NREL
NATIONAL RENEWABLE ENERGY LABORATORY

ATTACHMENT A

City of Akhiok, Kodiak Island, Alaska
Power System Assessment

Findings and Recommendations Report
14 October, 2015

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NREL is a national laboratory of the U.S. Department of Energy
Office of Energy Efficiency & Renewable Energy
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All Photos by Robert Butt, NREL

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Preface

The Akhiok electrical power system has experienced numerous costly power plant generator and electrical cable failures in the recent past. An assessment of the Akhiok power plant and electrical distribution system was conducted by the National Renewable Energy Laboratory (NREL) from 25-27 September, 2015. This report describes the findings from that assessment and provides recommendations for resolving the issues that were encountered.

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Jed Drolet, Energy Information Analyst, Alaska Energy Authority

Jessie Huff, Energy Development Specialist, Alaska Energy Authority

Rick Lindholm, Director, Kodiak Island Housing Authority

Dan McCoy, Akhiok City Manager

Kris Noonan, Rural Power Systems Upgrade Program Manager, Alaska Energy Authority

James Perry, Project Manager, Alpine Electric

Brian Putnam, Electrician, Alpine Electric

Jed Smith, Community Regional Affairs, State of Alaska

Nomenclature or List of Acronyms

A	amperes/amps
AEA	Alaska Energy Authority
AFCI	Arcing Fault Circuit Interrupter
ANSI	American National Standards Institute
EPR	ethylene propylene rubber
GFCI	ground fault circuit interrupter
HDPE	high density polyethylene
Hz	hertz
IEEE	Institute of Electrical and Electronics Engineers
JB	medium voltage junction box
kV	kilovolts
kVA	thousand volt-amps
kW	thousand watts
LBJ	Load Break Junction
LV	low voltage
NEMA	National Electrical Manufacturers Association
MCM	thousand circular mils
MV	medium voltage
NEC	National Electrical Code
NETA	National Electrical Testing Association
NREL	National Renewable Energy Laboratory
PVC	polyvinyl chloride
ROM	rough order of magnitude
THD	Total Harmonic Distortion
V	volts
Var	volt-amperes reactive
XFMR	transformer
XLPE	cross-linked polyethylene

Executive Summary

Electrical power data was logged, thermal images of terminations were taken, and equipment was observed during the site visit. A number of issues were observed, including unbalanced electrical load conditions, MV and LV cable systems that need replacement, safety concerns, possible low voltage/regulation concerns, inadequate maintenance, and the need for utilities planning. Each of these issues was reviewed and mitigation options were considered.

Recommendations were made for initial safety and unbalanced electrical load issues, and a phased replacement of the existing underground cable system was suggested. The next step will be to use this report to request funding for $1.3M and to provide a roadmap for improving safety, efficiency and replace the aging and failing Akhiok electrical distribution system.

Table of Contents

List of Figures

List of Tables

1 Background

A request for technical assistance for a power system assessment was received from Akhiok (a village on the southern end of Kodiak Island), and the response to this request was facilitated by the Alaska Energy Authority (AEA) and the Alaska Department of Commerce. The Akhiok Tribal Council applied on behalf of the city to DOE through the Tribal Technical Assistance program. The electrical issues described by the Akhiok City Manager include multiple generator failures, significant line loss, voltage spikes, and frequency issues. The request was to help them identify possible sources of these issues as well as to create a prioritized list in which the problems should be addressed.

The current Akhiok population is approximately 90 individuals, and this figure has doubled since 1999. Electrical loads are increasing as families acquire entertainment systems, computers, and other modern devices. Other village utilities besides electrical distribution include telephone, water, and sewer lines.

Winds can be severe. 60-80 mph winds are not uncommon. Speeds of >100 mph have been observed. These environmental conditions severely impact Akhiok activities.

1.1 Akhiok Electrical Infrastructure

The City of Akhiok manages the electrical generation and medium voltage (MV) distribution system for the area. Facilities that receive power that are not Akhiok residents or local government include the Akhiok weather station and an FCC radio frequency tower.

On 3 August, 2015, Rick Lindholm, Director of the Kodiak Island Housing Authority provided comments to NREL on some low voltage (LV) line work that was performed approximately 7-8 years ago. The transformer secondary cables were supplying three homes and needed repair. Rick noted that wiring and splices in handholes used for secondary distribution were in very poor condition. Faulted circuits and wiring were found in homes that did not meet National Electrical Code (NEC) wiring method requirements. GFCI and AFCI upgrades are needed in homes, and other code issues exist. Losses in the primary and secondary systems are excessive (estimated at 30%) and likely due to failing MV & LV cables. Original houses were built in 1978, and others were added in 1987 (the site electrical distribution system is approximately 34 years old).

Kris Noonan was involved with the Akhiok electrical distribution system many (30+) years ago, and he provided the following comments during a 1 July 2015 teleconference call: primary cables are direct-bury #2 with concentric neutral; transformers may not be compatible with the marine environmental conditions; service drops to homes are also direct-bury; trenches are very shallow – lots of rock/do not meet code; new installations should be in duct; many of the meter bases at homes need to be replaced; power plant generators may be oversized to compensate for unbalanced conditions; Generator nameplates for Units 2 & 3 are incorrect – they were re-wired for 480/277 V; primary and secondary cables have reached the end of their useful life.

1.2 Failure Events

The distribution system had two major generator failures and several distribution cable failures (line to ground faults) in the past year which have had significant negative financial impacts. Akhiok had to purchase a new engine for Power Plant Unit 1 and a new generator for Unit 3 (unit two is not currently functional). Linemen from the town of Kodiak were required to repair the recent cable faults. Most of the underground cable system was installed 30 years ago.

On Friday, 8/7/15 one third of the village was without power due to a dead short in the ground. The City office, water treatment plant, and communications systems were without power. The faulted cable was subsequently located and repaired by linemen. Power was lost to the affected areas for 4 days.

2 Akhiok Site Visit and Findings

Robert Butt, Senior Electrical Engineer with NREL, arrived at Akhiok on Friday, 25 September 2015 to observe the site electrical power system, record data, and interview utilities personnel. Dan McCoy provided survey maps and other information on the village. Measurements were taken at the power plant, school, water treatment plant, and Health Clinic. Brian Putnam of Alpine Electric assisted in the work by connecting instrumentation sensors and opening electrical equipment. Thermal images were also recorded at several locations. Electrical distribution system components (distribution transformers and MV junction boxes) were located, and high level one line diagrams, along with site electrical plans, were developed. Routing of underground feeders on site plans was estimated based on equipment locations. Other buried utilities in the village include telecommunications, sanitary sewer, and water (these systems were not observed or recorded).

The electrical load on the power plant was relatively low during the site visit due to many residents being away on travel (school functions, meetings, vacation, etc.). Peak system load conditions are approximately 90 kW and occur during holidays (school functions are under way and village residents are cooking). During these high load periods, a second generator at the power plant is started.

2.1 Power Plant

The Akhiok power plant houses three generator sets, including one 75 kW generator (Unit #1), a 70 kW (Unit #2, currently not operational), and a 117 kW (Unit #3) generator. Each generator is connected to the synchronizing panel paralleling bus (power distribution blocks) through a contactor and circuit breaker. Woodward controllers and relays synchronize the generators and close the respective contactors for each generator. The power plant generator breakers do not appear to have ground fault protection.

Batteries are used for power plant control power and for starting the engine-generators. Auxiliary power for the power plant loads is derived from the generator synchronization panel. A 15 kVA, 3-phase, 480-208/120V dry type transformer supplies power to two radiator fans, power plant lights, convenience receptacles, battery chargers, diesel fuel day tank pump controls, metering, and other devices.

From the generator paralleling bus, cables are routed to a fused disconnect mounted outside the generator conex enclosure. On the load side of this disconnect, 500 MCM cables (1 per phase) connect to the main step-up transformers (three single-phase, 75 kVA, configured grounded wye-wye, 480 V primary/12.47 kV secondary). A high level one line diagram of the power plant is shown in Figure 1.

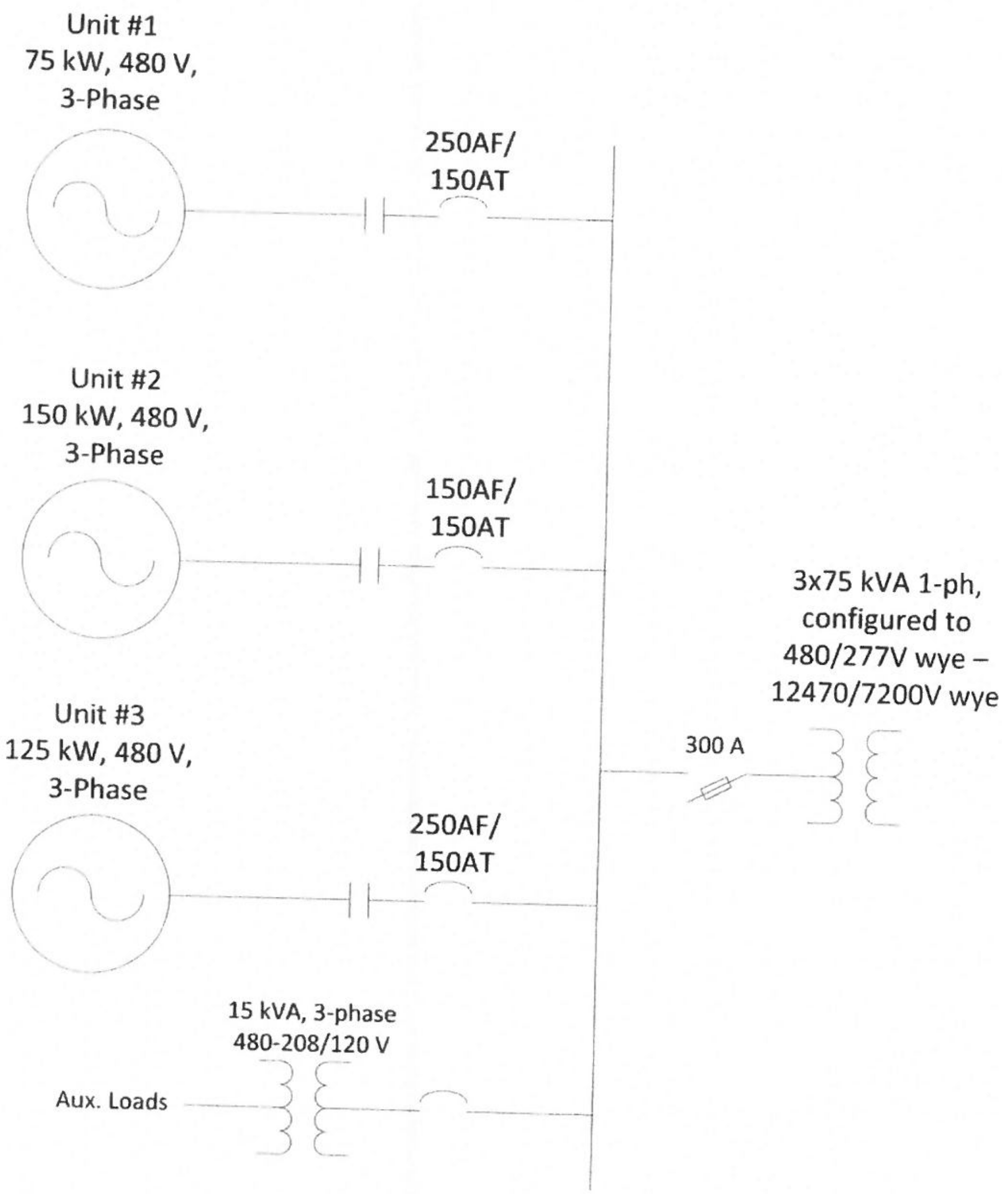

Figure 1 - Power Plant One Line Diagram

A Fluke Model 1735 data logger (serial number S11151152094) was connected to the fused disconnect on the power plant exterior, and electrical data was recorded for three days (refer to Table 1).

Table 1 – Electrical Data Logging Information – Power Plant

Recording Interval	Date(s)	Approximate Times
30 seconds	25 – 26 September	1340 - 1008
5 seconds	26 September	1014 - 1614
30 seconds	26 – 27 September	1645 - 1555

One set of graphical load data is presented in Figures 2 & 3. Note that Phase A is lightly loaded (average about 25 A) compared to Phase C (90 A) during the recorded peak hours. In the initial snapshot in Figure 3, the Phase A/L1 load was 21 amps while the load in Phase C/L3 was 91 amps. These significant unbalance conditions were observed during on several occassions. Note the power meter time stamps are Colorado times, Akhiok is actually 2 hours earlier.

