instant of tripping for each succeeding back-up breaker from the point of fault or overload to the power company transformers. This is known as a "co-ordinated system."

This system operates in a manner designed to interrupt and remove from service the smallest possible part of the electrical distribution network in the plant, due to a fault or over-current condition, maintaining continuity of service on other feeders from common sources, if at all possible. If future operating experience dictates, this system may be installed to minimize production outages. Operating experience to date does not warrant installing this improvement.

DESIGN FEATURES -- CORROSION RESISTANCE

Many special design features have been incorporated in the underground electrical construction to hold salt corrosion of the installation to a minimum. All conduit, condulets, fitting, cable trays, junction and pull boxes, fluorescent lighting fixtures, and device enclosures, including motor control centers, portable switch houses and substations, the 4160 volt mine fan starter and mine-face feeder double-throw switch, control panels, lighting panels, etc., are copper-free aluminum.

The enclosures mentioned all are of NEMA XII (gasketed, oil and dust tight) construction, with either welded on aluminum conduit half couplings or special aluminum moisture and dust-tight hub fittings for conduit entry. Each device enclosure is equipped with internal space heaters to prevent moisture condensation when the device is de-energized.

The electrical equipment is painted with a special primer and epoxy resin-based paint. All mounting bolts, straps, clamps, etc., and all device hardware is either stainless steel, copper-free aluminum, or hot-dipped galvanized steel.

All wall-mounted equipment and devices are fastened to wood blocks or framework and the wood is then fastened to the wall to keep the device out of direct contact with the salt. All floor-mounted equipment is set on concrete pads, recessed into wall niches, to minimize contact corrosion and reduce housekeeping requirements. Semipermanent mine power feeder cables are run along the tunnel roofs in wood block clamps.

Exposed ground wires are aluminum cables with thermoplastic jacketing. All ground wire splices are aluminum cadweld type and all exposed ground connections are made with bolted aluminum, cadwelded lugs.

High-voltage, oil-immersed circuit breakers are used where possible. The oil helps to keep the salt out of the breaker contacts. For low-voltage circuits, use of fuses will not permit slight corrosion, if any, of fuses or fuse clips to remain unnoticed. This condition can be easily controlled through periodic maintenance. Also, the sealed internal parts of fuses are not subject to easy entry of salt dust. The use of current limiting, slow-blow type fuses, properly sized for motor protection, practically eliminates the danger of single-phase operation of three phase motors since the increased current required for a motor operating in this manner will cause one of the remaining fuses to blow on long time overload.

All power transformers are sealed, nitrogen-filled, dry-type. The lighting and control transformers are dust-tight, dry type. All motors are totally enclosed, fan-cooled type.

DESIGN FEATURES -- GENERAL CONSTRUCTION

The underground installation features the use of a special design, nickel-plated, 3/8" diameter, threaded stud, set into the wall with a blank cartridge-type driving gun, for support of all wall and ceiling mounted conduit, equipment and devices.

Special eight-foot, two-lamp, industrial type powergroove fluorescent fixtures with copper-free aluminum, NEMA XII enclosures and epoxy paint were specifically designed for the overhead tunnel lighting, economically producing a high level of overall illumination in the crushing and screening area.

480 volt portable distribution panels on skids were designed and built for this installation, incorporating the copper-free aluminum, NEMA XII, epoxy painted enclosures. Each of these panels contains a 480 volt fused fan starter, 480 volt fused power tool outlet and a fused lighting transformer and lighting panel ground monitored up to the panel bus. They are arranged for portable cord connection to the devices it feeds, including portable working-face vent fans, portable floodlight stands and hand lamps, and 110 volt and 480 volt power tools.

Conduit and wire-type construction is used for all permanent equipment fed from the solidly grounded 480 volt system in the crushing and screening area. Portable mine power cables are used for all 4160 volt and 480 volt, resistance-grounded circuits. Permanent 4160 volt cables in the crushing and screening area are in an aluminum cable rack. Semipermanent 4160 volt cables to the portable switching stations are run in wood cable blocks. 4160 volt and 480 volt cables in the mine-face areas are either hung on temporary pins in the tunnel walls or laid along the wall on tunnel floors, using 500 foot lengths made up with plugs on each end. A bus tap box has been provided to allow the 4160 volt feeder from the main underground substation to the mine-face areas to be split and run in several directions. Plug connected, 480 volt distribution boxes have also been designed and built to allow two of the smaller mining machines to be fed from one portable substation feeder breaker while maintaining the ground monitoring to both machines.

