

PB273479



GUIDELINES FOR TROLLEY CARRIER PHONE SYSTEMS

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prepared for

UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF MINES

by

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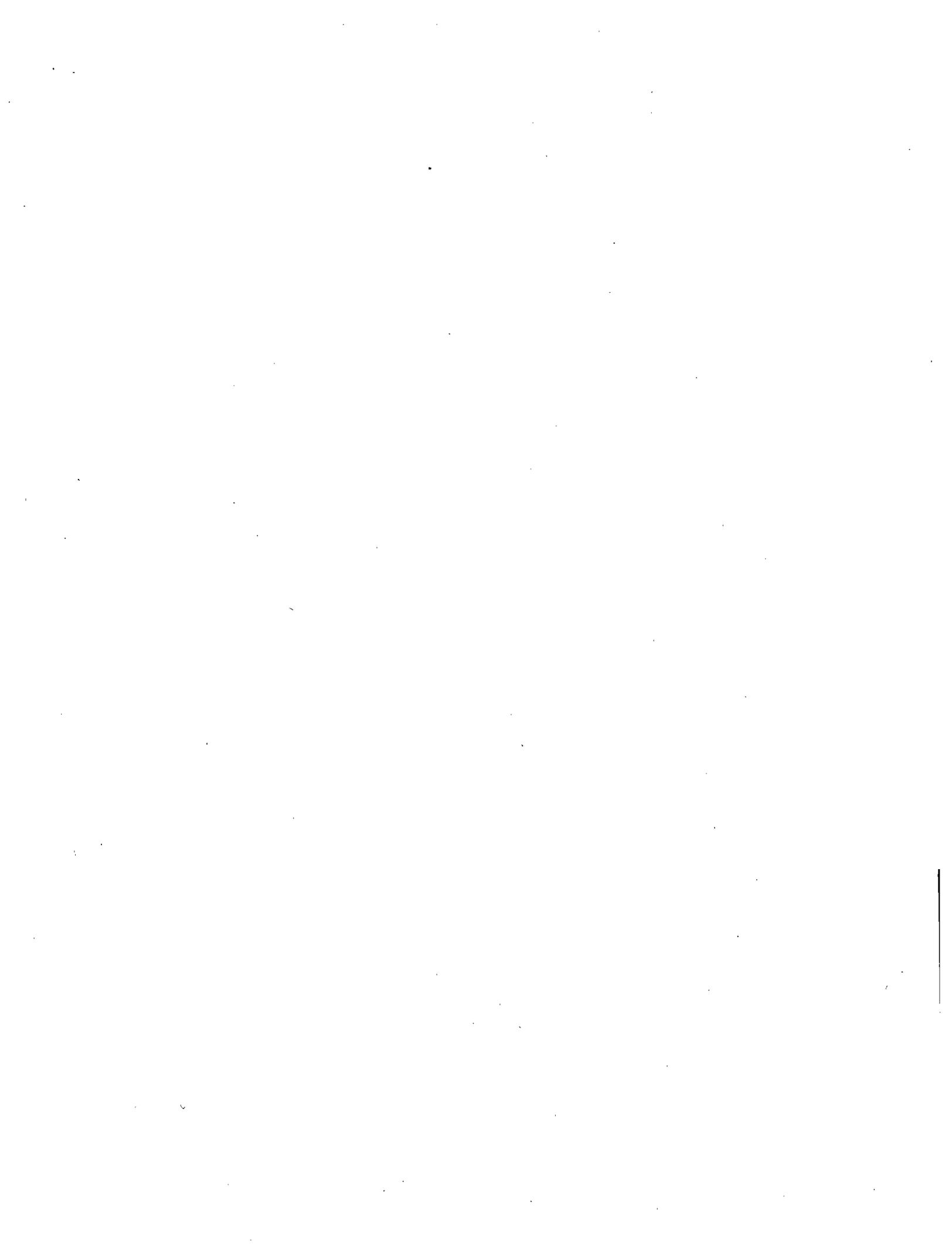
FINAL REPORT

On Contract No. JO166010

Bureau of Mines Open File Report 150-77

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SPRINGFIELD, VA. 22161

Arthur D. Little, Inc.



REPORT DOCUMENTATION PAGE

1. Report No. BuMines OFR 150-77	2.	3. Recipient's Accession No. PB273479	
4. Title and Subtitle Guidelines for Trolley Carrier Phone Systems		5. Report Date Published March 1977	
7. Author(s) Richard H. Spencer, Paul O'Brien, Dennis Jeffreys		8. Performing Organization Report No. 78663	
9. Performing Organization Name and Address Arthur D. Little, Inc. Cambridge, Massachusetts 02140		10. Project/Task/Work Unit No.	
12. Sponsoring Organization Name and Address Office of the Assistant Director-Mining, Bureau of Mines, Department of the Interior, Washington, D.C. 20241		11. Contract or Grant No. J0166010	
15. Supplementary Notes Approved for release by the Director, Bureau of Mines, November 1, 1977.		13. Type of Report Final	
16. Abstract Guidelines for trolley carrier phone systems have been prepared and documented to enable operating personnel to improve and upgrade their carrier phone systems. These guidelines cover installation of equipment, conversion of a rail haulage trolley wire and feeder system into a functional carrier frequency transmission line, performance checkout of the trolley carrier phone system, and the development of practical portable test instrumentation. This report summarized the program that led to the development of the guidelines and recommends a program to test and improve their effectiveness. The guidelines were developed using data compiled from four activities: (1) visiting and interviewing persons knowledgeable in and familiar with trolley carrier phone systems; (2) examining the Code of Federal Regulations, Title 30, Mineral Resources, to determine the federal regulations that apply to carrier phones; (3) examining equipment in the laboratory loaned by carrier phone manufacturers; and (4) performing in-mine measurements and tests. A full set of the guidelines is appended to this report.			
17. Originator's Key Words Carrier Communications Guidelines Coal Mine Communications Trolley Wire Communication		18. Availability Statement Release unlimited by NTIS.	
14. U. S. Security Classif. of the Report	20. U. S. Security Classif. of This Page 17c. 08I	21. Price	22. Price A08-A01

FOREWORD

This report was prepared by Arthur D. Little, Inc., Cambridge, Massachusetts under USEM Contract J0166010. The contract was initiated under the Coal Mine Health and Safety Program. It was administered under the technical direction of PMSRC with Mr. Harry Dobroski acting as Technical Project Officer. Mr. A. G. Young was the Contract Administrator for the Bureau of Mines.

The report is a summary of the work recently completed as part of this contract during the period 21 August 1975 to 15 March 1977.

No inventions or patents were developed and no applications for inventions or patents are pending.



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I. SUMMARY

The trolley carrier phone systems of electric rail haulage mines serve the vital dispatching function. Performance of this critical communication system is often poor or marginal. The reason for performance deficiencies lie in the several areas of equipment, installation, maintenance, testing and the transmission medium itself. Five guidelines have been developed to enable operating personnel to improve and upgrade their carrier phone systems. These guidelines treat:

- The installation of trolley carrier phone equipment on board mine vehicles
- The installation of trolley carrier phone equipment at the dispatcher's room
- The converting of a rail haulage trolley wire and feeder system into a functional carrier frequency transmission line
- The performance checkout of the trolley carrier phone system to determine that the equipment is functional, that the transmission path is acceptable, and specific areas that require maintenance
- The development of practical portable instrumentation to be used by electricians and inspectors.

This report summarizes the program that led to the development of the guidelines and recommends a program to test and improve the effectiveness of the guidelines.



II. INTRODUCTION

At the present time there are two backbone coal mine communication systems in general use in electric rail haulage mines. These are comprised of pager phones and the trolley carrier phone. Both of these systems are in day-to-day use in coal mining operations and are essential to the safe conduct of mining operations. The carrier phones operate in a wide variety of mine topographical layouts - mines ranging from as small as a few miles to many miles in dimensions and encompassing many miles of trolley wire/rail, including switches, crossovers, sidings, and the usual configurations found in rail haulage systems. They operate in a wide variety of mine sizes and layouts with various kinds of equipment, moisture contents in mines, acid contents in the moisture, branches on the phone lines and standing wave phenomenon and the problems presented thereby. They also operate in the face of an ever-changing mine layout as the mining progresses. They operate in an environment that is generally detrimental to electronic equipment. They also generally operate with a minimum of maintenance and a lack of good maintenance tools. Because of these conditions, there are frequent problems with carrier phone system performance. These problems are evidenced by lack of coverage of certain regions of the mine, breakdown of equipment, and noise imposed performance limitations.