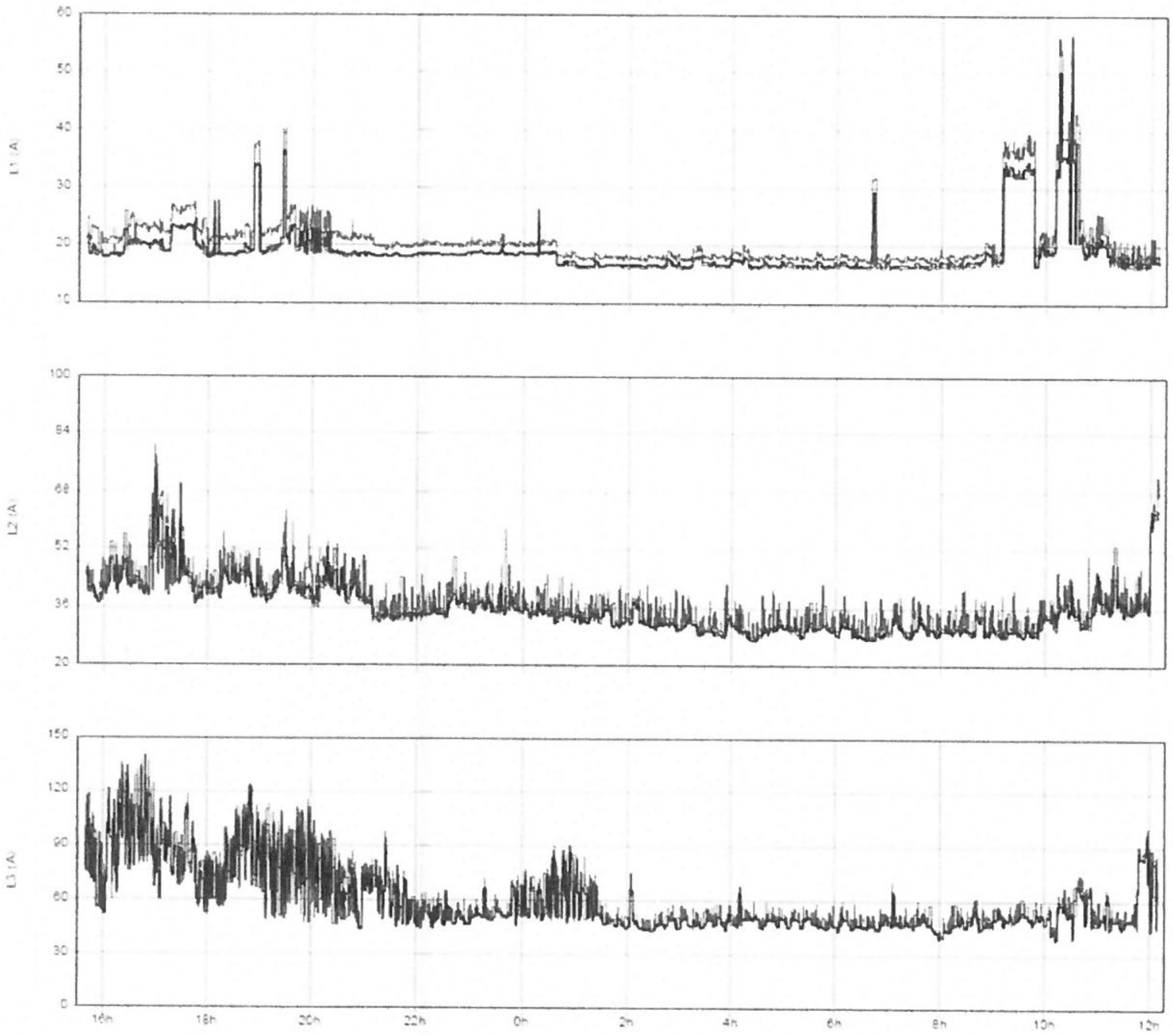

Figure 2 - Load Data (Amps), Generator #1, 9/25-9/26/2015

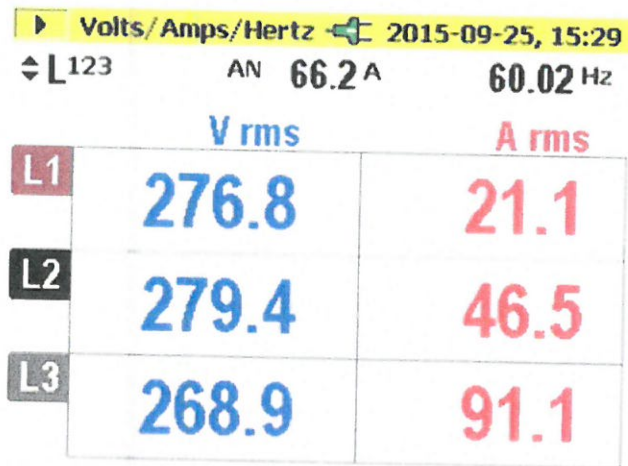

Figure 3 - Load Data Snapshot, Generator #1, 9/25/2015, 1329

System frequency in the first set of measurements peaked around 61 Hz and a minimum close to 59 Hz was observed. Phase A line to neutral voltage averaged 277 volts while Phase C average was approximately 270 V and was as low as 260 V. Neutral current average was 50 amps. Voltage distortion was less than 4% THD. Load power factor was typically close to unity, and actually leading in many cases (see Figure 4). An excessive leading power factor (reactive power flowing back to the source) can often result in generator shutdown.

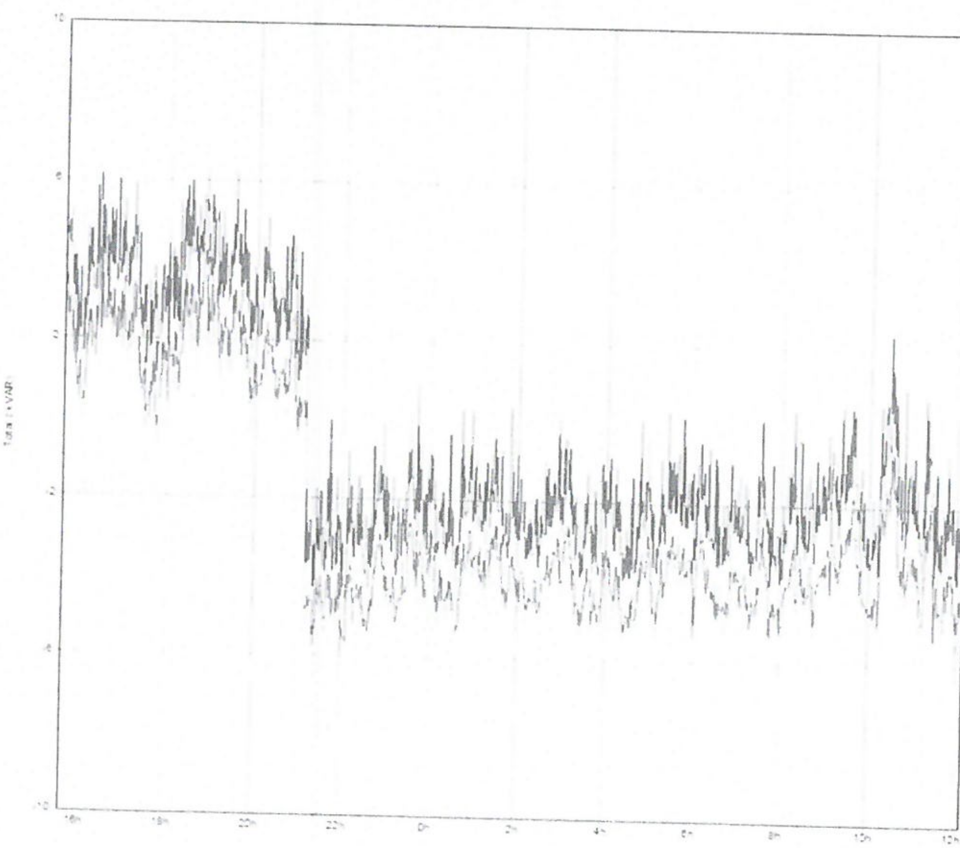

Figure 4 – Reactive Power Data, Generator #1, 9/25-9/26/2015

Load data from the second recording is shown in Figure 5. The phase unbalance issue (see phases A and C) still exists. The graph for the third data set is shown in Figure 6, and although the unbalance issue still exists, it does not appear as bad. The school was closed on Sunday and this could have affected the results.

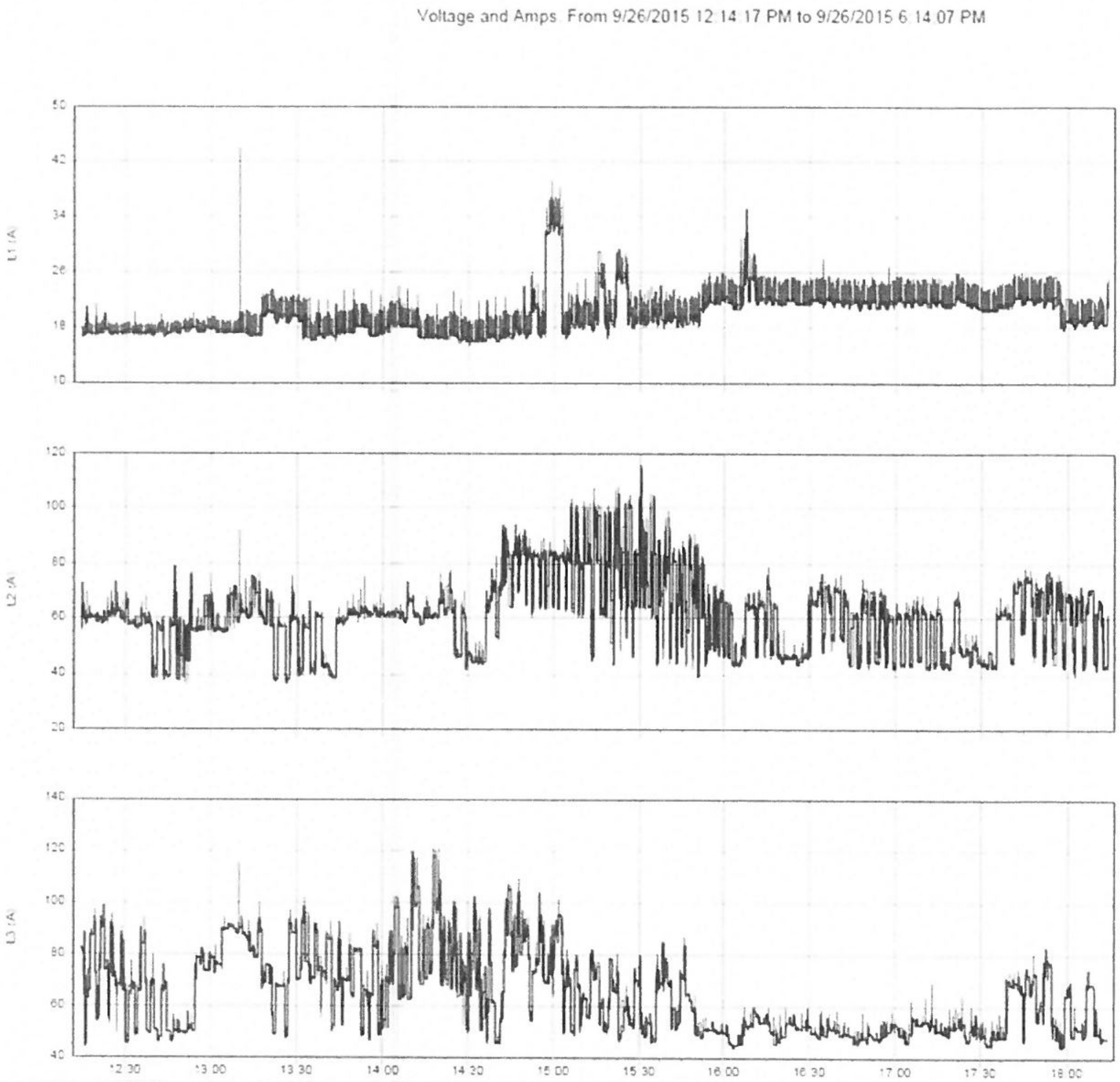

Figure 5 - Load Data (Amps), Generator #1, 9/26/2015

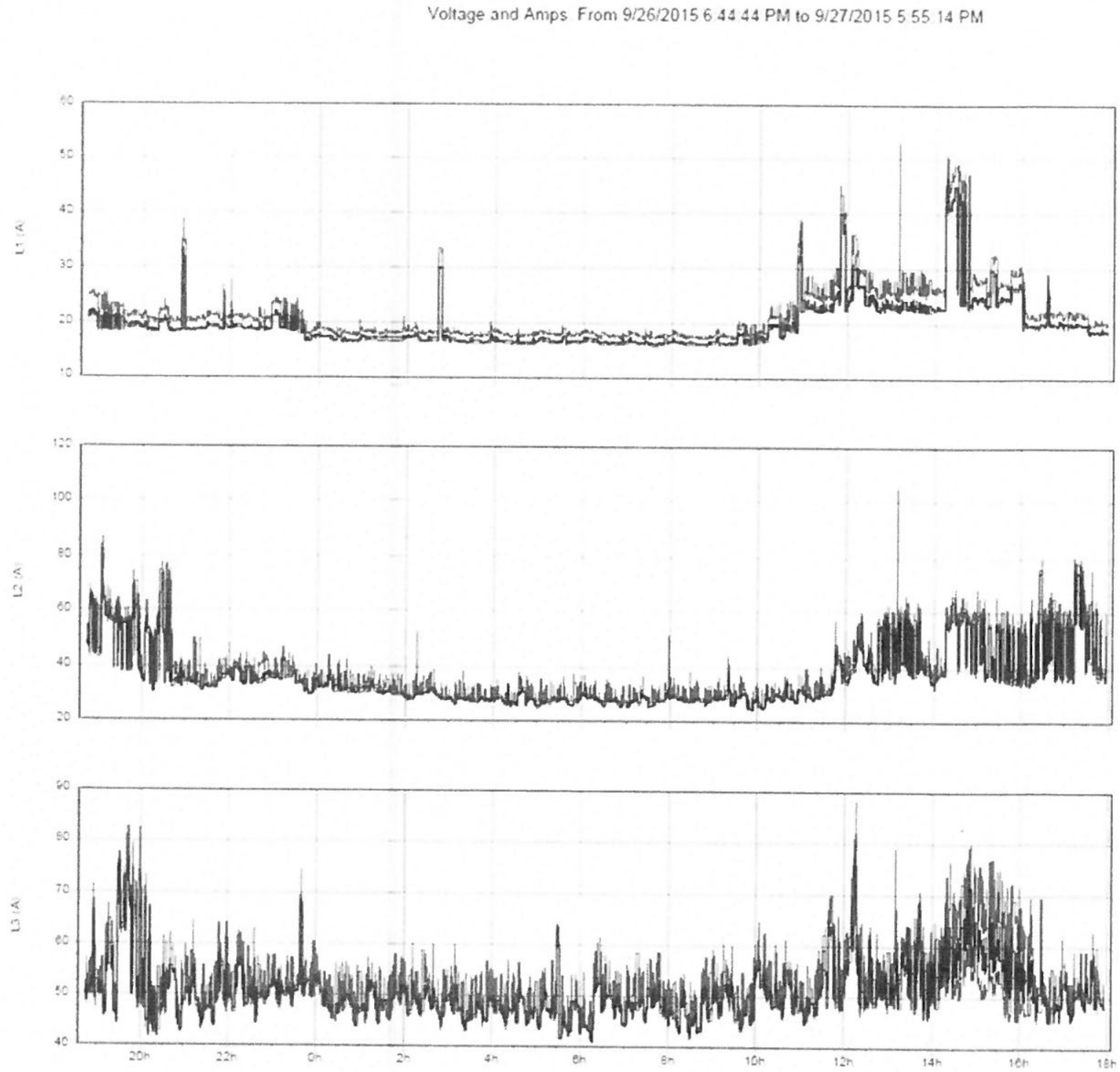

Figure 6 - Load Data (Amps), Generator #1, 9/26 – 9/27/2015

A Fluke Model Ti25 thermal imager (serial number 10110972) was used to record the cables at the Unit #1 circuit breaker, and the resulting image is shown in Figure 7. Phases A, B, and C are shown left to right. This thermal image indicates that the Phase C conductor is warmer and thus carrying significantly more current than the Phases A and B conductors.