Both the power and control cables are carried down the Access Shaft suspended at 200 foot intervals on pre-formed cable grips made of spiralled stainless steel wire, plastic coated. They are racked into place between supports in slotted wood blocks.

All wire is stranded copper except exposed ground wire which is stranded aluminum. Single conductor 600 volt wire run in conduit in the crushing and screening area is rubber insulated and jacketed type RHW for 480 volt power circuits and thermoplastic insulated and jacketed type TW for lighting and control. Exposed ground wire is also type TW. Wire for lighting fixture tails is asbestos insulated type AVA.

Multi-conductor, un-monitored, 4160 volt power cable run down the access shaft is 3-conductor butyl-insulated cable with semi-conducting shielding tape, 3 ground conductors, and neoprene jacket. Multi-conductor, un-monitored, 4160 volt power cable for use in the mine is 3-conductor butyl-insulated copper-shielded cable with 3 ground wires and neoprene jacket. Multi-conductor, monitored 4160 volt power cable for use in the mine is 3-conductor butyl-insulated, copper-shielded cable with 2 bare ground and 1 insulated monitor wire, with neoprene jacket.

Multi-conductor, monitored 480 volt power cable for use in the mine is 3-conductor rubber-insulated type PCG cable with 2 bare ground and 1 insulated monitor wire, with neoprene jacket. Multi-conductor, un-monitored, 480 volt portable cable for use in the mine is respectively 4-conductor and 3-conductor type W cable with one of the conductors used as a ground wire.

Multi-conductor control cable down the access shaft is rubber-insulated, neoprene-jacketed, with a galvanized steel center strand for support for hanging vertically in the shaft.

All cables and equipment, from the portable switch houses out to the mobile mining machinery, are equipped with the special plugs described under the ground monitoring system. The portable fans, lights, and power tools, fed from the portable distribution panels, together with their portable cords, are equipped with standard grounding type plugs.

DESIGN FEATURES -- ELECTRICAL DISTRIBUTION

Two double-throw, 4160 volt switches are provided at the main underground substation. The main underground substation transformer and the mine fan are connected to one switch, and the feeder to the mine-face area to the other. Each switch is fed by both main 4160 volt feeders down the access shaft, allowing the connected loads to be switched to either of the two feeders. Each feeder has sufficient capacity to carry approximately seventy percent of the total present underground load. This will be reduced to approximately fifty percent with the future addition of two more 300 KVA portable substations and additional mobile mining machinery for increased mine production. Additional 4160 volt feeder cables may be brought down the shaft at that time to restore feeder capacity to the original percent load capabilities. The double-throw switches allow the mine to operate with reduced production in the event of loss of one of the two 4160 volt main feeders.

An automatic voltage regulator is provided in the 4160 volt feeder to the mine-face areas. The function of the regulator is to raise the primary voltage on heavy load and lower it on light load, which compensates for voltage drop in the feeder and holds the primary voltage at the 300 KVA portable substations nearly constant at a selected value. The regulator is capable of raising the voltage fifteen percent or lowering it five percent automatically, and needs readjustment only when the 4160 volt feeder cable length is changed. This allows the portable substations to be operated much further out from the mine shaft than would be normally possible. Also, because of this regulation, the allowable length of 480 volt feeder cable to mobile mining machinery can be made and kept quite high (approximately 1,500 feet) without too severe a voltage drop effect on motor starting torque.

Metering is provided on equipment at critical points for determination of plant loading and voltage conditions. Ammeters, voltmeters, and reactive KVA meters (varmeters) allow loading, voltage, and power factor conditions to be computed at any time. Watthour meters with demand registers provide a means of apportioning plant power expenses to the various areas, processes, or departments.