III. OBJECTIVE OF WORK

The objective of this program was to improve and upgrade the operating capability of the trolley carrier phone system by developing guidelines covering the following specific areas:

- The installation of trolley carrier phone equipment on board mine locomotives
- The installation of trolley carrier phone equipment at the dispatcher's room
- The converting of a rail haulage trolley wire and feeder system into a functional carrier frequency transmission line
- The performance check-out of the trolley carrier phone system to determine: (1) that the equipment is functional, (2) that the transmission path is acceptable and (3) the specific areas that require maintenance
- The development of practical portable instrumentation to be used by electricians and inspectors



IV. METHOD OF DEVELOPING GUIDELINES

A. FACTUAL DATA COLLECTION

Existing knowledge was assessed by making a number of visits to those familiar with trolley carrier phone systems. These visits and interviews encompassed: staff members of the Bureau of Mines, users of equipment, manufacturers and distributors of equipment and service personnel. The listing below identifies the persons interviewed and the organizations represented:

Howard Parkinson, PMSRC
Harry Dobroski, PMSRC
Robert Bradburn, PMSRC
Donald Collins, National Mine Service
Robert Havener, Mine Safety Appliances
Harry Brown, Mine Safety Appliances
Raymond Helfrich, then at FEMCO
Dr. Thomas Agnew, then at FEMCO
Sidney Thomas, FEMCO
Dave Momyer, FEMCO
Harry Dushac, Lee Engineering
Stanley Boscovich, Robena Mine
Peter Sisco, Robena Mine
Robert Morrow, Robena Mine
Derek Paice, Westinghouse
Sam Passafiume, CSE
Ken Betsh, Gaitronics
John Conti, Renton Mine
Henry Kolesar, Renton Mine
William Simpson, Renton Mine
Paul Mohr, Mathies Mine
Dr. James Wait, Dept. of Commerce, ITS
Dr. David Hill, Dept. of Commerce, ITS

These interviews together with our knowledge and experience provided the basis for establishing the status of trolley carrier phone systems as they are currently used in electric rail haulage coal mines as is summarized below:

Equipment

Trolley carrier phone transceivers are relatively unsophisticated equipments, typically operating at carrier frequencies of 88 or 100 kHz and using narrow-band frequency modulation (FM). The equipment typically is rated at 25 watts, providing 25 volts into a 25-ohm resistive load. Most mines use a few fixed location trolley carrier phones and a large number of mobile trolley carrier phones on locomotives, jeeps, and, in some instances, on portal buses.

Environment

The operating environment for trolley carrier phones is quite severe. The mobile units are subjected to constant vibration and shock, and suffer the extremes of temperature variation from season to season. They also operate in 100% relative humidity (RH) environments during much of the warm season. Not only do they have to operate in the 100% RH region, but they are frequently exposed to acid vapors often found in mines, and to dust and dirt. The mere presence of electronic equipment in conjunction with the heavy equipment commonly found in mines places it in a hazardous environment. The electrical environment in which the carrier phones must operate is quite severe. For example, the trolley wire is known to have voltage extremes running as high as 12,000 volts for a few milliseconds, and to be subject to the ever-present AC ripple generated by the rectifiers and the variations of nominal values that are measured in terms of $\pm 25\%$.

Maintenance

Maintenance problems relate to two particularly vital portions of the carrier phone system: the transceiver equipment itself and the transmission medium. Equipment maintenance is frequently performed with an absolute minimum of service equipment. In fact, some mines have hundreds of carrier phone sets that are maintained with no more measurement equipment than a multimeter. In some mines vendors are contracted to repair carrier phone transceivers; these vendors are either the original suppliers or a service organization.

Transmission Line

The transmission line that interconnects the carrier sets represents the major difficulty in obtaining and maintaining good carrier phone performance. It is not the fundamental character of the transmission line (comprised of a trolley wire/rail) that imposes this problem. Rather, it is the many bridging loads necessarily placed across the trolley wire and the branches imposed on the trolley wire/rail by rail haulage requirements that make the transmission medium the most difficult factor in maintaining good carrier phone communications.

The attenuation rate for a typical trolley wire rail in a conductive medium in a tunnel is approximately 1 dB/Km. A typical trolley carrier phone can accommodate a 70 dB transmission loss, that is, a loss from 25V rms to 8mV rms. For such a condition it can be seen that a 70 Km communication range can be expected, or 40 miles of coverage. However, the bridging loads interfere with achieving anywhere near such a communication range. These bridging loads, which eat into the allowable transmission loss at an extremely rapid rate, are comprised of such items as:

- personnel heaters
- rectifiers
- pumps



- mine motors
- lightning arrestors
- signal and illumination lights
- locomotive and jeep light bulbs
- carrier phones
- vehicles
- insulators
- bore hole shorts

These bridging loads range in impedance from a few ohms to as much as 1000 ohms. The amount of insertion loss that can be expected from such bridging loads is shown in Table I.

The very large insertion losses imposed by certain of these loads has compelled mine operators to attempt to raise the impedance of certain of the offending loads at the carrier frequency so that better carrier signal transmission occurs. In some instances, very large air core inductors, using as much as 100 pounds of copper, have been made to isolate the otherwise very low impedance presented to the trolley wire/rail by a rectifier, for example. Smaller inductors have frequently been used, sometimes in conjunction with parallel tuning, to isolate such items as pumps from presenting low impedance to the trolley wire/rail.

The performance of trolley carrier phone systems is further degraded by the presence of certain sources of noise on the trolley wire/rail. Key among these are the many rectifiers which produce very high order harmonics of the fundamental frequency extending into the carrier range, the arcing noise produced by the moving mine motors, and the noise generated by fixed DC motors. These sources combine to produce noise levels typically in the order of a few millivolts on the trolley wire/rail within the band used by trolley carrier phones.

There is evidence of seasonal effects on the performance of trolley carrier phone systems; the good season being the dry season, which is typically the fall and winter months, and the bad season being the spring and summer months. The dampness present in mines in the summer months and the relative dryness present in the fall and winter months are apparently the causes, respectively, of the "bad" and "good" seasons.

Aided Transmission

The extreme seriousness of the many bridging loads across the trolley wire/rail has often made it impossible for carrier communications to be achieved over distances of more than a few miles. The mine operators, with the assistance of the equipment manufacturers, have tried to use



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TABLE I

CHARACTERISTICS OF BRIDGING LOADS

<u>Bridging Load</u>	<u>Estimated Impedance at 100 kHz (ohms)</u>		<u>Insertion Loss* (dB)</u>	<u>Loss in Voltage</u>
Rectifier with minimum setback		2	34.1	51-1
Rectifier with 50-foot setback [†]		9 [†]	21.6	12-1
Rectifier with 100-foot setback [†]		19	15.9	6-1
Carrier phone with 20 Ω receiver		20 Ω	15.6	6.0 - 1
Carrier phone with 100 Ω receiver		100 Ω	6.0	2.0 - 1
Jeep or portal bus motor		500 Ω	1.6	1.2 - 1
44-ton locomotive motor		60 Ω	8.5	2.7 - 1
Vehicle with two 150-watt, 30-volt headlights isolated resistively **	300 V system	60	8.5	2.6 - 1
	600 V system	120	5.3	1.8 - 1
Illumination lights (assumed to be 200-watt load)	300 V system	450	1.7	1.22 - 1
	600 V system	1800	0.5	1.06 - 1
Single insulator		200,000	0.0043	1.0005 - 1
1 mile of insu- lators with 12- foot spacings (440 insulators)		-	1.90	1.2 - 1
1000-watt per- sonnel heater	300 V system	90 Ω	6.5	2.1 - 1
	600 V system	360 Ω	2.1	1.3 - 1
5000-watt personnel heater	300 V system	18 Ω	16.3	6.6 - 1
	600 V	72 Ω	7.6	2.4 - 1

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Notes to Table I

- * This insertion loss is that calculated for an otherwise unencumbered trolley wire/rail having a 200-ohm characteristic impedance, using the formula

$$L = 20 \log_{10} \frac{Z_o + 2R}{2R}$$

where

R is bridging load resistance. (See page 14 under Trolley Wire Section)

For a trolley wire/rail having a large number of loads, the total net transmission loss will in most practical cases be less than the sum of these tabulated losses due to load interaction.

- ** At the trolley wire carrier frequency the bridging impedance of a locomotive or vehicle appears to be dominated by the headlights. Motors have impedances at carrier frequencies that are somewhat larger than these values and therefore the load imposed by the lights only is considered. Newer vehicles with DC to DC converters that supply the light circuits have appreciably less effect.