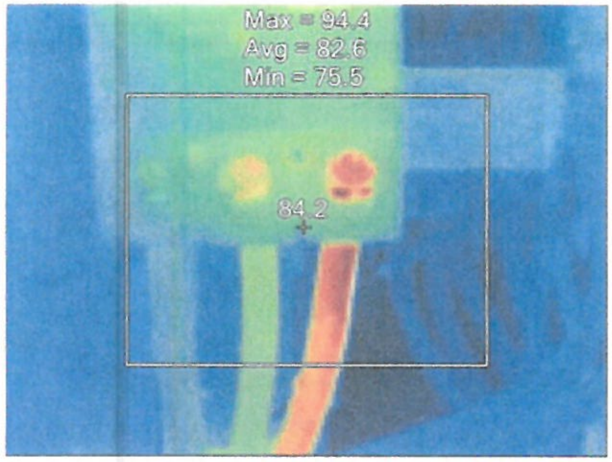

Figure 7 - Thermal Image, Generator Unit 1 Circuit Breaker, 9/25/2015

2.2 12.47 kV Distribution

Three single-phase direct-bury MV cables (15 kV-insulated cables #2 cross-linked polyethylene (XLPE) cables with concentric neutral) are routed from the power plant main step up transformers to the Akhiok distribution system. Phase tape color coding is typically brown-orange-yellow. The system is multi-point grounded wye. Ground rods are typically installed at MV junction boxes and distribution transformers, and the concentric neutral is bonded at these points. These concentric neutrals provide a return current path to the power plant main 75 kVA source transformers. As cable ages and the components are subjected to weathering and corrosion along its length, the system begins to fail. At a recent cable repair following a line to ground fault, utility personnel noted that the concentric neutrals on the buried cables are badly corroded. This limits both return and fault currents.

A series of MV junction boxes are used to redirect the three phase power via load break junctions (LBJ's) to transformers and other MV junction boxes. The MV junction boxes are typically of fiberglass construction. The LBJ's are 3-point or 4-point (meaning that there can be up to three or four load break elbow connection points per phase). Unused LBJ bushings typically have insulated caps. A simplified diagram of the Akhiok distribution system is shown in Figure 8.

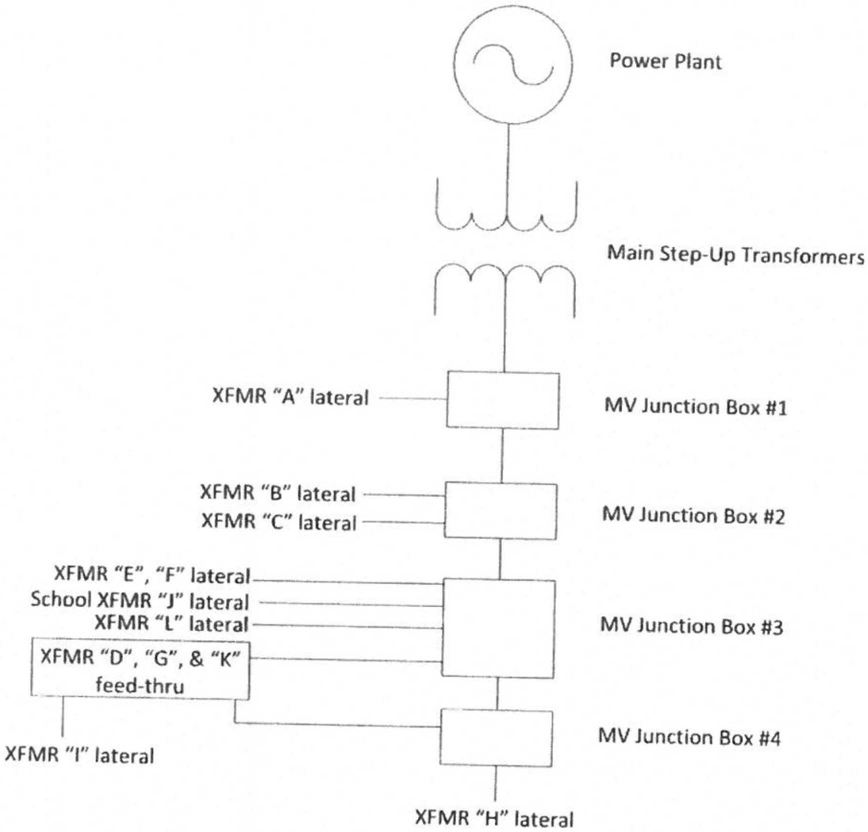

Figure 8 - Power System Simplified Diagram

There are a total of four MV junction boxes in the distribution system. The first (JB#1) is near the airstrip, approximately 550 feet from the power plant. A tap on the Phase A LBJ in JB#1 feeds the Akhiok Weather Station. Figure 9 shows the layout of JB#1.

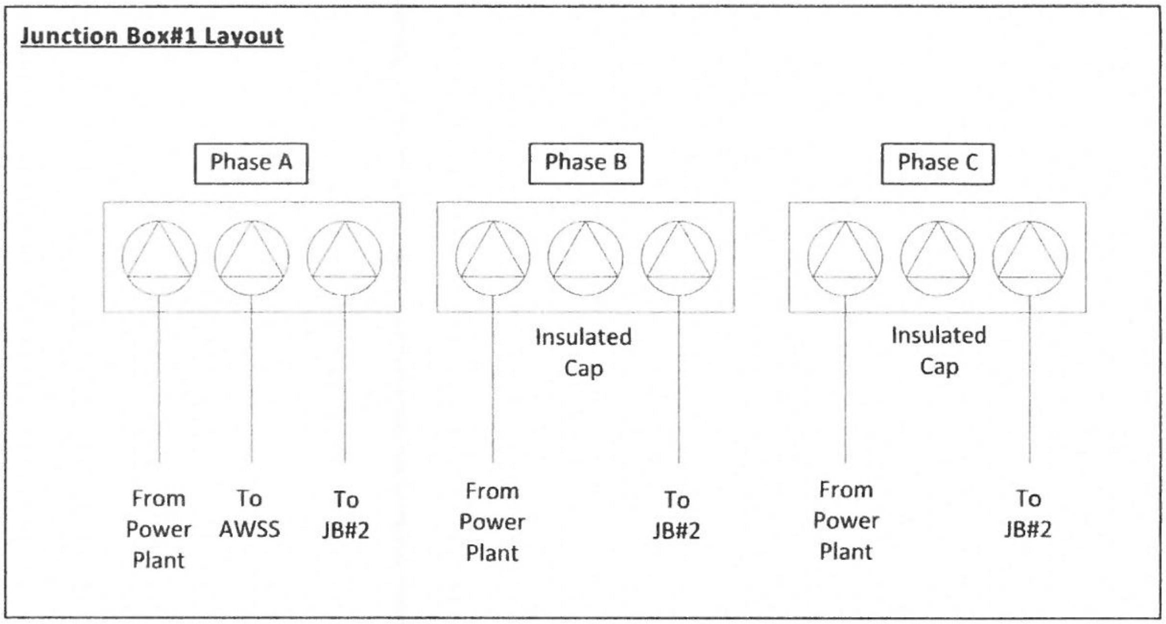

Figure 9 - Junction Box #1 Layout

The second junction box is located on Airport Way near the first group of homes (refer to the appendices for distribution system maps), approximately 1000 feet from JB#1. Figure 10 shows the layout of JB#2. It is likely the Phase B & C cables feed the two distribution transformers that are in the immediate vicinity of the junction box. However, transformers are not clearly identified, so it is unclear which loads are supplied by these cables. The maps included in the appendices show a best guess at the routing of feeder cables between MV junction boxes and to distribution transformers.

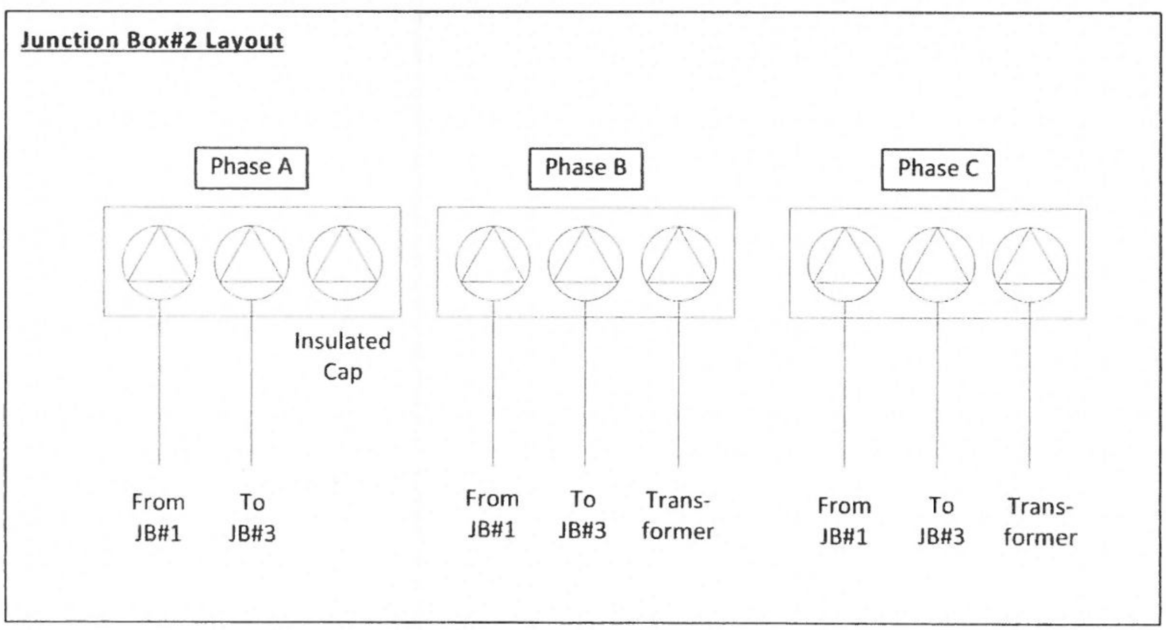

Figure 10 - Junction Box #2 Layout

The third MV junction box is near the clinic, approximately 500 feet east of JB#2. Figure 11 shows the layout of JB#3. Again, since transformers are not clearly identified it is unclear which loads are supplied by the Phase B & C cables. Phases A & B supply Junction Box #4, although it appears that Phase B feeder passes through one or more transformers (feed-thru).

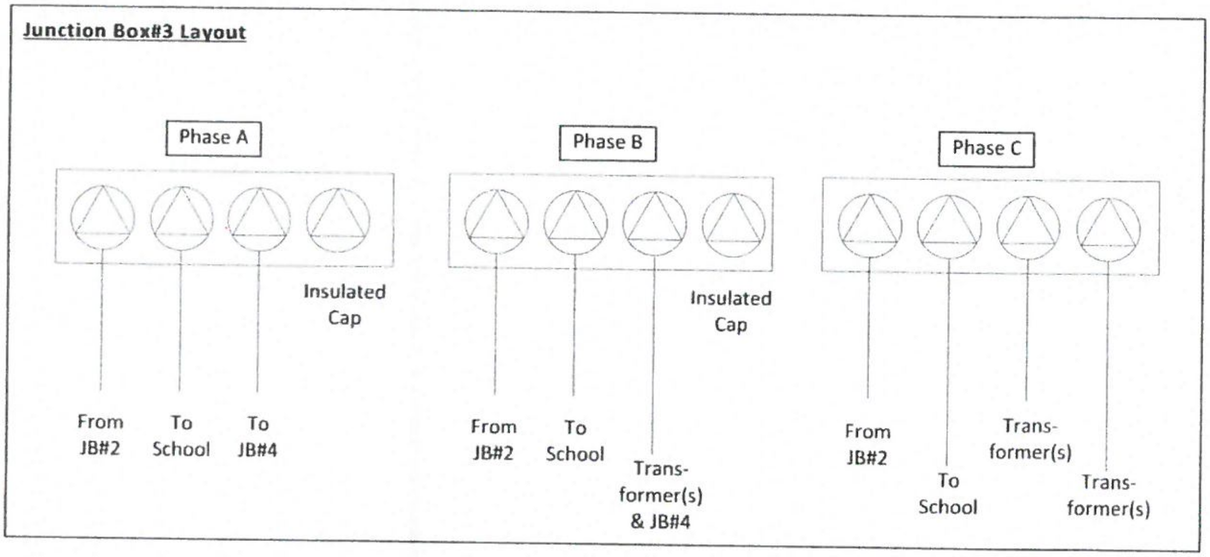

Figure 11 - Junction Box #3 Layout

The fourth junction box is approximately 500 feet from JB#3 and near the City Office building. JB#4 is a steel enclosure (as opposed to the fiberglass construction used with the other junction boxes) and has rusted to the point that it is open to the environment (See Figure 12). A temporary plywood enclosure was built to protect this equipment.