At present, power factor correction has not been added to the system but is included in future plans. A load survey has been conducted, aided by the metering built into the distribution system. From this data, an installation including capacitors connected to equipment busses and capacitors connected to motor leads, so as to be switched with their respective motors, has been developed. The bus connected capacitors aid lumped small inductive loads and the larger motors (30 Horsepower and up) are to be equipped with individual starter switched capacitors. This will prevent unwanted voltage rises during light loaded conditions, caused by an excess of capacitive reactance for the amount of KVA load.

DESIGN FEATURES -- CONTROL, SIGNAL AND ALARM

Motor Controls

All motors in the crushing and screening area are started from control panels with indicating lights and each motor also has a local jog-stop pushbutton station. All conveyors, crushers and screens are interlocked. By-pass switches and other special controls have been provided on certain equipment. Emergency rope limit switches have been provided for each conveyor along the entire length and an emergency stop pushbutton is located on each control panel to instantly shut down the crushing and screening operation.

The truck dump hopper has a counting controller which adds each load dumped in and subtracts each equivalent load run out through the primary crusher, stopping the crusher when the minimum number of loads in the hopper is reached. This layer of salt at the bottom reduces impact damage to the primary conveyor belt due to dumping.

Signals and Alarms

Some of the signals and alarms provided for the mine include alarm bells at the top and bottom of the shaft for both the mine fan bearing temperature relays and the production shaft sump pump high water probe. The truck dump hopper is provided with automatic traffic lights and alarm horns with indicating lights for the indication of high salt level at the skip-loading hopper. The reject bin and FC removal system have lights and bells to indicate a nearly full condition. These signals are operated by revolving paddle type bin level indicators which are actuated by the paddle stalling when covered by salt build-up.

Alarm horns and indicating lights actuated by a ground current relay are provided at both the above-ground main switchgear and the plant gatehouse guard station to indicate a line-to-ground fault on the power company substation 4160 volt bus, so that immediate steps can be taken to eliminate this condition.

Communications

In the mine, provisions have been made for both Ohio Bell and plant telephones. A plant telephone line is run to the access hoist (Koepe hoist) cage. A shaft buzzer system has been provided in the Production Shaft with top and bottom stations plus a station at the production hoist operator's console.

A wireless hoist phone system has been recommended for the production shaft tibble for use when carrying men for inspection purposes. This system is based on transformer action (induction) using the steel shaft cable as the iron core with stationary coupling coils around it for the stations, allowing free passage of the cable. This system eliminates the objectionable radio frequency waves used in other wireless phone systems. If operating experience dictates, this system may be installed in the future.

SUMMARY

The Fairport Mine has been in production since August, 1959. Let us examine the operating results to date.

Safety

The ground monitoring system has functioned excellently. There have been no accidents due to shock. All portable cable failures to date have been line-to-ground faults which have tripped the ground fault relays quickly enough to prevent damaging arcing. Each circuit is tripped at the end of each shift by use of the test pushbutton installed on each mobile mining machine. The solidly grounded portion of the system in the permanent crushing and screening area has an equally fine safety history.

Reliability

The entire system has proved to be extremely reliable. There have been only two outages on the 4160 volt feeders, both caused by power company failures which shut down the entire plant. The plant is served by two separate power company lines, although only one is in use while one is standby. This normally provides good continuity of service.

480 volt portable cable outages have averaged four per year, all due to mechanical damage from the mobile mining machinery and trucks. They have all been easily repaired with cable splicing and vulcanizing equipment used by the mine maintenance force. Over twice this number of outages have been prevented by repairs to cables being made prior to a fault when inspection revealed possible cable damage.

The only motor failures to date have been three 7 1/2 Horsepower portable fans used at the mine face. The rating and characteristics of these motors were not suitable for the application and location at which they were used, causing their burnout.

The mine maintenance forces pursue a schedule of maintenance which includes the inspection and overhaul, if required, of each motor in the mine a minimum of every six months. From experience, certain motors receive more frequent attention. During this periodic down time for each drive, the control equipment such as starters, switches, and pushbuttons receive preventive maintenance. The excellent results testify to the adequacy of this program.

The down time due to control equipment failure, circuit breaker tripping or blown fuses caused by overloading has been negligible.