- † The bridging impedance of a setback rectifier is higher in value than one with minimum setback due to the feed wire inductance. These figures assume a feed wire inductance of 0.3 microhenrys per foot and a frequency of 100 kHz. The values of Z will be somewhat less, but not significantly for 88-kHz operation.



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aided transmission, which is typically effected by coupling the trolley carrier signals from the trolley wire to the mine pager phone line, using it in a common mode as a single conductor to extend the communication range of the trolley carrier phone systems. Alternatively, some mine operators have made use of auxiliary wires strung for the sole purpose of providing aided transmission. This line is free of the branches and other impediments to good propagation that occur on the pager phone line. Compared to the use of the phone line, the use of an auxiliary wire also avoids the possibility of adding trolley wire audio noise to the phone line.

Performance Difficulties

The performance difficulties experienced with carrier phone systems are dominated by the excess transmission loss between a pair of carrier phone sets. Such a loss is, in turn, dominated by the large number of bridging loads across the trolley wire/rail which, in the absence of bridging loads, would provide a very good transmission medium for trolley carrier signals. Minor problems are presented by certain equipment shortcomings. However, major improvements in trolley carrier phone systems can only come about by treating the transmission medium as the first-order cause of carrier phone system difficulties.

B. FEDERAL REGULATIONS

This information was supplemented by an examination of the Code of Federal Regulations, Title 30, Mineral Resources, to determine the federal regulations that apply to carrier phones.

C. EQUIPMENT

The carrier phone manufacturers cooperated by loaning us the individual sets of equipment as are noted below:

- battery-powered mine Trolley-PhoneTM, Model 73-1901 from the FEMCO Division, Gulton Industries, Inc. Irwin, Pa.
- Mine PhoneTM, Model 1601, Mine Safety Appliances, Pittsburgh, Pa.
- Trolley-CommTM, Model 219, Pyott-Boone, Tazewell, Va.

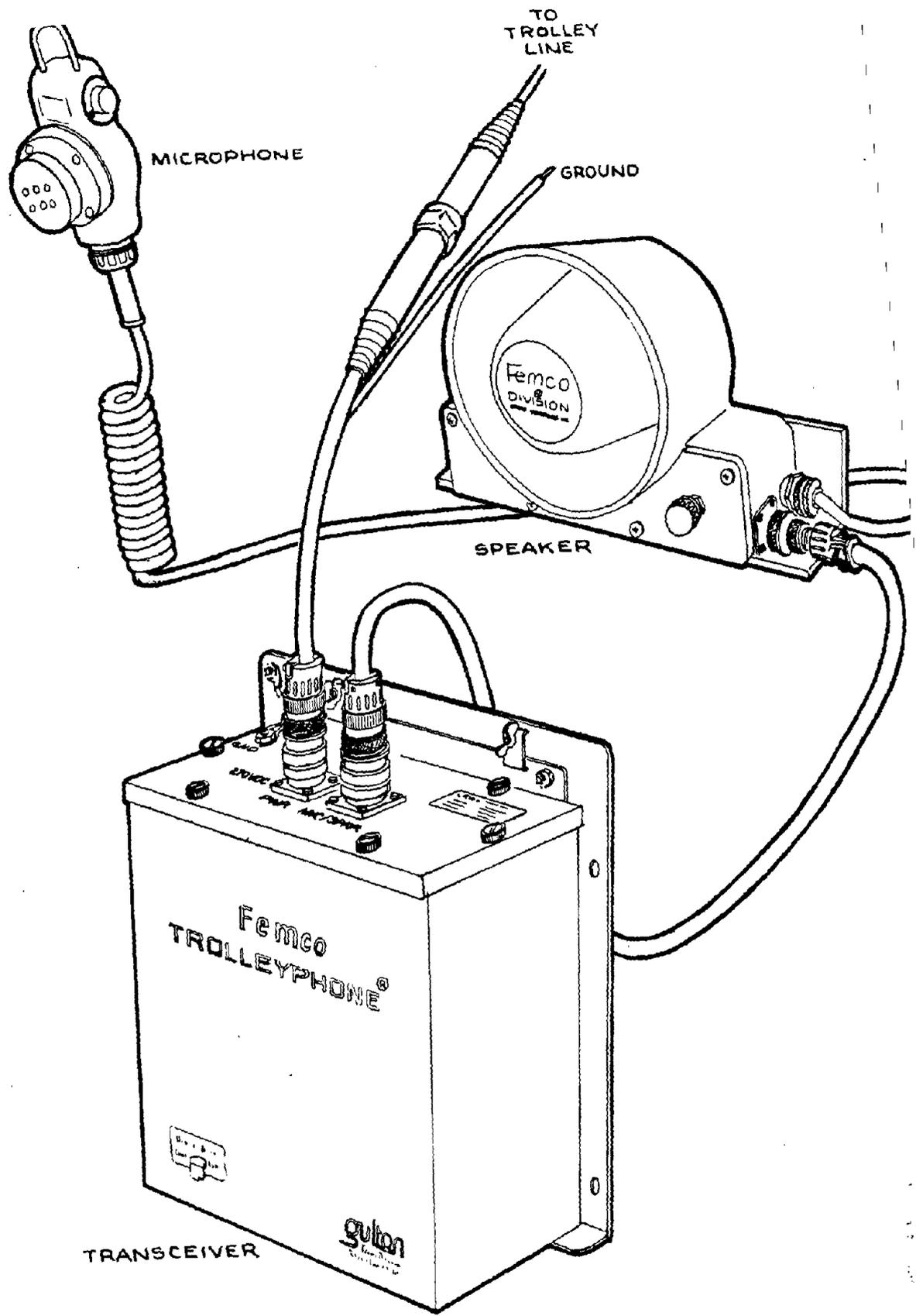
These equipments were operated in the laboratory and examined to obtain information pertinent to developing the guidelines. Pictorial representations were made of these equipments as shown in Figures 1-3.

D. IN-MINE MEASUREMENTS

In-mine measurements were made to ascertain the characteristics of an unencumbered trolley wire/rail. The results of measurements made in the Renton coal mine in a 6-foot coal seam are as follows:



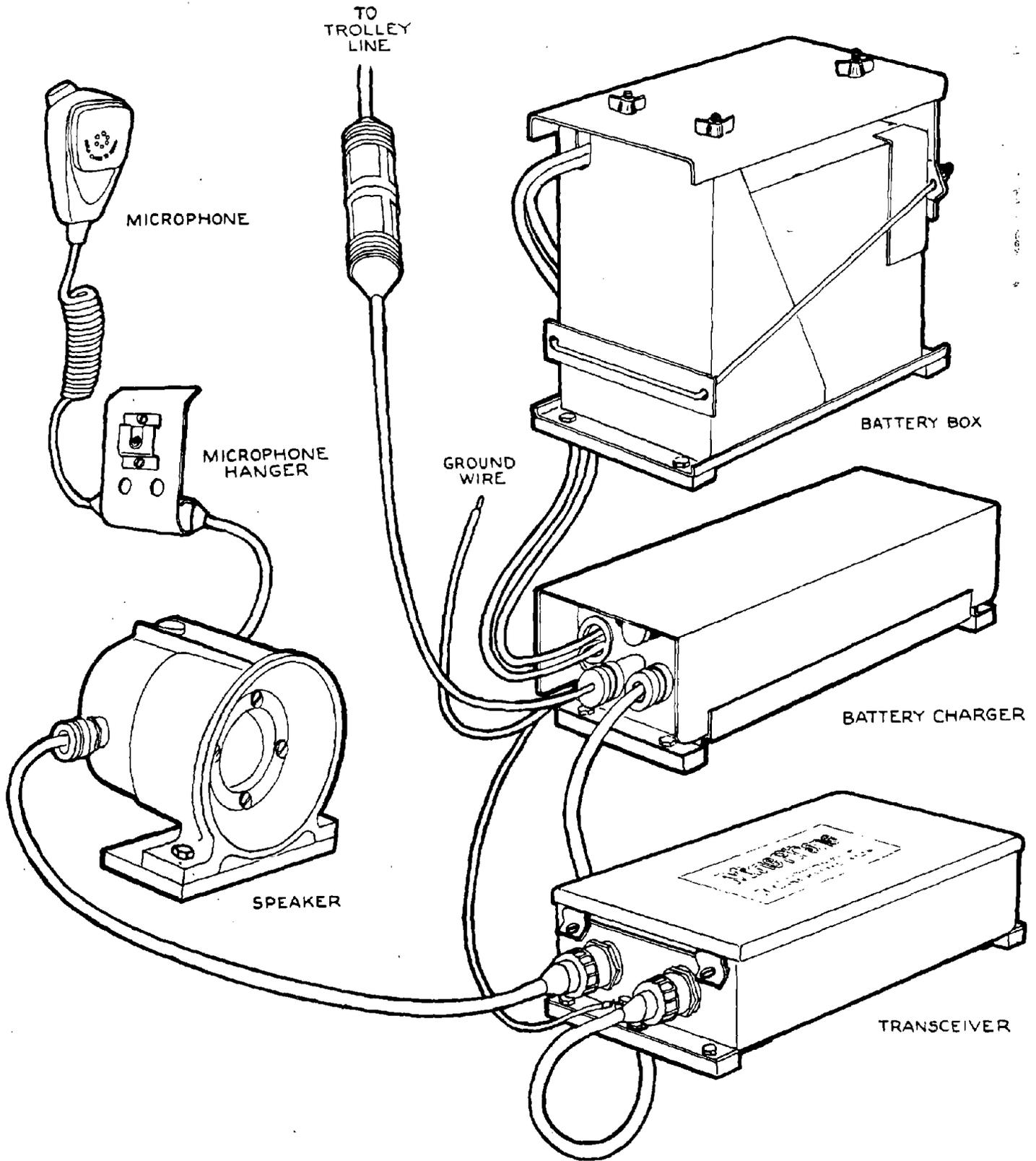
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FEMCO TROLLEY PHONE MODEL 73-1901
CARRIER PHONE