Figure 12 – Rusted Junction Box #4

Since only two feeder cables are brought to this enclosure (Phases A & B), only two LBJ's exist. Figure 13 shows the layout of JB#4. Phases A & B are assumed left to right, as this matches other junction box layouts). The labels in this junction box could not be read, except for one marked "East". The incoming feeder cables are unmarked. One feeder cable on the Phase A LBJ is also unmarked. It is likely both load cables supply the transformer that is approximately 50 yards east of JB#4 (Transformer "H"). Inspection of the transformer revealed that two incoming MV cables exist, with one load break elbow connected to bushing H1B and the second elbow on a parking stand. The second feed provides some measure of redundancy for this transformer.

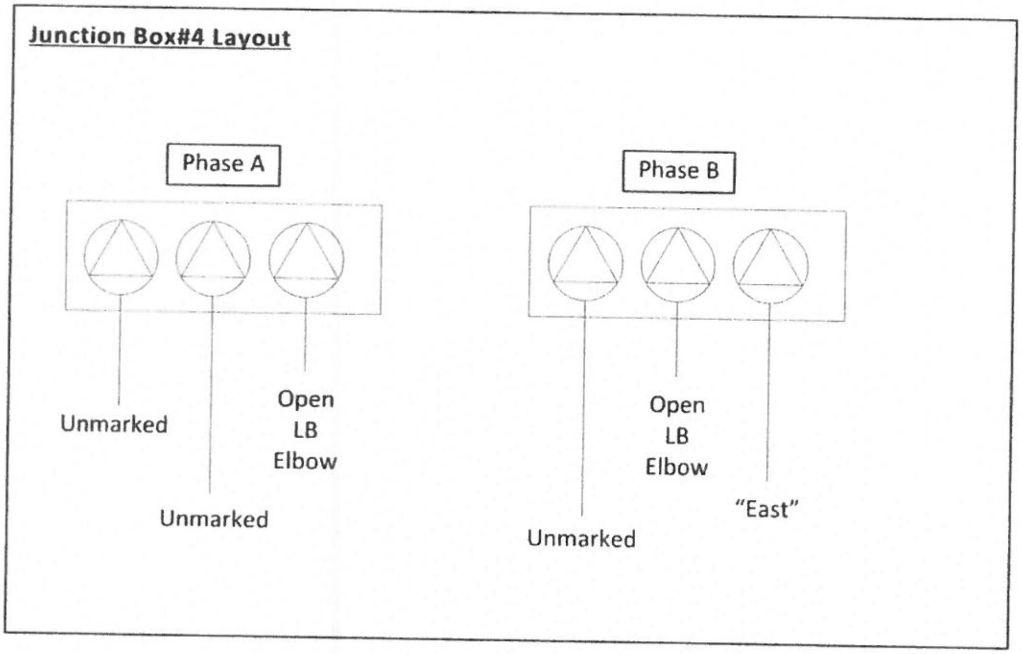

Figure 13 - Junction Box #4 Layout

Typical distribution transformers in the Akhiok distribution system are single phase, 15 kVA, 7200V-120/240V oil-filled pad-mount style and supply 4-5 homes or other buildings. Primary terminations are 200 amp load break elbows, and the transformer primary typically includes tap changers and fusing. Many transformers have loop-feed provisions for feed-thru applications. No lightning arresters were observed. All primary and secondary wiring is underground. Due to the harsh marine environment, most transformer enclosures rust out in about 15 years.

Critical loads at Akhiok include the school, health clinic, water treatment plant, the City Office (Tribal, Post Office, and City administration facility), and telecommunications equipment. The school has a standby diesel generator with automatic transfer switch, and the communications facility has a backup propane generator.

The school is the only three phase load in the system and its transformer is 75 kVA, 12.47 kV-208/120V. The school comprises approximately 25% of the entire Akhiok load. Several three phase motor loads were observed in the school mechanical room, including air handlers. Gym lights are high bay style and appear to be mercury vapor. A load measurement taken on each phase at the school electrical service equipment indicated phase currents of 50A, 30A, and 31A (with all lights in the building turned on). These phase currents do not necessarily match the distribution system A-B-C phase rotation, and it is not unusual to observe secondary cables changed to suit the needs of the facility (i.e., obtain correct motor shaft rotation). A standby generator and automatic transfer switch (ATS) were being installed at the school during NREL's September 2015 site visit.

The health clinic transformer is rated 25 kVA and is a feed-thru (see Figure 14). The 240 V electrical load on the panel at this facility was minimal (3-5 amps) on 9/26, although there were no patients in the clinic at the time and medical equipment was not operational. Voltage at a convenience receptacle inside the clinic was found to be 119.5 V under low load conditions.

Figure 14 – Health Clinic Transformer

The water treatment facility electrical load was observed and also found to be very low (2-3 amps). At the City Office facility, voltage was measured at 118.5 at early morning light load conditions and 117.2 V at mid-day.

3 Problem Statement and Options

Several significant issues were discovered during the investigation, including unbalanced electrical load conditions, MV and LV cable systems that need replacement, safety concerns, possible low voltage/regulation concerns, inadequate maintenance, and the need for utilities planning.

3.1 Severe Load Unbalance

The severe electrical phase loading unbalance at Akhiok is a concern, with Phase C load levels more than three times those of Phase A. Unbalanced loading leads to unbalanced phase voltages, and electrical equipment, especially motors and their controllers, will not operate reliably on unbalanced voltages in a 3-phase system. Generally, the difference between the highest and the lowest voltages should not exceed 4% of the lowest voltage. Motors operated on unbalanced voltages will overheat, and many overload relays can't sense the overheating. In addition, many solid-state motor controllers and inverters include components that are especially sensitive to voltage imbalances. NEMA MG 1-2014, Part 12.45 calls for three-phase motors to "operate successfully" at rated load if voltage unbalance at the motor terminals is 1 percent or less.

Unbalanced voltages can result in adverse effects on equipment and the electric distribution system. Under unbalanced conditions the distribution system will incur more losses and heating effects, and be less stable. The effect of voltage unbalance can also be detrimental to equipment such as induction motors, power electronic converters, and adjustable speed drives (ASDs).

A fairly simple option for improving the phase unbalance issue is to move loads from Phase C to Phase A. This is difficult at the low voltage utilization level due to the increased number and size of conductors, but the work is fairly straightforward at the medium voltage level. In Junction Box #2, a load break elbow that is connected to the Phase C LBJ supplies transformers, and this cable can be relocated to the Phase A LBJ. In Junction Box #3, one of the cables on the C Phase LBJ can also be relocated to the Phase A LBJ if necessary. The system load balance should be re-checked after the first cable has been moved.

3.2 Failing Cable Infrastructure

In addition to the severe unbalance issue, the Akhiok electrical underground cable infrastructure is at the end of its life. Electrical cables installed in the 1980's were only expected to last 30 years. In addition, the Akhiok underground system is direct-burial, which means it is buried with dirt, rocks, and other material, and over time the subsurface materials will shift as water ingress, freezing, surface traffic, and other events occur. This leads to corrosion of the concentric neutral conductors and also deterioration of the cable insulation. The XLPE cable insulation is subject to treeing, which includes current flow through miniscule paths in the insulation to the outer conductor (shield or concentric neutral). Over time this current increases in magnitude until it is high enough to break down the insulation completely and become a full blown line to ground fault. These faults have been occurring in the Akhiok underground cables, and the failures are expected to increase in frequency with time. The costs of ongoing repairs will be extensive and can be avoided by replacing the underground cable system.

3.2.1 *XLPE Cable Insulation History*

When medium voltage XLPE insulated cables were first installed in the late 1960's, cable manufacturers and electric utilities expected them to perform reliably for 20 or even 30 years. History has shown that the service life of some of these early cables was far shorter than expected. At that time, cable engineers and material scientists were not aware that moisture, voltage stress, omitting jackets, and imperfections within the cable structure would combine to accelerate the corrosion of neutral wires. These defects degraded the cable performance so severely that many cables failed after only 10 to 15 years in service. Voids and contamination in the insulation, combined with ionic contamination in the semiconducting shields, as well as other design and manufacturing deficiencies, led to voltage stress concentrations within the cables. These elevated voltage stresses, combined with moisture ingress into the cable structure created what are known today as water trees. These dendritic growths of microscopic cavities degraded the insulation over time, ultimately causing the cables to fail. Today, cable manufacturers have improved the quality of XLPE, and other insulation material is also available.

3.2.2 *Overhead/Underground Distribution Assessment*

A review was conducted of overhead line conductors (on poles) versus underground cable systems, and the following arguments/highlights for each option are presented:

1. In the past, the largest obstacle to placing overhead power lines underground has been the higher cost of installation and maintenance for underground lines. Although overhead power lines are typically more economical, they are susceptible to damage from wind-borne tree branches, debris and high wind and ice-loading conditions from extreme weather. The damages can cause extended power outages that in extreme cases cannot be restored for days or even weeks, depending on the availability of utility personnel and equipment. During long outages after a catastrophe, there are also associated intangible impacts to a utility's customers such as despair, discomfort, anxiety and helplessness. These tangible and intangible impacts challenge the electric utility industry's attempts to justify the installation of overhead electric distribution and transmission systems.

2. According to the May 2011 paper *Underground Electric Transmission Lines* published by the Public Service Commission of Wisconsin, underground lines are better protected against weather and other conditions that can impact overhead lines, but they are susceptible to insulation deterioration because of the loading cycles the lines undergo during their lifetimes. As time passes, cable insulation weakens, which increases the potential for a line fault. If the cables are installed properly, this debilitating process can take many years. If and when a fault occurs, however, the cost of finding its location, trenching, cable splicing, and re-embedment is sometimes five to 10 times more expensive than repairing a fault in an overhead line where the conductors are visible, readily accessible and easier to repair. In summary, the above data for that part of the country states that there are only about 1/5 as many outages on the underground circuits as there are on the above ground circuits. At the same time, it takes 2.25 times longer to address the outages on the underground installations as it does for the overhead installations.

3. Advantages of underground systems include:

    a. They are less subject to damage from severe weather conditions (mainly wind and freezing)

    b. Underground cables pose no hazard to low flying aircraft or to wildlife

    c. Underground cables need a narrower surrounding strip to install, whereas an overhead line requires a wider surrounding strip to be kept permanently clear for safety, maintenance and repair

4. Disadvantages of underground systems include:

    a. Undergrounding is more expensive, since the cost of burying cables is several times greater than overhead power lines, and the life-cycle cost of an underground power cable is typically two to four times the cost of an overhead power line

b. Whereas finding and repairing overhead wire breaks can be accomplished in hours, underground repairs can take days or weeks

c. Underground cable locations are not always obvious, which can lead to unwary diggers damaging cables or being electrocuted

d. Whereas overhead lines can easily be uprated by modifying line clearances and power poles to carry more power, underground cables cannot be uprated and must be supplemented or replaced to increase capacity. Transmission and distribution companies generally future-proof underground lines by installing the highest-rated cables while being still cost-effective

At Akhiok, no equipment for overhead line maintenance exists, and repair would take as long as for underground cables. Therefore this argument for overhead lines was not considered to be as significant as described. The persistent winds at Akhiok would also likely result in more frequent outages than normally experienced with overhead systems. In addition, the existing airstrip is near the power plant, and any overhead lines could be a hazard for pilots.

With this information and discussion in mind, several options were considered for the site electrical infrastructure. These options and the associated pros and conditions for each are described below.

3.2.3 *Replace underground system as-is (direct-bury)*

Description: With this option, a new trench would be dug, and new direct-buried 15 kV cables, sized per existing (#2 AL, 90 deg. C) would be installed. Refer to the appendices for cut-sheets. Damaged MV junction boxes and other distribution system components would be replaced as required. This cable is good for 165 amps, or 3,560 kVA at 12.47 kV, and provides adequate flexibility for future growth of the village (current peak at 90 kW/100 kVA).

Pros: This is option matches existing conditions.

Cons: Cost of underground is high. Potential for damaged cable jacket and insulation due to subgrade material. Imported fill would increase the costs significantly.

3.2.4 *Install new raceway system and MV cables*

Description: With this option, a new trench would be dug, and a 4-inch duct would be installed for protecting the cables. 15 kV cables (#2 AL, 90 deg. C) with EPR insulation would be installed in the main feeder and lateral conduits. Damaged MV junction boxes and other distribution system components would be replaced as required. Pulling tension on 3-1/C #2 AL cables should be reviewed as part of design. 300 ft maximum spacing between pull points should be followed as a common rule of thumb.

Pros: Cable is protected and system will last longer. In the event of future cable failure, bad cable can be removed and new cable can be installed in the same conduit.

Cons: Increased cost over direct-bury option (for ducts and pull boxes).

3.2.5 *Install raceway system, pull new LV cables*

Description: With this option, a new trench would be dug, and a duct bank consisting of multiple 4-inch ducts would be installed. The main step-up transformers would be eliminated and a 480 V system would supply power to Akhiok. LV cables would be installed in the conduits. LV pull boxes would be required.

Pros: Step-up transformers and associated losses are eliminated. Low voltage cables are less per foot than MV cables.