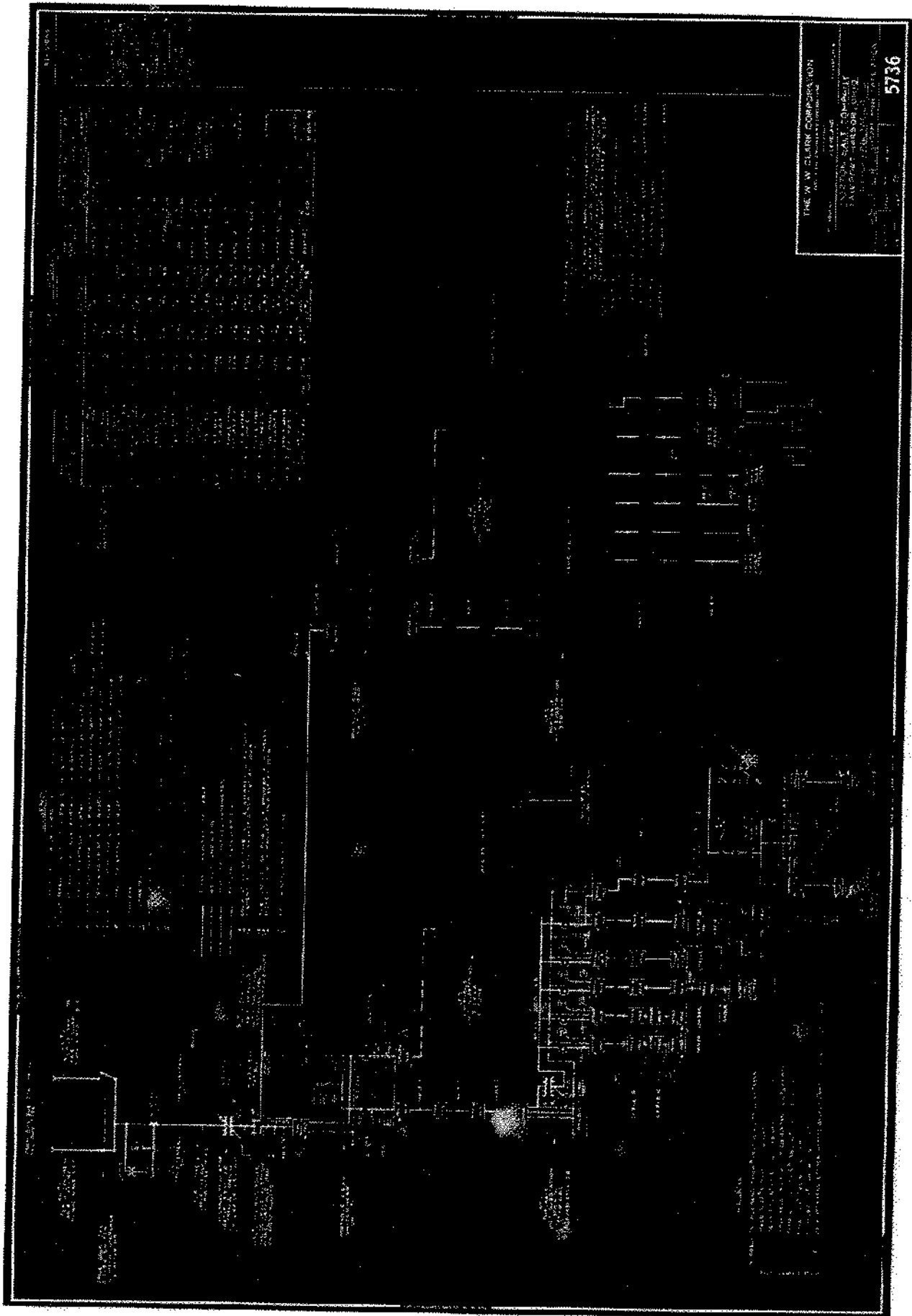
Voltage Regulation

The voltage regulation problem has been no problem at all. With the maximum lengths of both 4160 volt and 480 volt cable in use to date, the terminal voltage lower limits set by design criteria have not been reached. At present, with 4,000 feet of combined semipermanent and portable 4160 volt cable in use from the voltage regulator out to the furthest 300 KVA portable unit substation plus 1500 feet of 480 volt portable cable from the substation to the largest machine, there has been no starting difficulty no has any motor stalled. The limiting length has not yet been determined for 480 volt portable cables since there are only enough 500 foot lengths (14) to allow 1500 foot operation for the required number of simultaneous operating locations at the mine faces.