FIGURE 1

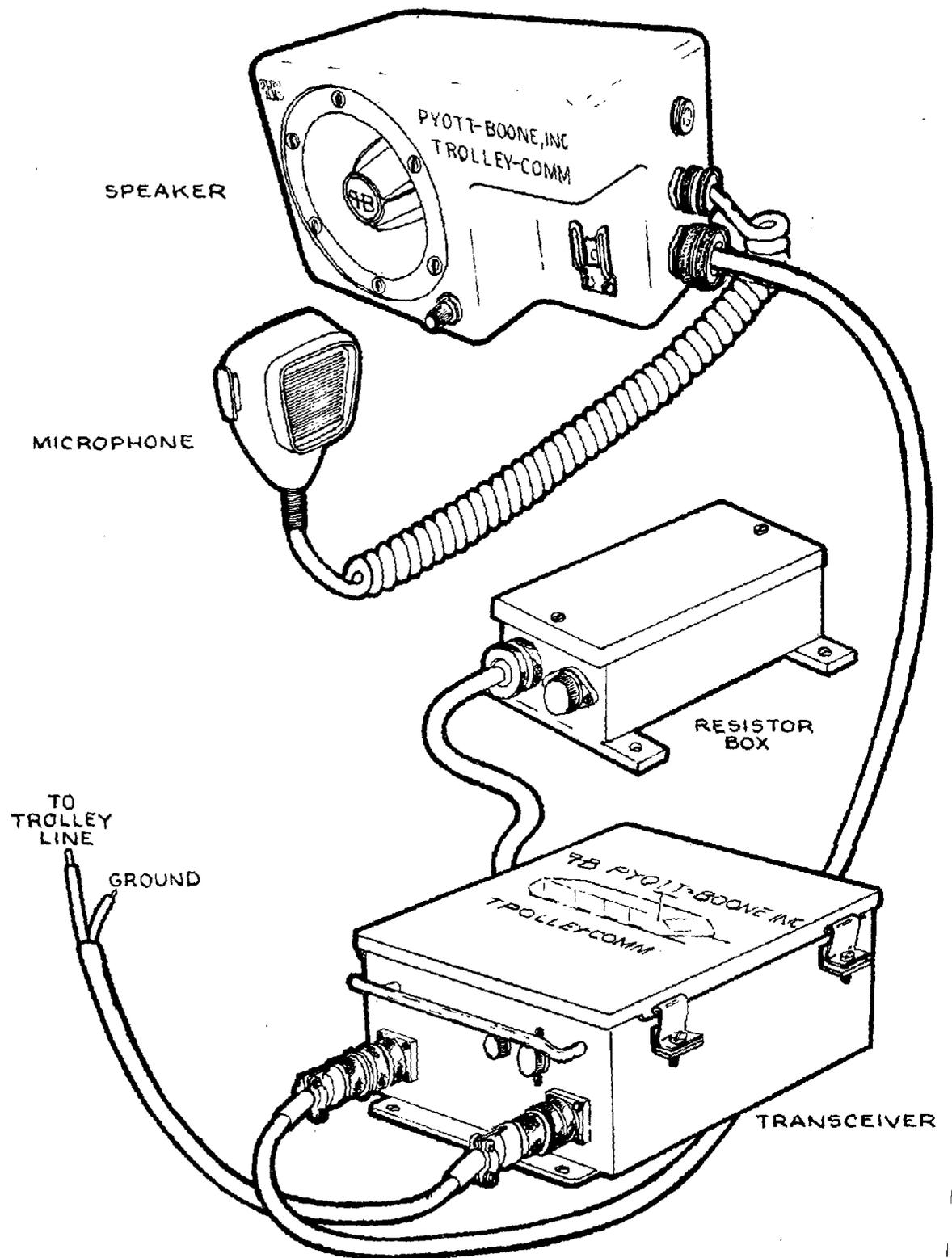
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MSA MINE PHONE MODEL 1601
CARRIER PHONE

FIGURE 2

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PYOTT-BOONE TROLLEY-COMM MODEL 219
CARRIER PHONE

FIGURE 3

- Characteristic impedance: 200 ± 30 ohms
- Attenuation rate for unencumbered trolley wire/rail: 1.6 dB/km
- Inductance per unit length: $0.35 \pm 10\%$ μ H/ft
- Capacitance per unit length: 9 ± 2 pF/ft
- Velocity of propagation: 0.64 that of the velocity of propagation in free space

The measured data were compared with estimates prepared by Dr. James Wait and Dr. David Hill* and reasonable agreement was found.

* D.A. Hill and J.R. Wait, *Analysis of Radio Frequency Transmission Along a Trolley Wire in a Mine Tunnel*, to be published in November 1976 issue of IEEE, Electromag. Compat.

J.R. Wait and D.A. Hill, *Radio Frequency Transmission via a Trolley Wire in a Tunnel with a Rail Return*, March 1977 issue of IEEE Trans. on Antennas and Propagation.



V. RESULTS

On the basis of the above procedure and by making use of frequent consultation with Bureau personnel, operating personnel and equipment manufacturers, the five following guidelines were prepared:

"Installation of Carrier Phone Equipment on Board Mine Vehicles"	19 pages	6 illustrations
"Installation of Carrier Phone Equipment at the Dispatcher's Room"	21 pages	8 illustrations
"Converting a Rail Haulage Trolley Wire and Feeder System into a Functional Carrier Frequency Transmission Line"	38 pages	19 illustrations
"Performance Check-out of a Mine Trolley Phone System"	40 pages	13 illustrations
"Portable Instrumentation to Aid in Maintenance of Trolley Carrier Phone Systems"	12 pages	7 illustrations

The outlines of these guidelines are presented in the following with the inclusion of sample pages.



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OUTLINE

INSTALLATION OF CARRIER PHONE EQUIPMENT

ON BOARD MINE VEHICLES

Introduction

Equipment Sources

Physical Location and Mounting

Microphone Speaker Location

Transceiver Location

Power Conditioning Unit Location

Battery Location

Mechanical Mounting

Electrical Connections

Microphone Cable

Speaker Cable

Power Cable

Battery Cable

Cable Protection

Fuse Requirements



INTRODUCTION

Vehicle-mounted carrier phones provide voice communication between fixed stations and other vehicles operating on the same track haulage system. The trolley wire and the track, which distribute the DC power to drive the vehicle, are also used as the transmission path for this communication system. The carrier phone typically consists of a transceiver assembly, a microphone-speaker assembly, and power conditioning units; these are sometimes an integral part of the transceivers.

There are many state and federal regulations that affect the installation of phones on vehicles. These include the *Code of Federal Regulations*, Title 30, *Mineral Resources*, Part 75. The major federal regulations that apply to carrier phones are noted below, along with a brief description of the subject matter in each of the relevant paragraphs. The paragraphs of Title 30 cited contain explicit details on these regulations. (This brief description is for reference purposes only.)