Cons: Increased total cost for cable due to need for multiple cables/phase for allow for voltage drop. Two 500 MCM cables required to maintain voltage drop less than 5%. There is limited flexibility in future growth of the village. Distribution transformers need to be replaced with 480V-120/240V or 480V-208/120V (school), and many of these are fairly new.

3.2.6 *Install new poles and overhead system*

Description: With this option, a new system comprised of overhead lines would be installed from the power plant to the distribution transformers. Overhead systems are typically much lower in cost than underground system (2-4 times). Pole risers would supply the pad-mount transformers.

Pros: Probably a lower cost than the direct-bury option, although hole excavation and preparation for setting poles may be costly (6-8 ft. holes in shale).

Cons: Poles would likely not last long due to high winds, freezing water on lines, and high humidity levels. Concrete poles could address this issue but would be more expensive (material and installation). Safety issues near the airstrip with overhead lines in the flight path could force a mixed overhead/underground system and increase overall costs.

3.2.7 *Relocate power plant to village*

Description: With this option, the existing conex housing the power plant would be relocated to an area near the village. A 480 V distribution system would be installed.

Pros: Lower system cable costs (low voltage) than the LV option from the existing power plant location since voltage drop is much less.

Cons: Cost of relocating the conex and installing new ground system. Cost of replacing the distribution transformers. Need to backfeed the weather station (long run).

3.2.8 *Discussion*

Overhead line options were not considered further because of the reliability and flight safety concerns. The low voltage option does not provide future growth flexibility and has significant cost impacts. An underground system using conduits (ducts) would provide increased reliability and provides the best overall solution.

As an alternative to excavating a new trench for an underground system, it is possible that the existing trench can be re-used and possibly improved upon. This would require longer outages since the existing buried cables would need to be pulled out (and exchanged for scrap value).

New ducts would be installed in the vacant trench (one spare for future use). Concrete encasement provides protection but would add to the overall cost of construction.

3.3 Electrical Safety

Electrical safety is a concern. The MV junction boxes are subject to damage due to their construction material. One of the fiberglass lids (JB#2) was blown off by high winds, leaving the MV cables and terminations exposed both to the environment and to Akhiok residents. Another was damaged during a traffic incident, leaving a large hole on the side and structural damage to the lid (See Figure 15). Children were observed playing on and around this damaged enclosure.

Figure 15 – JB#3 Damage

The pentahead bolts used on transformers are an effective method of preventing unauthorized entry, although the sockets for these are difficult to obtain and Akhiok utilities do not own any. Stainless steel padlocks with a common key are a reasonable option.

Other safety and maintenance concerns were observed at distribution transformers besides the ever-present corrosion problems. At Transformer "H", several issues were observed (refer to Figure 16), including 1) a feed-through bushing has a plastic cap, which is not rated for the voltage that exists (7200V) on the transformer bushing, 2) the transformer appears to be leaking oil through the H1B bushing, 3) the secondary lugs are not rated for the number of conductors that are installed, and 4) there is insufficient working clearance in front of this transformer.

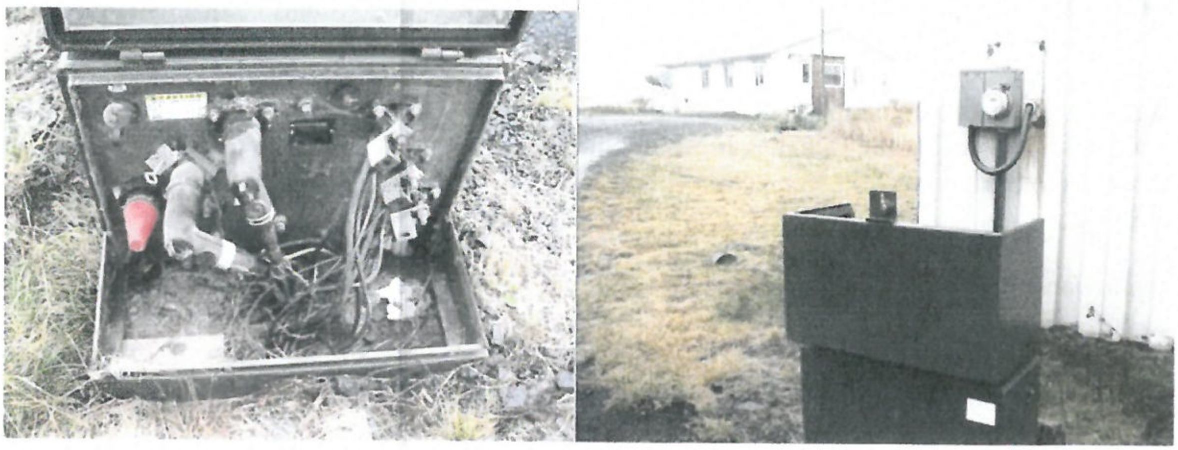

Figure 16 – Transformer "H"

Effective maintenance of electrical equipment is essential for both reliability and safety. Periodic inspection and testing of torque on cable terminations, thermal scanning, etc. prevents costly outages. A routine electrical maintenance program should be planned and included in the annual budget; start with generators, step-up transformer, distribution transformers. The system ground resistance and continuity of equipment grounding conductors should be tested.

Load break junctions and elbows are a good choice due to dead front construction (no live front issues on MV equipment).

The existing synchronizing/paralleling panelboard uses obsolete equipment. Modern governors and synchronization relays have progressed and would provide greater reliability.

3.4 Voltage Regulation

The term "voltage regulation" is used to discuss long-term variations in voltage. It does not include short term variations, which are generally called sags, dips, or swells. The ability of equipment to handle steady state voltage variations at its utilization voltage varies from one device to another. Voltage regulation standards in North America vary from state to state and from one utility to another.

The ANSI C84.1 standard establishes the nominal voltage ratings and operating tolerances for 60-Hz electric power systems in the US. Voltage regulation requirements are defined for two categories (service voltage and utilization voltage) in two ranges – A and B. For example, the service voltage at the Akhiok School would be at the main distribution panel in the generator building, and utilization voltage would be at a remote receptacle in the school. The difference between minimum service and minimum utilization voltages is intended to allow for voltage drop in the customer's wiring.

For Akhiok homes and facilities (nominal 240/120V single phase and 208V three phase systems), the allowable <u>service</u> voltage ranges are as follows:

- Range A is for normal conditions and the maximum voltage is 105% of nominal voltage; minimum voltage is 95% of nominal voltage

- Range B is for short durations or unusual conditions and maximum voltage is 105.8% of nominal voltage; minimum voltage is 91.7% of nominal voltage

Range A is the optimal voltage range. Range B is acceptable, but not optimal. The occurrence of service voltages outside the Range A limits should be infrequent. Corrective measures should be undertaken to bring back voltages within Range A limits in cases of frequent Range B values occurrence.

The allowable utilization voltage ranges at Akhiok homes and facilities are as follows:

- Range A minimum voltage is 90% of nominal voltage; maximum voltage is 104.2% of nominal voltage. The allowable upper and lower ranges for lighting circuits are more restrictive.
- Range B minimum voltage is 86.7% of nominal voltage; maximum voltage is 105.8% of nominal voltage.

At the City Office (one of the most remote facilities from the power plant), voltage measurements were taken under lightly loaded conditions and found to be 117 V at a convenience receptacle. Measurements should be taken here and at the school during peak system loads to determine operating voltages under worst case conditions. Voltage at receptacles should be higher than 108 V. Lighting circuits should be higher than 110 V. Adjustments may be required on distribution transformer taps (when de-energized) where voltage levels are found to be less than the voltages described above under peak load conditions.

3.5 Electrical Maintenance

Routine maintenance has been shown to improve system reliability and save costs by preventing or predicting equipment failures. Recommended maintenance testing standards provided by the National Electrical Testing Association (NETA) are part of an effective maintenance program. The NETA procedures include routine inspection, performing thermal image inspections and checking torque on cable terminations, checking levels and testing transformer fluids, and testing generator windings.

3.6 Future Planning

Akhiok has been growing and expanding during the recent past. Planning for future growth should include infrastructure layout, utility easements, corridors, etc. to ensure safe development. This includes existing electrical, telecom, water, sanitary, and other future utilities that are anticipated.

As part of the planned growth, wind and microhydro technologies should be considered for offsetting power plant diesel fuel and home heating oil consumption. Electrical heating systems are possible if ample energy was available. The region has significant wind resources as well as nearby water flow/storage possibilities. Resource assessments were not conducted as part of this project, but may provide valuable information for future energy security.

4 Priority List

The work identified in this report should be prioritized as follows:

1. Safety concerns, including padlocks on transformers and MV junction boxes, replacement or reinforcement of JB#3 enclosure, and replacement of JB#4 enclosure
2. Balance phases A, B, and C loads in system, at MV or LV level (school?)
3. Distribution system cable and infrastructure replacement
4. Maintenance activities
5. Distribution transformer replacement
6. Check voltage levels under peak loading
7. Future planning/assessments

5 Recommendations

The recommended Action Plan follows the priority list in Section 4.

5.1 Initial work

Address safety concerns. Padlocks, pentahead sockets, and/or other hardware (estimated cost $1.5K) should be procured/installed on all MV enclosures, including distribution transformers. A properly-rated insulated cap should be installed on transformer bushings that currently have plastic caps (estimated cost $3.5K, installed).

It is also suggested that the school load be measured over period of time to determine the level of unbalance at that facility. The system electrical loads should be balanced to improve efficiency and prevent equipment failures. To assist with this, power quality instrumentation ($5K-$8K range) should be procured for monitoring selected equipment.

5.2 Phase 1 - Distribution Infrastructure Main Feeder Replacement

The underground distribution system from the power plant to junction boxes and all distribution transformers should be replaced, following funding and design. New 15 kV single conductor cables in conduit, together with a grounding conductor are suggested.

For the new underground cable system, the initial work (Phase 1) should include utility locates and surveys to pinpoint exact routing of all existing underground utilities (potholing is not necessary at this time). Completed site electrical plans should be provided to Akhiok in electronic format.

Project phases should be planned for summer months where conditions are favorable. Main feeders (those from the power plant to MV junction boxes and between MV junction boxes) should be replaced in Phase 1. The initial work will start at the power plant, and will include excavation and installation of new duct(s), adjacent to the existing direct-buried cable, to JB#1.

As part of the initial construction and new system tie-in, the power plant will need to be shut down as new cables are installed from the power plant step-up transformers to JB#1, and new LBJ's should be installed in JB#1 at this time. Recommended cable is #2 AL EPR insulated with concentric neutral and separate 600 V ground conductor. Maintenance activities can be performed at the power plant during the first cable install outage, including testing of the main step-up transformers checking torque on cable terminations, etc. The synchronizing switchboard should be replaced or upgraded at this time, if possible.

During Phase 1, an alarm beacon can be installed on the power plant exterior, visible from the City Office (light illuminated under alarm conditions, including loss of coolant/high engine temperature, low fuel, fire, ground fault, etc.). The system can also use a radio for communicating alarm conditions, if feasible.

During this initial and subsequent outages, it is suggested that the new school generator be leveraged to back-feed the distribution system and supply village loads. A temporary modification to wiring at the school transfer switch will be required for this, and load break elbows will need to be removed in MV junction boxes (supply cables from power plant) to prevent hazardous voltages at junction boxes where work is being performed. Power to the Akhiok weather station will be interrupted until work is completed from the power plant to JB#1 (a portable generator can be used to supply this load if necessary).

Following the initial excavation work, a new trench will be dug between JB#1 and JB#2, and new duct and cables installed. This will impact travel in the road from the village to the airport, tank farm, and power plant, and will need to be planned accordingly. However, the summer months are ideal for this due since many residents are absent from the village.

Feeders from JB# 2 to JB#3 and from JB# 3 to JB#4 would be installed to complete Phase 1 work. New MV JB's are suggested near the village (below grade with traffic rated covers). Consider bollards at JB#2, 3, 4 if below grade construction is not feasible.

5.3 Phase 2 - Distribution Infrastructure Lateral Feeder Replacement

This phase replaces the cables from the main feeds/junction boxes to the distribution transformers. These feeders (laterals) are mostly single phase, with the exception of the school feeder. Most outages to homes and facilities will last for several days, and portable generators may be required for temporary power.

5.4 Phase 3 – Transformer Secondary Feeder Replacement

This phase replaces the cables from the distribution transformer secondaries to the service entrances at homes and facilities.