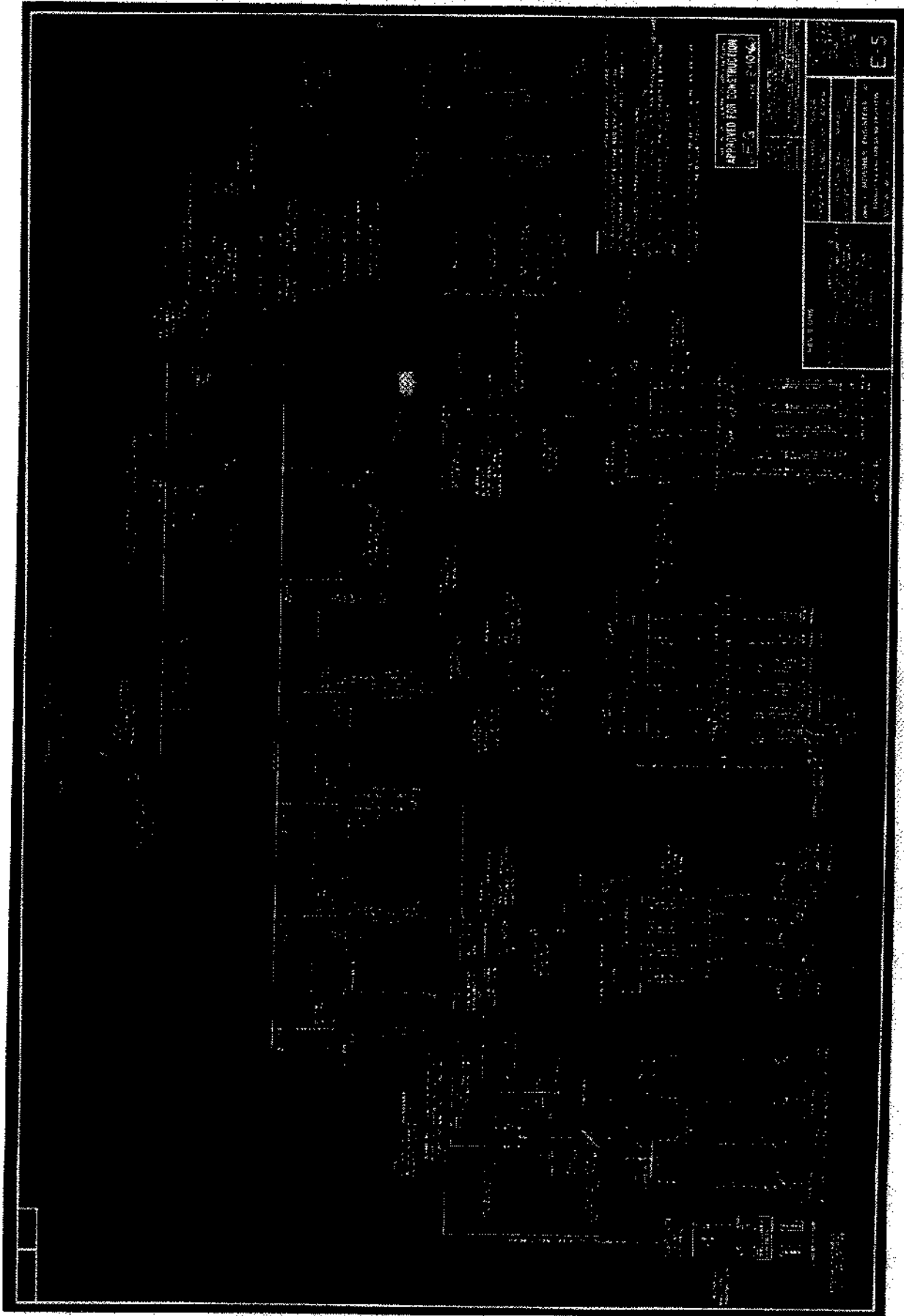
The operating forces at Fairport Mine are well pleased with the voltage regulator operation. Proper voltages are maintained over wide ranges of load. The regulator normally makes a total of from 25 to 30 steps of voltage adjustment, both up and down, for an average production hour.