- *Power Requirements* (paragraph 75.1600-2 (c))

If the carrier phone system is the only communication system in the mine, then a means must be provided to permit continued communications in the event the mine's electric power fails or is cut off.

- *Grounding Procedures* (paragraph 75.1600-2 (d))

Carrier phones must be grounded in accordance with subpart H, paragraphs 75.701-2,4,5.

- *Examination, testing, and maintenance* (paragraph 75.512)

Under this statutory provision, frequent examination, testing, and maintenance of electrical equipment found on locomotives and personnel carriers are required to assure safe operating conditions.

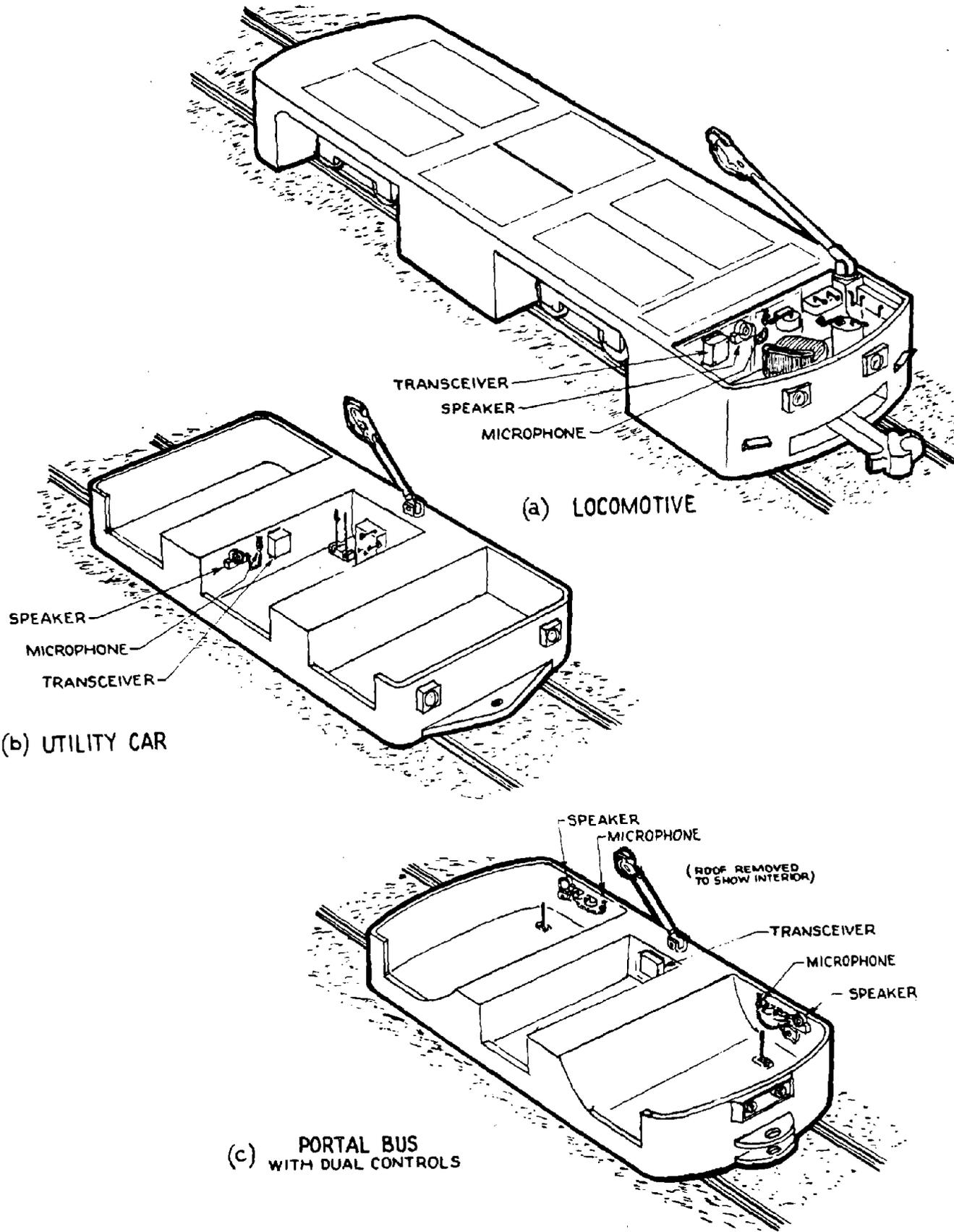


FIGURE 4

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OUTLINE
INSTALLATION OF CARRIER PHONE EQUIPMENT
AT THE DISPATCHER'S ROOM

Introduction

Equipment Sources

Dispatcher's Location

- Physical Location and Mounting
- Microphone Speaker Locations
- Transceiver Location
- Power Conditioning Unit Location
- Battery Location
- Mechanical Mounting
- Electrical Connection
- Microphone Cable
- Speaker Cable
- Power and Signal Cable
- Signal Connections
- Power Connections
- Battery Cables
- Fuse Requirements



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The trend in modern coal mining is to locate the dispatcher above ground in a separate building or a separate room in the mine office complex. This location provides a continuously manned communications center even if the mine must be evacuated due to emergencies or ventilation failures. The mining laws of West Virginia, since 1974, have required that the dispatcher be located on the surface for all new mines and for existing mines if the dispatcher is relocated, per Article 22-2-37, Part T5.

Underground dispatchers' locations vary greatly, depending on the mine layout and growth. The two most common locations are close by the bottom of the main shaft and in the physical center of the mine topology.

The dispatcher's local environment is generally the same for both surface and underground locations. He normally works in a heated room equipped with a table or desk, which provides him with a writing surface for record keeping; see Figure 4.

The carrier phone equipment is installed on a panel which is mounted on a wall adjacent to the dispatcher's desk. This panel provides one convenient location for all the subassemblies that make up a carrier phone and protects the interconnecting cables from unnecessary flexing and stretching.

The distance between the dispatcher's location and the trolley power distribution system generally determines the type of signal coupling technique used to connect the dispatcher's carrier phone to the trolley line. Once the signal coupling technique is determined, then the type of carrier phone power can be selected.

PHYSICAL LOCATION AND MOUNTING

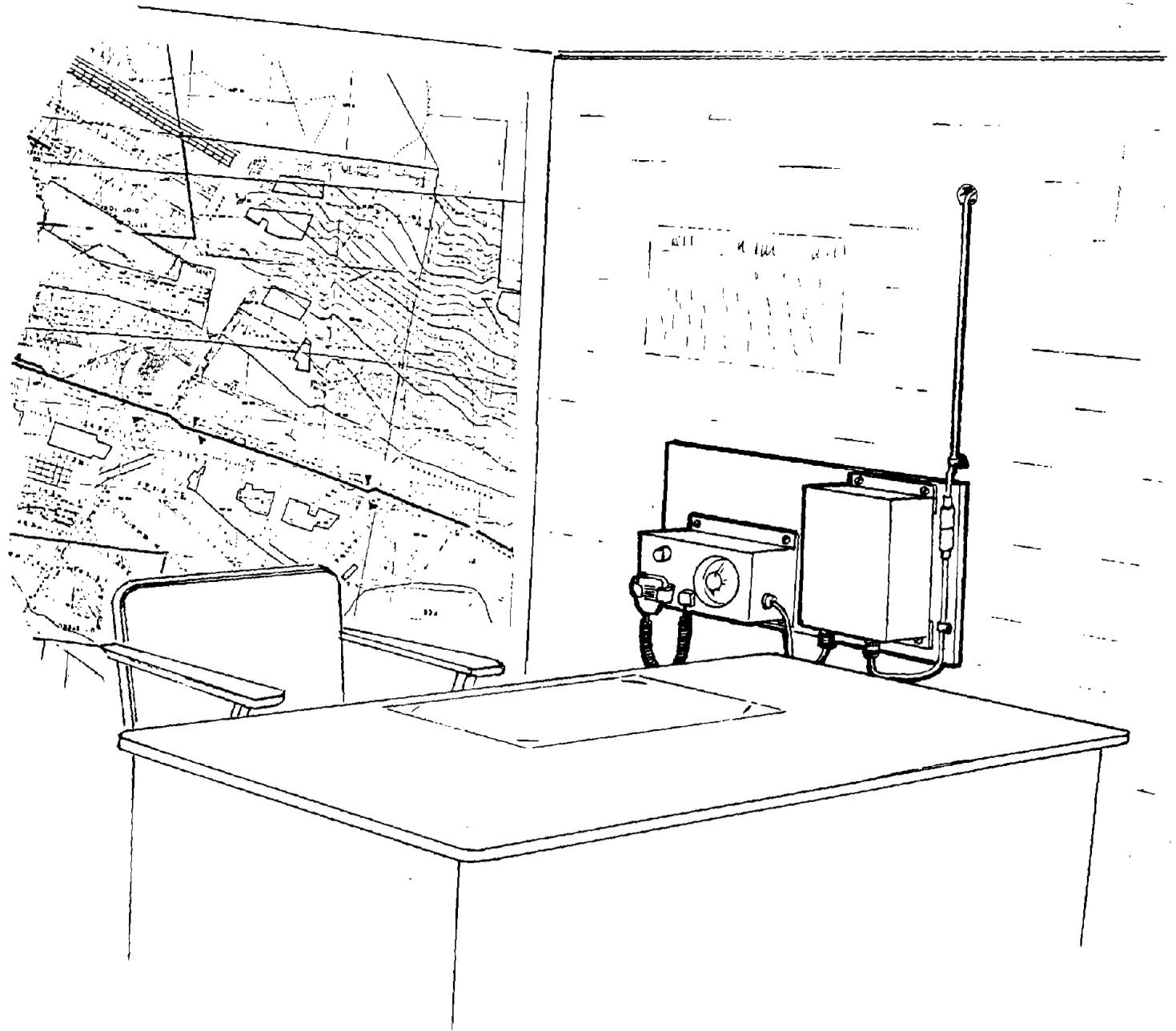
The carrier phone typically consists of a transceiver assembly, a microphone-speaker assembly, and power conditioning units; these are sometimes an integral part of the transceiver. The mounting of these subassemblies on one wall-mounted panel greatly simplifies the installation.