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References

ANSI C84.1 – 2011, *American National Standard for Electric Power Systems and Equipment – Voltage Ratings (60 Hertz)*

NEMA MG 1-2014, *Motors and Generators*

NEC, *National Electrical Code*

NETA, *Maintenance Testing Specifications*

Appendices

A1. Akhiok Site Electrical Plans

A1.1 – Power Plant Area

A1.2 – Airport Way

A1.2 – East Akhiok

A2. Cut Sheets

A2.1 Okonite EPR Cable

A2.2 Below grade Utilities Enclosures

A2.3 Cooper LBJ's

A2.4 HDPE Conduit

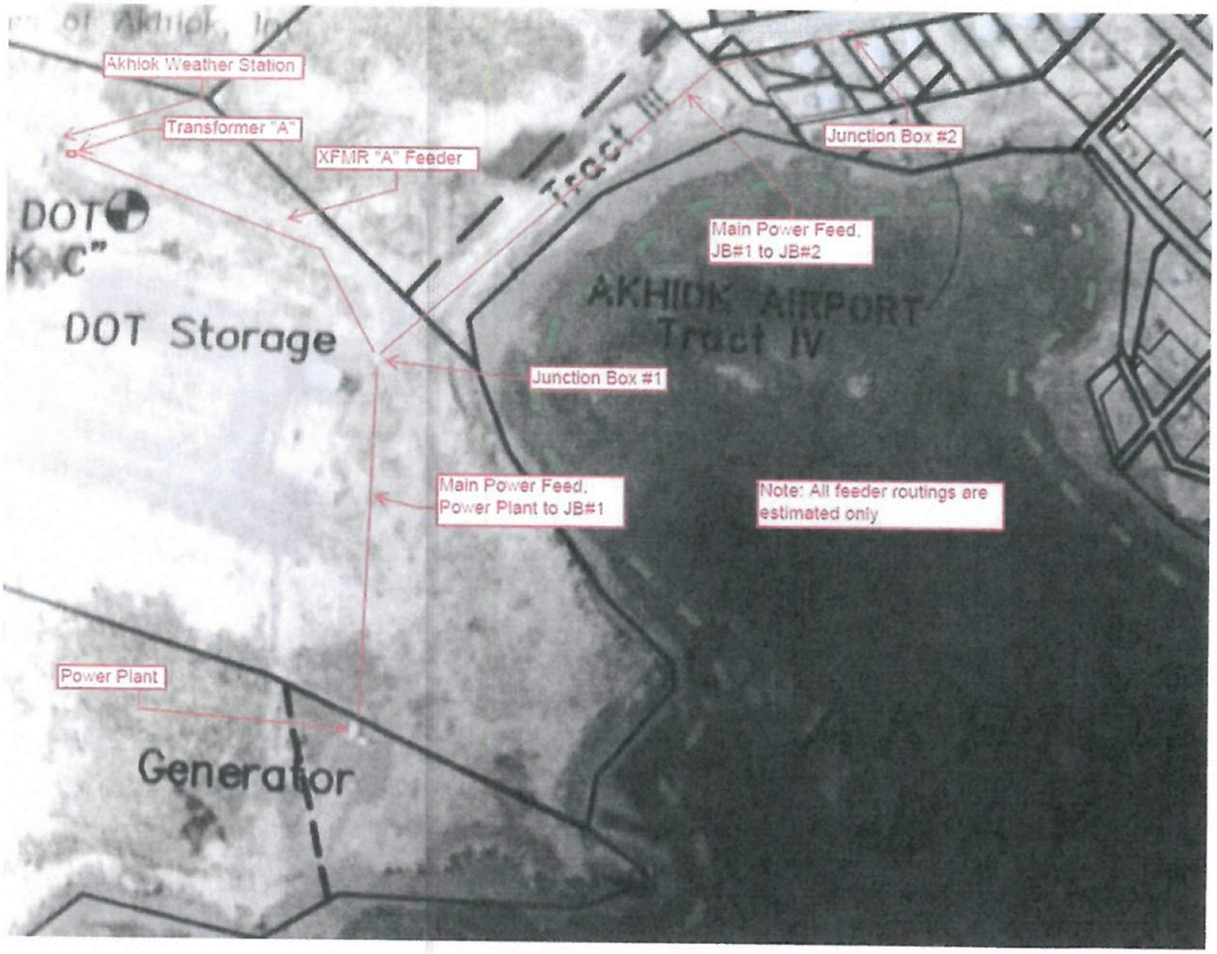
A1. Akhiok Site Electrical Plans

Site plans for the Akhiok electrical distribution system are shown on the following pages.

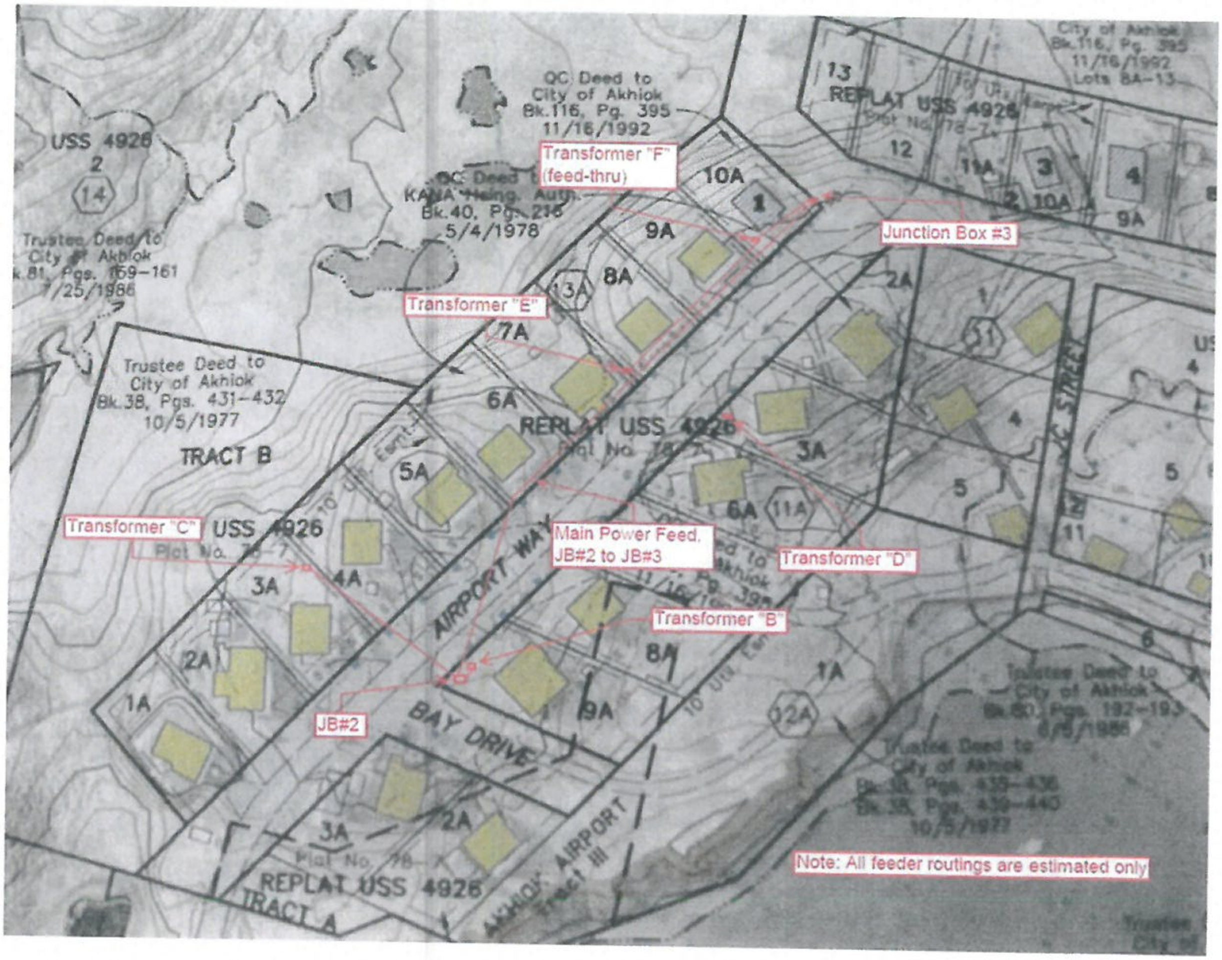
Equipment locations are estimated and based on observations. Transformers are labeled in the MV junctions boxes, but are confusing. Therefore, a new system, using letters for transformer designators rather than numbers, is followed for the electrical plans and this report.

Underground routing of feeders was estimated based on equipment locations and common sense. Where a feed-thru was used, the next logical transformer or equipment was assumed for downstream location. If a transformer was radial-fed, the closest or most logical upstream source was assumed. As part of the replacement project, all underground utilities should be located so the new system can be effectively designed.

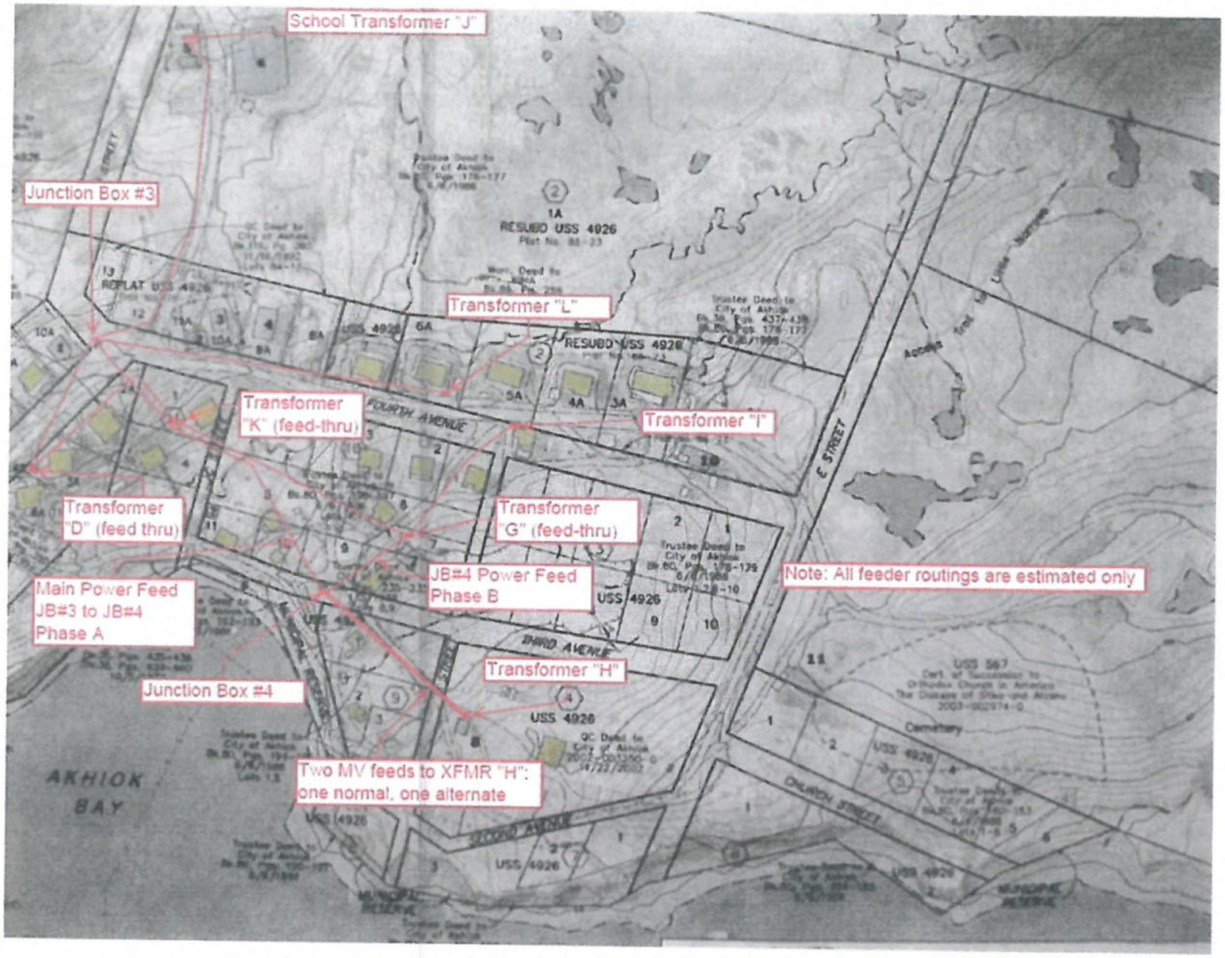
A1.1 – Power Plant Area Electrical Plan



A1.2 – Airport Way Electrical Plan



A1.2 – East Akhiok Electrical Plan



A2. Cut Sheets

This section includes cut-sheets for possible equipment that would be used as part of the electrical infrastructure/cable replacement project. They include 15 kV cable, enclosures for below-grade applications, loadbreak junctions, and high density polyethylene (HDPE) conduit.

A2.1 Okonite EPR Cable

100% insulation, #2 conductor, full neutral suggested.

Okoguard® URO-J

15kV Underground Primary Distribution Cable-Jacketed

Red Identification Stripes

Filled Strand Aluminum Conductor/105°C Rating
100% and 133% Insulation Levels

- Conductor - Stranded Aluminum with Filled Strand - Water Swellable Powder
- Strand Screen - Extruded Semi-conducting EPR
- Insulation - Okoguard EPR
- Insulation Screen - Extruded Semi-conducting EPR
- Concentric Conductor-Bare Copper Wires
- Encapsulating Jacket Okolene with Extruded ID Stripes & NESC lightning bolt

Insulation

Okoguard is Okonite's registered trade name for its exclusive ethylene-propylene rubber (EPR) based, thermosetting compound, whose optimum balance of electrical and physical properties is unequaled in other solid dielectrics. Okoguard insulation, with the distinctive red color and a totally integrated EPR system, provides the optimum balance of electrical and physical properties for long, problem free service.

The triple tandem extrusion of the screens with the insulation provides optimum electrical characteristics.

The compressed conductors are filled with water swellable powder. This construction slows the migration of water through the strands in the event of a mechanical dig in followed by external exposure to water.

An insulation screen of ethylene-propylene rubber is extruded over the insulation. The copper concentric wires are uniformly spaced around the insulation screen. The overall polyethylene jacket provides protection against mechanical damage and corrosion.

Product identification is provided through the use of three red stripes placed 120° apart in the black jacket, with an NESC lightning bolt.

Applications

Okoguard URO-J cables provide maximum circuit longevity in underground residential distribution systems. They can be buried directly or installed in underground ducts or conduits.

Specifications

Central Conductor: Aluminum per ASTM B-609, Class B stranded per B-231.

Filled Strand: Water swellable powder meets or exceeds ICEA T-31-610 water penetration resistance and ANSI/NEMA class A connectorability requirements.

Conductor Screen: Extruded semiconducting ethylene propylene rubber meets or exceeds the requirements of ICEA S-94-649 and AEIC CS8.

Insulation: Extruded Okoguard meets or exceeds the requirements of ICEA S-94-649 and AEIC CS8.

Insulation Screen: Extruded semiconducting ethylene propylene rubber meets or exceeds the requirements of ICEA S-94-649 and AEIC CS8.

Concentric Conductor: Bare copper wires.