CONCLUSION

The actual operating characteristics and maintenance experience, in general, equal or exceed those anticipated at the time of the initial design. A modern underground alternating current distribution system can give excellent operating results if careful study, tempered by experience, is applied to the basic design, layout, and construction.

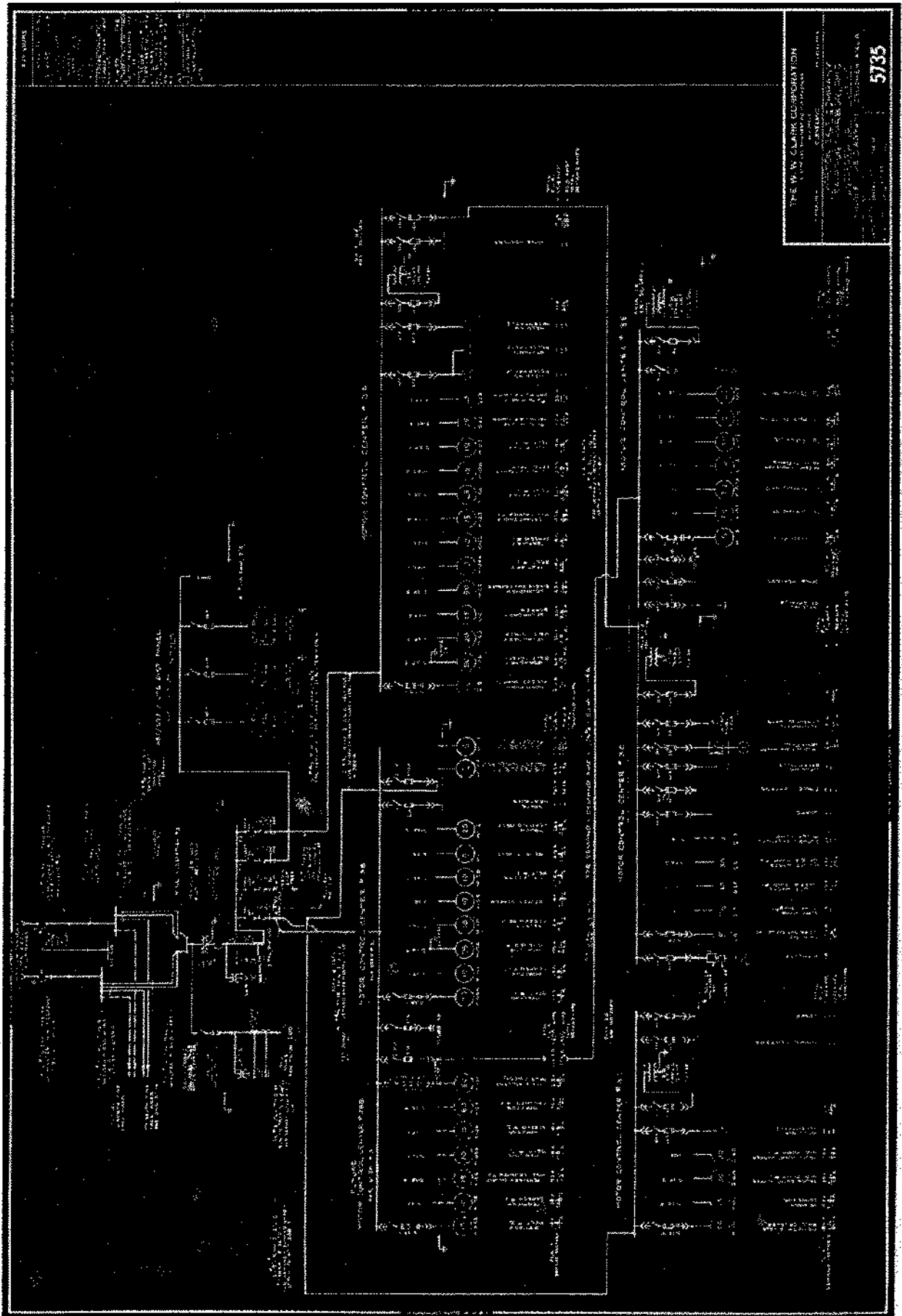


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