The panel should be made from at least 1/8-inch thick steel plate if the carrier phone uses a power-conditioning unit or resistor box that contains series dropping resistors. These units require a metallic mounting surface to help dissipate the heat generated by the resistors. Also, most carrier phones are designed with steel mounting plates that are easily welded to a steel panel. If desirable, a minimum of a 1/2-inch thick plywood panel can be used for mounting carrier phones that do not use series dropping resistors.

MICROPHONE-SPEAKER LOCATION

The microphone-speaker assembly is the only part of the carrier phone that interfaces directly with the dispatcher. Thus, it must be located so that he can reach it easily. The speaker volume control must also be within easy reach. The speaker should also be pointed directly at the dispatcher





DISPATCHER'S ROOM

FIGURE 4

OUTLINE

CONVERTING A RAIL HAULAGE TROLLEY WIRE AND FEEDER SYSTEM
INTO A FUNCTIONAL CARRIER FREQUENCY TRANSMISSION LINE

Introduction

Why the Trolley Wire/Rail Often is a Poor Transmission Line for Carrier
Signals

Introduction

The Unencumbered Trolley Wire/Rail

The Real Trolley Wire/Rail

Determining the Status of the Trolley Wire/Rail as a Transmission Line

Introduction

Equipment Descriptions

Method of Using the Tuned Voltmeters for Carrier Signal Level
Mappings

Method of Taking Data and Tabulating Results

Use of Information from the Signal Level Map

Four Methods to Improve Carrier Signal Propagation

Introduction

Removal of Bridging Loads

Isolate Loads at the Carrier Frequency

General

Rectifiers

Tuning the Feed Wires

The Use of an Added Inductor

Tuning the Trolley Wire/Rail

Heaters

Vehicle Lights



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OUTLINE (Cont.)

Other Loads

Extending Carrier Phone Coverage Using an Auxiliary Line

Use of a Special Purpose Line

Use of the Pager Phone

The Use of a Remote Transceiver



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WHY THE TROLLEY WIRE/RAIL OFTEN IS A POOR TRANSMISSION LINE FOR CARRIER SIGNALS

Introduction

The trolley carrier phones used for dispatch purposes in electric rail haulage coal mines often show problems in providing coverage over the mine haulage system. The problem is often evidenced as areas of the mine where direct communications between the dispatcher and the vehicle is difficult or impossible. Two major reasons for these difficulties are evident when one considers the factors that determine how well the trolley wire/rail acts as a transmission line for carrier signals: First, characteristics of the trolley wire itself as a two-wire transmission line and second, effects that loads placed across the trolley wire/rail have on transmission. These two factors are considered below.

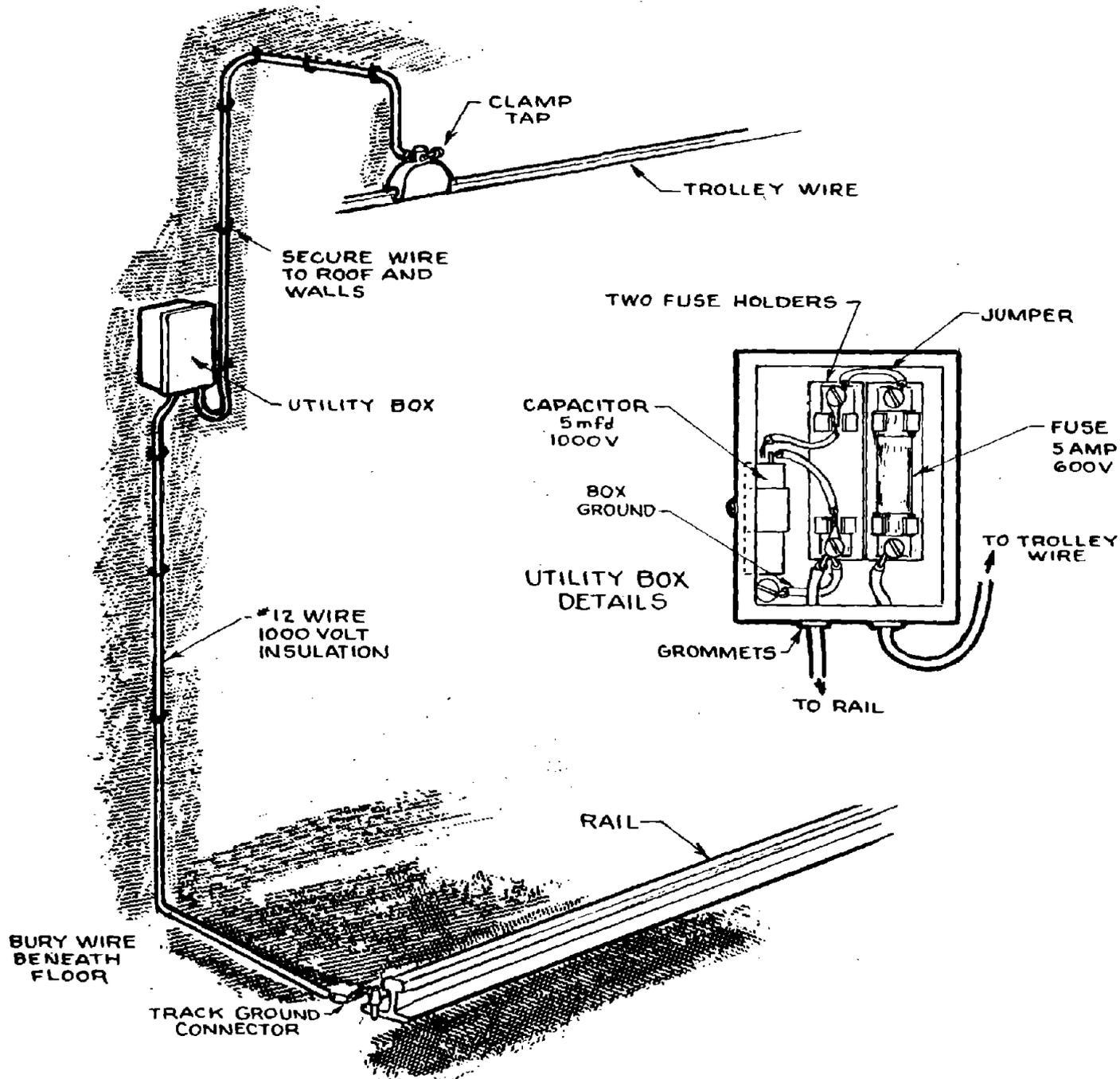
The Unencumbered Trolley Wire/Rail

Both theory and experiment show that the trolley wire/rail by itself is a relatively low loss transmission line for trolley carrier phone frequencies. In fact, the attenuation rate for such a transmission line is about two dB per mile, or a loss in signal levels of about 20% per mile. A carrier phone pair can tolerate about a 70 dB transmission loss (from 25 volts to 8 millivolts). Thus, on an unencumbered trolley wire/rail transmission line, a distance of 35 miles could be expected for communication range. Actually, such ranges are not achieved; the reasons are noted below.