Jacket: Black Okolene with red extruded stripes meets or exceeds the requirements of ICEA S-94-649 for polyethylene jackets.

Product Features

- Triple tandem extruded, all EPR system.
- Okoguard cables meet or exceed NEMA/ICEA and RUS U-1 standards.
- 105°C continuous operating temperature.
- 140°C emergency rating.
- 250°C short circuit rating.
- Excellent corona resistance.
- Low dielectric constant and power factor.
- Screens are clean stripping.
- Exceptional resistance to "treeing".
- Filled strand conductor.
- Moisture resistant.
- Overall jacket provides extended life.
- Excellent resistance to most chemicals.
- Can be listed by UL as Type MV-90 on special orders.
- Cable listed by CSA to C68.3 on special orders.
- Design Options:
  - Additional conductor sizes
  - Copper central conductor
  - Copper flat strap concentric neutral
  - Product identification via colored jackets.
  - Semiconducting jackets.
- Improved Temperature Rating.
  Okoguard insulation system has been tested and qualified for operation at 105°C continuous and 140°C emergency operating temperature.
- Minimum installation temperature of -40°C.

Okoguard Insulation: 175 mils 100% Insulation Level

Catalog Number	Conductor Size AWG/kcmil	Nominal Dia. over Insulation (in.)	Nominal Dia. over Insulation Screen (in.)	Copper Neutral. No. x AWG (1)	Nominal O.D. (in.)	Aprox. Net Weight lbs./1000'	Aprox. Ship Weight lbs./1000'	90° Ampacity Direct Burial (2)	90° Ampacity Duct (2)	105° Ampacity Direct Burial (2)	105° Ampacity Duct (2)
FULL NEUTRAL											
163-23-2060	2(7x)	0.68	0.76	10 x 14	1.00	536	626	165	120	180	130
163-23-2066	1(19x)	0.72	0.80	13 x 14	1.03	608	698	185	135	205	150
**163-23-2072	1/0(19x)	0.76	0.84	16 x 14	1.07	688	778	210	155	235	170
163-23-2075	2/0(19x)	0.81	0.88	13 x 12	1.15	820	910	240	175	270	200
163-23-2078	3/0(19x)	0.86	0.93	16 x 12	1.20	939	1029	270	200	305	225
163-23-2081	4/0(19x)	0.91	0.99	13 x 10	1.30	1138	1238	310	230	350	260
163-23-2084	250(37x)	0.97	1.04	16 x 10	1.36	1302	1418	340	255	385	285
163-23-2090	350(37x)	1.07	1.17	20 x 10	1.49	1615	1793	405	300	455	340
1/3 NEUTRAL											
162-23-2057	2(1x)	0.66	0.73	6 x 14	0.97	467	528	155	135	165	130
162-23-2060	2(7x)	0.68	0.76	6 x 14	1.00	489	579	155	135	165	130
162-23-2066	1(19x)	0.72	0.80	6 x 14	1.03	527	617	175	155	190	150
162-23-2072	1/0(19x)	0.76	0.84	6 x 14	1.07	572	662	200	175	215	175
162-23-2075	2/0(19x)	0.81	0.88	7 x 14	1.12	636	726	230	200	245	195
162-23-2078	3/0(19x)	0.86	0.93	9 x 14	1.17	722	889	260	230	280	225
162-23-2081	4/0(19x)	0.91	0.99	11 x 14	1.23	822	922	290	240	315	255
162-23-2084	250(37x)	0.97	1.04	13 x 14	1.28	918	1018	320	260	345	280
162-23-2090	350(37x)	1.07	1.17	18 x 14	1.41	1166	1315	380	320	415	345
162-23-2093	500(37x)	1.20	1.30	16 x 12	1.57	1513	1691	455	385	495	415
162-23-2096	750(61x)	1.39	1.49	15 x 10	1.87	2152	2402	555	470	600	510
162-23-2099	1000(61x)	1.54	1.68	18 x *(B)	2.06	2711	3059	645	550	685	585

* - Special Conductor Size (A) Wire O.D. =0.1066"

** Stocked as unfilled strand as 161-23-2072, see Sec 2, Sheet 35.

(1) Individual wire size and count may vary. The resulting combination meets the 1/3 or full neutral, size requirement.

Visit Okonite's web site www.okonite.com for the most up to date dimensions.

Ampacities

(2) Full neutral, single phase ampacities are based on 90°C or 105°C conductor temperature, 20°C ambient temperature, 100% load factor, and earth thermal resistivity of RHO 90.
One third neutral ampacities are based on ICEA P-53-426 triplexed or triangular configuration for the same conditions stated above.

A2.2 Below Grade Utilities Enclosures

Traffic rated, concrete or composite enclosures with pentahead bolts are recommended.

CARSON

HDPE plastic enclosures are easy to install and provide strong, durable, chemical and water resistant performance.
Load Categories: Pedestrian

CHRISTY

The R-Series is an extremely economical, high compression strength concrete material, which prevents lid and body chipping or cracking with a patented protective polypropylene ring guard on the lid and body.
Load Categories: Pedestrian

CARSON

Carson Hybrids are specially designed to interchange various lid materials with a HDPE body to maximize load ratings and interior volume at a great overall installed value.
Load Categories: Non Deliberate Vehicular Traffic

FIBRELYTE

Fibrelyte is a proprietary composite material designed to be lightweight, highly durable, and strong. Fibrelyte will not absorb moisture and degrade when holes are drilled through.
Load Categories: Non Deliberate Vehicular Traffic

SYNERTECH

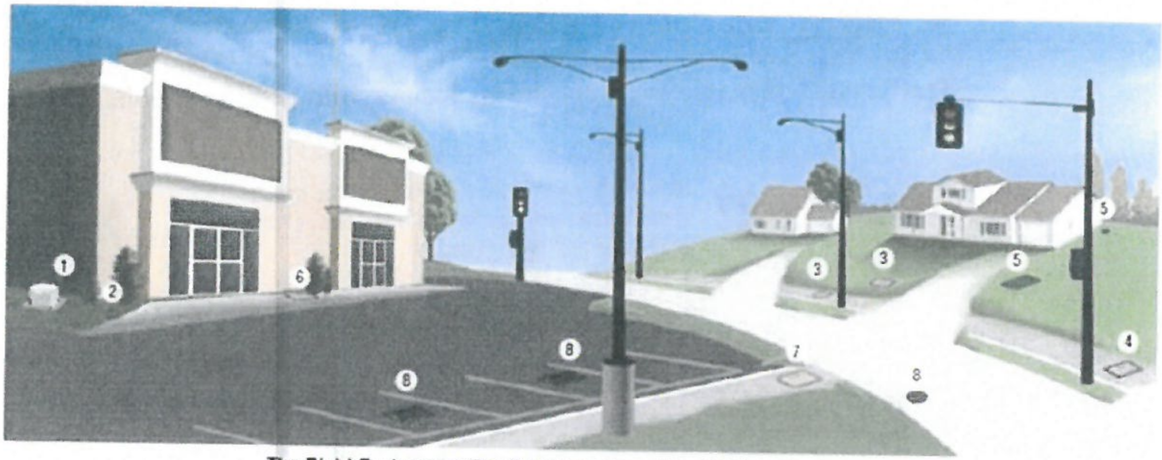
Synertech is engineered to combine the exceptional strength of High Density Polymer Concrete with the lightweight properties of Sheet Molding Compound to produce a tough, durable enclosure. Synertech is the strongest, lightest composite enclosure making it easier and safer to install.
Load Categories: Non Deliberate Heavy Vehicular Traffic

H-SERIES

H-Series Polymer Concrete is produced using a precise dry mix of select aggregate, which is bound with resin and fiberglass fabric. Our new polymer concrete manufacturing process results in enclosures with high flexural and tensile strength, yet lower weight than traditional concrete.
Load Categories: Non Deliberate Heavy Vehicular Traffic

CHRISTY

Christy concrete is reliable and cost effective. With a galvanized steel cover and frame in place, these boxes are traffic rated.
Load Categories: Deliberate Roadway Traffic



The Right Enclosure • The Right Location • The Right Application

1

Pedestrian / Greenbelt
Medium Duty
Pad: Polymer Concrete

WUC Guide 2.15
Single Phase
Transformer Pads

2

Pedestrian / Greenbelt
Light Duty
Body: HDPE Plastic
Cover: HDPE Plastic

3000# Vert. Test Load
ASTM 857
Telcordia GR-902

3

Right of Way / Sidewalk
Medium Duty
Body: Fibrelyte
Cover: Fibrelyte

12,000# Vert. Test Load
ANSI/SCTE 77 - 2010
TIER 5, 8

4

Right of Way / Sidewalk
Light Duty
Body: 2" Concrete
Cover: Concrete

Exceeds ASTM C 857
A-0.3 Pedestrian Traffic
Requirements

5

Pedestrian / Greenbelt
Light Duty
Body: HDPE Plastic
Cover: HDPE Plastic

To 3000# Vert. Test Load
ASTM 857
ANSI/SCTE 77 - 2010
Telcordia GR-902

6

Right of Way / Sidewalk
Heavy Duty
Body: Polymer
Composite SMC
Ring & Cover: Polymer Concrete

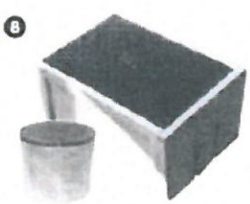
WUC 3.16 Category 3
ANSI/SCTE 77 - 2010
TIER 15, 22

7

Right of Way / Sidewalk
Heavy Duty
Body: Polymer Concrete
Cover: Polymer Concrete

WUC 3.16 Category 3
ANSI/SCTE 77 - 2010
TIER 15, 22

8



Roadway or Parking Lot
Traffic Rated
Body: 1¾"- 3½" Concrete
Cover: 1/2" Steel Checker Plate

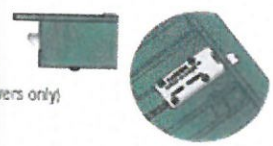
ASTM C 857
A-16

HARDWARE & SECURITY OPTIONS

Enclosures come equipped with standard lid fastening hardware (varies per box type). Standard assembly is shown below.

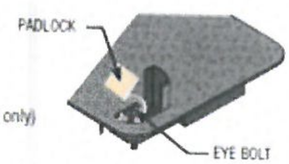
STANDARD HEX HEAD:
3/8 - 1/2 Stainless Steel Hex Head Bolt with Washer

DROP-N-LOCK™:
Automatic locking system
(available on select HDPE covers only)



STANDARD PENTA HEAD:
3/8 - 1/2 Stainless Penta Head Bolt with Washer

PADLOCK & EYE:
Eye bolt and padlock
(available on steel covers only)



VANDAL PROOF:
Oldcastle Enclosures Vandal Proof bolt with specialty key.

Security Level	Typical Tool
Low	Fingers, Car Key, Pen Knife
Medium	Screwdriver, Hammer, Hacksaw, Pliers
High	Power Tools, Crowbar, Wedge, Hammer
Extreme	Sledge Hammer, Disc Grinder, Bolt Cutter

ENCLOSURE OPTIONS

A. Rack Mount

B. Cable Racks/ Cable Arms

C. Unistrut

D. Pulling Eye - 1,000 lb. and 3,000 lb

E. Electronic Marker

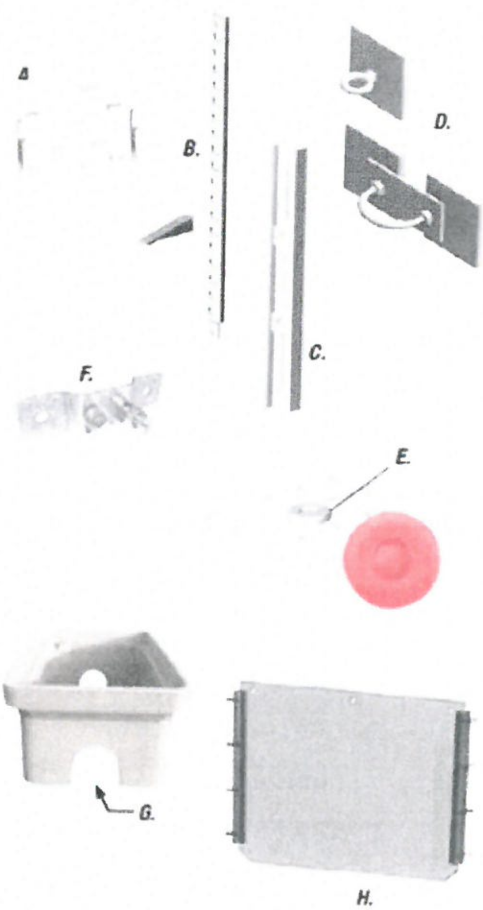
F. Ground Buss

G. Mouseholes / Circular Holes

H. Dividers

I. Solid Bottom (H-Series and Synertech)

J. Gaskets (H-Series and Synertech)



A2.3 Cooper Load Break Junctions

Loadbreak Apparatus Connectors

COOPER Power Systems

200 A 15 kV Class Loadbreak Junction

Electrical Apparatus

500-15

GENERAL

The Cooper Power Systems 200 A, 15 kV Class Loadbreak Junction provides two, three or four 8.3/14.4 kV loadbreak interfaces that are internally bused together and meet all requirements of **IEEE Standard 386™** — Separable Insulated Connector Systems. Loadbreak junctions are used in pad-mounted apparatus, underground vaults, and other apparatus to sectionalize, establish loops, taps, or splices, and to facilitate apparatus changeouts. Sectionalizing a cable run to find and isolate a cable fault is made easy when a loadbreak junction is used with 15 kV Class loadbreak elbows and other accessories meeting the requirements of **IEEE Standard 386™**. When mated with a comparably rated product, the junction provides a fully shielded, submersible, separable connection for loadbreak operation.