The Real Trolley Wire/Rail

The real trolley wire/rail can never perform as well as the unencumbered trolley wire/rail for several reasons. The many loads across the trolley wire/rail absorb carrier signal power and reflect carrier signal power. The list of these loads is long and includes rectifiers, personnel heaters, signal lights, vehicle motors, vehicle lights, the carrier phone itself, etc. It is probable that the net signal attenuation rate for a trolley wire/rail with typical loads placed across it is of the order of 10 to 20 dB per mile, and hence a transmission loss of 70 dB yields a useful range as low as 3.5 miles. The problem of obtaining good signal propagation is further aggravated by branches of the trolley wire where the signal splits in a totally uncontrollable way. Lack of termination at the ends of the trolley wire/rail further degrades signal propagation. The moving vehicles represent moving loads on the transmission line and add a further complication to obtaining or predicting good signal propagation. Also, advancing the mine face means that the transmission network changes with time, yielding more uncertainty to the quality of transmission.

The seriousness of the bridging loads can be seen by reference to Table 1, where the insertion losses for typical loads are tabulated. Using this table, one can make an estimate of the total signal loss by adding the individual losses (in dB). This procedure will give an estimate only because it does not consider load interactions.



PERMANENT INSTALLATION OF TUNING ELEMENTS FOR FEEDER WIRE

FIGURE B

SAMPLE ILLUSTRATION

OUTLINE

PERFORMANCE CHECK-OUT OF A MINE TROLLEY
PHONE SYSTEM

Introduction

Equipment Sources

Suggested Test Equipment

Routine Maintenance

Cables

Trolley Phone Units

Microphones

Batteries

Wet Cell Maintenance

"Gel/Cell" Maintenance

Trouble-shooting on the Vehicle

Trouble-shooting and Performance Checkout in the Service Shop

RF Transmitter Power

Receiver Sensitivity

Power Consumption

Audio Distortion and Microphone Efficiency

Battery Charger Testing

Verifying that the Trolley Wire/Rail Provides a Useful Transmission Path

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TROUBLESHOOTING ON THE VEHICLE

When an operator reports a malfunctioning trolleyphone, initial diagnosis of the problem can be carried out using only the equipment suggested in Group 1. The repairman may either take his equipment to the faulty vehicle, or the faulty vehicle may be returned to the test and maintenance area.

First, the battery voltage should be checked to make sure the battery has not become discharged. Methods of measuring the battery voltage have already been described in section on routine maintenance. If the battery is found to be good, all external fuses in the unit should be checked. If a faulty fuse is found, it should be replaced with a unit of the proper rating as shown on Table 1 and attempts should be made to operate the unit. If the fuse blows again, then the unit is faulty. It is possible that replacing the blown fuse with a new one will cause the unit to operate properly since a transient overload could have caused the original fuse to blow.

If these steps fail to make the unit operational, then repair by substitution is the most expedient way of getting the vehicle into operation again. Substitution should be in the order of items considered to be more or less vulnerable. Thus, the process should be carried out in the following order:

1. Change the microphone assembly and test for normal operation.
2. Change the transceiver assembly and check for normal operation.
3. Change the loudspeaker unit and check for normal operation.
4. Where relevant, change the battery charger box and check for normal operation.

By these steps, the faulty unit can be isolated and replaced. The faulty unit may then be returned to the repair area for a more detailed examination, including an overall performance checkout after the fault has been isolated and repaired.

On 300 V systems, a test can be made of the transmitter power output onto the trolleyline. A simple method of measurement in the field makes use of the testmeter with the range selector switch set to 50 V AC scale. The black meter lead should be plugged into the common (-) terminal of the meter and the free end connected to the ground. The red lead must be plugged into the meter "output" jack and connected to the trolley wire. The trolley pole must be in contact with the wire. A reading of 15 V or more when the transmitter is keyed indicates normal operation provided the test is made at least 200 feet from the nearest power rectifier that supplies the trolley wire. This test cannot be performed on 600 V DC systems since this voltage will over-stress some components inside the multimeter. In this case, the unit should be returned to the repair shop for a standard bench test. It should be noted that the meter will respond to the ripple present on the trolley wire, thus a base reading of up to 10 volts will be shown even with the transmitter off.



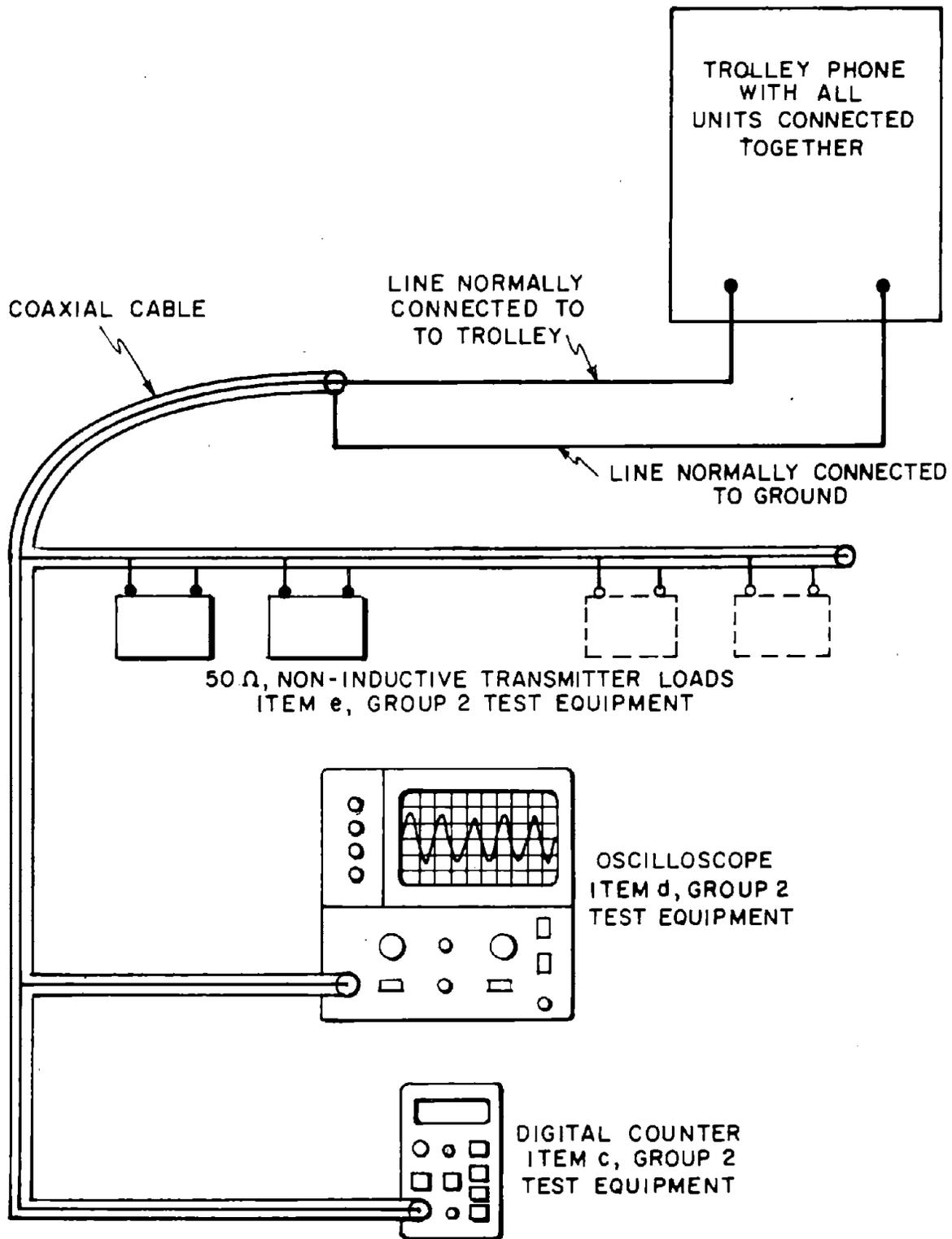


FIGURE 10. RF TRANSMITTER POWER TEST SET-UP.