The junction has a continuous solid current path of all copper alloy. No aluminum components are used. It also has an ablative arc interrupter with superior de-ionizing properties. The body is molded of high quality peroxide-cured EPDM insulation and has a molded on peroxide-cured semi-conductive EPDM shield.

Cooper's latch indicator ring, located on the circumference of the interface collar, eliminates the guesswork of loadbreak elbow installation on the interface. The bright yellow ring provides immediate feedback to determine if the elbow is properly installed on the junction. If the yellow ring is completely covered by the loadbreak elbow, the elbow is fully "latched." If the ring is visible, the elbow is not fully installed, so the operator can correct it before any problems occur.

The loadbreak junction has an adjustable stainless steel bracket for mounting at various operating angles on flat or curved surfaces, with up to 90° tilt in 10° increments. The solid backplated channel provides strong, rigid support of the junction for optimum loadbreak operation. Parking stands accommodate insulated standoff bushings or portable feedthrus. Drain wire clamps can each accommodate two wires up to 1/0 stranded (3/8" diameter).

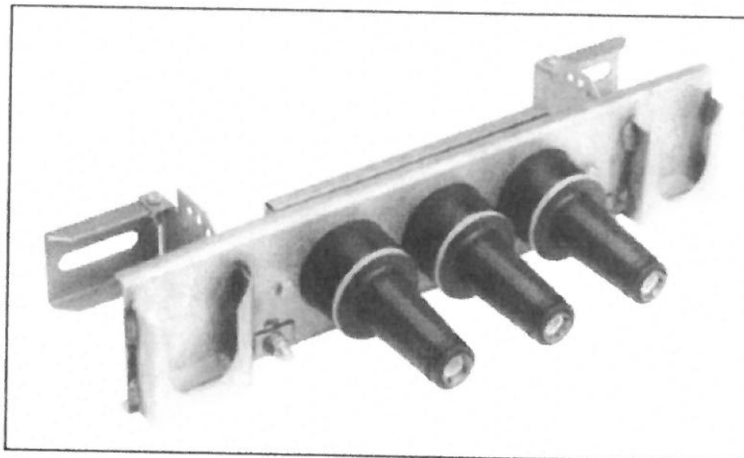


Figure 1.
Three-way Loadbreak Junction with latch indicator rings and adjustable bracket: also available as Two-way and Four-way.

Stainless steel "U" straps are available for direct wall mounting.

ADDITIONAL AVAILABLE OPTIONS

For additional available options, refer to catalog section 650-10. Options include:

- In-line junctions with up to 6 positions
- Junctions with combinations of 200 A wells and 600 A bushings
- "L" splice configurations
- "Y" splice configurations, Single-phase and three-phase
- Stacked configuration

INSTALLATION

No special tools are required. Junctions are bolted to the mounting surface. Refer to Installation Instruction Sheet S500-15-1 for details.

PRODUCTION TESTS

Tests conducted in accordance with **IEEE Standard 386™**:

- AC 60 Hz 1 Minute Withstand – 34 kV
- Minimum Corona Voltage Level – 11 kV

Tests conducted in accordance with Cooper Power Systems requirements:

- Physical Inspection
- Periodic Dissection
- Periodic X-ray Analysis

TABLE 1
Voltage Ratings and Characteristics

Description	kV
Standard Voltage Class	15
Maximum Rating Phase to Phase	14.4
Maximum Rating Phase to Ground	8.3
AC 60 Hz 1 Minute Withstand	34
DC 15 Minute Withstand	53
BIL and Full Wave Crest	95
Minimum Corona Voltage Level	11

Voltage ratings and characteristics are in accordance with **IEEE Standard 386™**

TABLE 2
Current Ratings and Characteristics

Description	Amperes
Continuous	200 A rms
Switching	10 operations at 200 A rms at 14.4 kV
Fault Closure	10,000 A rms symmetrical at 14.4 kV for 0.17 s after 10 switching operations
Short Time	10,000 A rms symmetrical for 0.17 s 3,500 A rms symmetrical for 3.0 s

Current ratings and characteristics are in accordance with **IEEE Standard 386™**

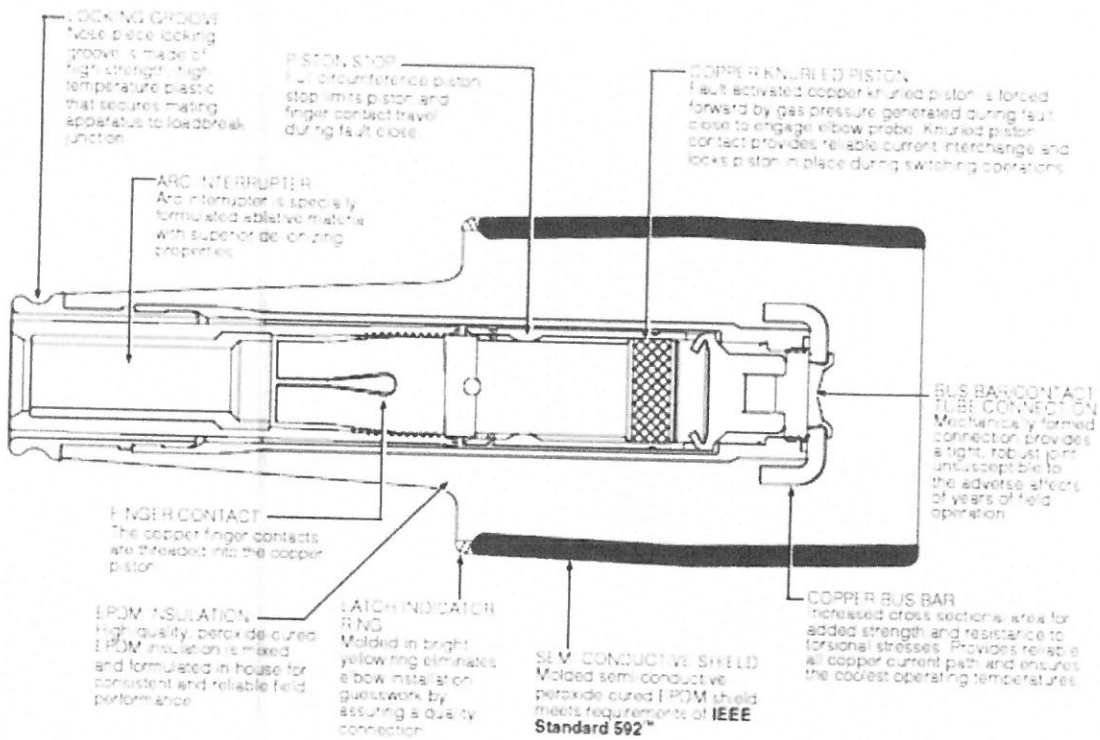


Figure 2.
Illustration shows cutaway of loadbreak junction with continuous current path of all copper alloy. Field proven, all copper alloy current path ensures the coolest operating temperatures and reliable current flow.

ORDERING INFORMATION

To order the 15 kV Class (8.3/14.4 kV) Loadbreak Junction, refer to Table 3.

Each kit contains:

- Loadbreak Junction (with mounting bracket or straps, depending on product ordered)
- Shipping Caps (not for energized operation)
- Silicone Lubricant
- Installation Instruction Sheet

TABLE 3
Loadbreak Junctions

Number of Interfaces	Junction Only	Junction with U-Straps	Junction with Stainless Steel Bracket
2	LJ215C2	LJ215C2U	LJ215C2B
3	LJ215C3	LJ215C3U	LJ215C3B
4	LJ215C4	LJ215C4U	LJ215C4B

TABLE 4
Replacement Parts

Description	Catalog Number
U-Strap Kit with Hardware (1 strap)	2625439A16B
Stainless Steel Bracket Assembly (2 way)	2637172B01BS
Stainless Steel Bracket Assembly (3 way)	2637172B02BS
Stainless Steel Bracket Assembly (4 way)	2637172B03BS

A2.4 HDPE Conduit

HDPE is easier to install than rigid nonmetallic (PVC), which reduces installation costs.

PERMAGUARD-L (Listed)

www.duraline.com

Customer Service
800-847-7661

FEATURES:

- ETL Listed to UL 651A, used per NEC Article 353
- Manufactured from flexible HDPE, makes gradual bends without special equipment
- Excellent low temperature properties, for better handling in cold climates
- Outstanding ductility and strength, protects cables from shifting ground
- Protects cables from rock and root impingement, increasing UG cable life
- Provides a permanent pathway, simplifies future cable repair and replacement
- Added UV stabilization package

APPLICATION:	Innerduct placed into existing conduit, direct buried, concrete encased	
INSTALLATION METHODS:	Trenched, Trenchless – horizontally directionally bored (HDD) and chute or pull plowed, concrete encased (minimum of 2" of cover)	
MARKET APPLICATION:	Enterprise C&I Energy DOT	
DUCT COLOR:	UV Stabilized	
STRIPE:	C (Custom) Color coded with minimum of 3 extruded stripes (equally separated 120° degrees apart) or extruded color surface	
OPTIONS:	FOOTAGE MARKINGS	Sequential foot or meter markings. Custom print streams available.
	PREINSTALLED TAPE	Factory pre-installed Bull-Line™ Pull Tape with EVEN-LOAD™, ensures extra slack at any access point throughout the reel. Available 500lb - 6,000lb tensile strength or locatable.
	PACKAGING	Long continuous lengths on reels or coils. Stick lengths of 40' or 50'
STANDARDS:	Meets or exceeds the HDPE resin requirements per ASTM D 3350 UV Black (minimum carbon black loading of 2%), Sequential footage markings, permanent ink jet or indent print, tested and listed by Intertek Laboratories (ETL) to assure compliance with UL 651A, certified by Dura-Line to comply with all UL 651A property and testing requirements.	

PERMAGUARD-L PHYSICAL AND DIMENSIONAL

Customer Service 800-847-7661 www.duraline.com

Wall Type	Pipe Size	½"	¾"	1"	1 ¼"	1 ½"	2"	2 ½"	3"	4"	5"	6"	
	Nom OD (in)	0.840	1.050	1.315	1.660	1.900	2.375	2.875	3.500	4.500	5.563	6.625	
	OD Tolerence +/–	0.004	0.004	0.005	0.005	0.006	0.006	0.007	0.008	0.009	0.010	0.011	
	Bend Radius (in) – Supported	8	10	13	17	19	24	29	39	50	61	73	
	Bend Radius (in) – Unsupported	16	20	26	34	38	48	58	78	100	122	146	
EPEC-B/ SDR 13.5	Min. Wall (in)		0.078	0.097	0.123	0.141	0.176	0.213	0.259	0.333	0.412	0.491	
	Wall Tolerance +/–		0.020	0.020	0.020	0.020	0.021	0.026	0.031	0.040	0.049	0.059	
	Avg ID (in)		0.874	1.101	1.394	1.598	2.002	2.423	2.951	3.794	4.689	5.585	
	Weight (#/ft)		0.104	0.162	0.259	0.340	0.530	0.777	1.151	1.902	2.909	4.126	
	Safe Working Load		570	894	1,425	1,867	2,917	4,274	6,335	10,472	16,004	22,697	
EPEC-40/ SCH 40	Min. Wall (in)	0.109	0.113	0.133	0.140	0.145	0.154	0.203	0.216	0.237	0.258	0.280	*EPEC 40 Diameters 4" - 6"
	Wall Tolerance +	0.020	0.020	0.020	0.020	0.020	0.020	0.024	0.026	0.028	0.031	0.034	available in stick length only
	Avg ID (in)	0.602	0.804	1.029	1.360	1.590	2.047	2.445	3.042	3.998	5.016	6.031	
	Weight (#/ft)	0.109	0.145	0.215	0.291	0.349	0.469	0.744	0.973	1.387	1.882	2.443	
	Safe Working Load	601	798	1,340	1,604	1,919	2,579	4,090	5,348	7,618	10,320	13,395	
EPEC-80/ SCH 80	Min. Wall (in)	0.147	0.154	0.179	0.191	0.200	0.218	0.276	0.300	0.337	0.375	0.432	
	Wall Tolerance +	0.020	0.020	0.021	0.023	0.024	0.026	0.033	0.036	0.040	0.045	0.052	
	Avg ID (in)	0.526	0.722	0.936	1.255	1.476	1.913	2.290	2.864	3.786	4.768	5.709	
	Weight (#/ft)	0.139	0.188	0.277	0.383	0.465	0.644	0.982	1.315	1.923	2.668	3.669	
	Safe Working Load	768	1,040	1,533	2,116	2,564	3,545	5,409	7,238	10,578	14,669	20,172	

Notes:

1. Supported bend radius for ½" through 2 ½" is 10 times the OD while the unsupported bend radius is 20 times the OD. Supported bend radius for 3" through 6" is 11 times the OD while the unsupported bend radius is 22 times the OD.
2. "Safe Working Load" is calculated using a 20% safety factor with the minimum resin tensile strength of 3,000 psi, the average OD and minimum wall thickness.

Resin Requirements per ASTM D 3350, having a minimum cell classification of 334420 C for black and E for color.

Cell #	Property	Description Minimum Requirements	Acceptable Test Methods
3	Resin Density	0.940-0.947 g/cm3	ASTM D 1505 or ASTM D 792 or ASTM 4883
3	Melt Index	<0.4 grams/10 minutes	ASTM D 1238
4	Flexural Modulus	80,000 psi	ASTM D 790
4	Tensile Strength	3,000 psi	ASTM D 638
-	Elongation	400%	ASTM D 638
8	Slow Crack Growth Resistance	Condition B, 10% Igepal/H2O solution, F50>24hrs	ASTM D 1693
0	Hydrostatic Design Basis	Non-pressure rated	ASTM D 2837
C	Black UV Resistance	Added carbon black @ 2% by weight	ASTM D 4218
or E	Color UV Resistance	Color with UV inhibitor and antioxidant	ASTM D 4238