OUTLINE

PORTABLE INSTRUMENTATION TO AID IN MAINTENANCE
OF TROLLEY CARRIER PHONE SYSTEMS

Introduction

Equipment Description

Method of Using the Tuned Voltmeters for the Carrier Signal Level
Mapping

Method of Taking Data and Tabulating Results

Use of Information from the Signal Level Map

Appendix



31

INTRODUCTION

The maintenance of trolley carrier phone systems requires not only the maintenance of the equipment involved, but the maintenance of the transmission line used to transmit the dispatcher's signal from his position to the vehicles in the mine. This line also serves as a path from the vehicles to the dispatcher's office. Evidence accumulated over the years indicates that this signal path is subject to many impediments to the propagation of useful signals over the long distances typically encountered in coal mines.

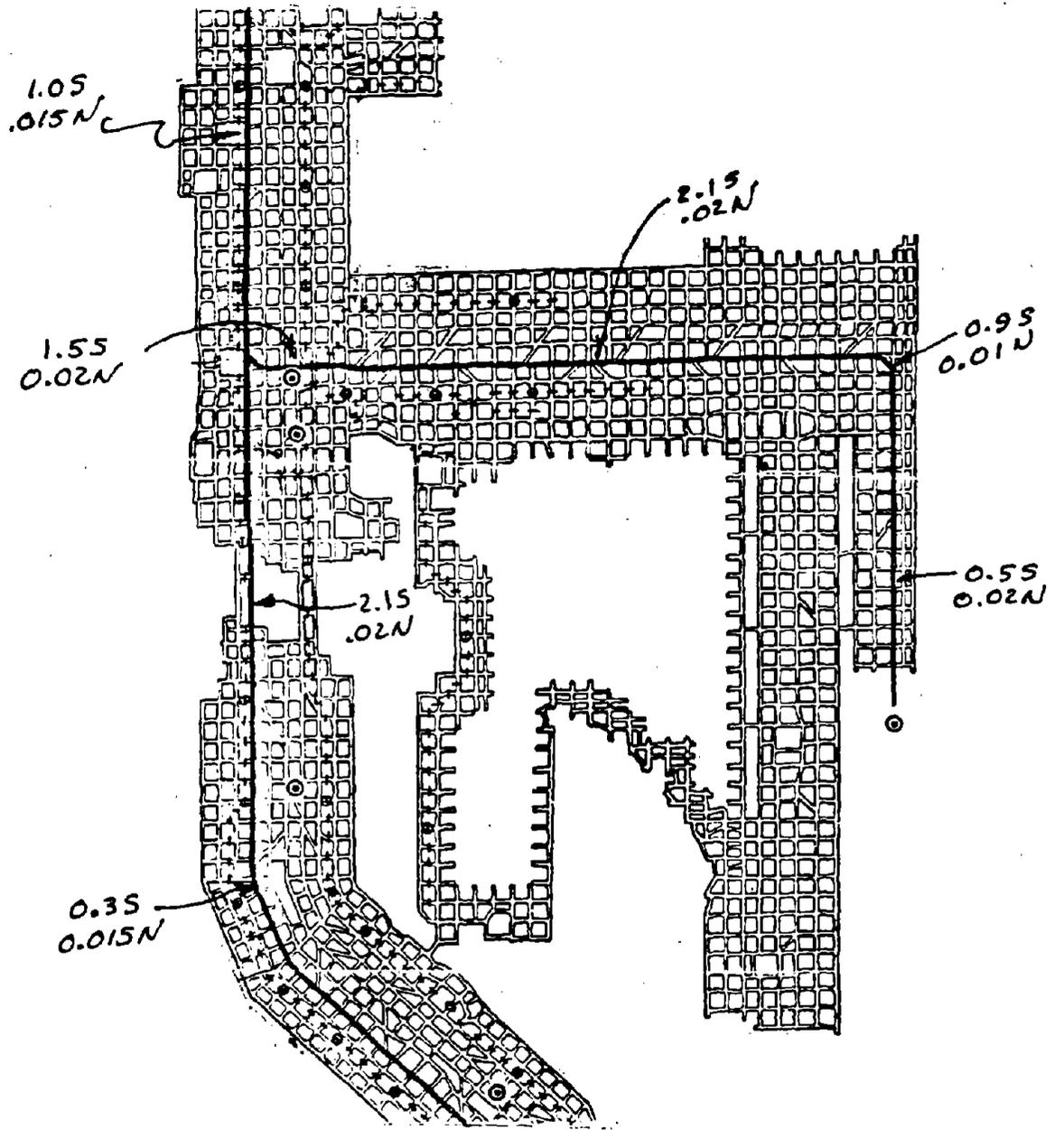
One of the most useful ways of determining the state of the overall system is to map the signal and noise strengths throughout those regions of the mine which are covered by the trolley carrier phone system. Such mapping requires a tuned signal-measuring device, typically not available in most mine maintenance shops. This guideline suggests two instruments which can be used to map the signal strength and noise levels in a rail haulage mine.

The mapping is preferably carried out by measuring the signal strength produced by the dispatcher's transmitter at various points along the rail haulage system where vehicles operate. A satisfactory way of conducting the measurements is to place a suitable tuned voltmeter aboard a mine vehicle (such as a jeep) and progressing throughout all those regions of the mine where dispatcher-to-vehicle communication is desired. At appropriate places along the rail haulage - for example, at 2000 or 3000 foot intervals - the received dispatcher's signal and the background noise are both measured. These values are noted on a mine map for future reference as the mine expands, or as carrier phone problems occur. Except under extremely unusual conditions, the signal strength map produced in this manner will also indicate the level of signal that a vehicle transmitter at the measuring position would produce at the dispatcher's place.

An example of a portion of a mine map annotated with such readings is shown in Figure 1.



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EXAMPLE OF SIGNAL LEVEL MAP

FIGURE 1

VI. CONCLUSIONS AND RECOMMENDATIONS

Five guidelines treating installation, maintenance, tests, and equipment related to improving and upgrading trolley carrier phone system performance have been prepared. These guidelines fill a need for placing information in the hands of mine personnel concerned with their trolley carrier phone systems.

There does remain one critical step in the process of making these guidelines gain acceptance. This step is the "testing" step wherein the present finished guidelines are carefully scrutinized by potential users. This step can improve, and gain acceptance for, the guidelines. Therefore, we recommend that three or four selected individuals who actually work on carrier phone systems in operating mines be asked to critique the guidelines. We feel the critique can best be handled by having these people meet with the authors of the guidelines for discussions of changes, modifications, deletions and additions. It is almost certain that this procedure will improve the guidelines and, more importantly, help gain them an acceptance in the mining community.



GUIDELINES

The five guidelines developed under this contract are included in their entirety in the following pages.

INTRODUCTION

The trolley carrier phone systems of electric rail haulage mines serve the vital dispatching function. Performance of this critical communication system is often poor or marginal. The reasons for performance deficiencies lie in the several areas of equipment, installation, maintenance, testing and the transmission medium itself. Five guidelines have been developed to help operating personnel improve and upgrade their carrier phone systems. These guidelines are presented in the following pages and treat:

- Installation of trolley carrier phone equipment on board mine vehicles
- Installation of trolley carrier phone equipment at the dispatcher's room
- Converting a rail haulage trolley wire and feeder system into a functional carrier frequency transmission line
- Performance checkout of the trolley carrier phone system to determine that the equipment is functional, that the transmission path is acceptable, and specific areas that require maintenance
- Development of practical portable instrumentation to be used by electricians and inspectors.

INSTALLATION OF CARRIER PHONE EQUIPMENT
ON BOARD MINE VEHICLES

INTRODUCTION

Vehicle-mounted carrier phones provide voice communication between fixed stations and other vehicles operating on the same track haulage system. The trolley wire and the track, which distribute the DC power to drive the vehicle, are also used as the transmission path for this communication system. The carrier phone typically consists of a transceiver assembly, a microphone-speaker assembly, and power conditioning units; these are sometimes an integral part of the transceivers.

There are many state and federal regulations that affect the installation of phones on vehicles. These include the *Code of Federal Regulations*, Title 30, *Mineral Resources*, Part 75. The major federal regulations that apply to carrier phones are noted below, along with a brief description of the subject matter in each of the relevant paragraphs. The paragraphs of Title 30 cited contain explicit details on these regulations. (This brief description is for reference purposes only.)

- *Power Requirements* (paragraph 75.1600-2 (c))

If the carrier phone system is the only communication system in the mine, then a means must be provided to permit continued communications in the event the mine's electric power fails or is cut off.

- *Grounding Procedures* (paragraph 75.1600-2 (d))

Carrier phones must be grounded in accordance with subpart H, paragraphs 75.701-2,4,5.

- *Examination, testing, and maintenance* (paragraph 75.512)

Under this statutory provision, frequent examination, testing, and maintenance of electrical equipment found on locomotives and personnel carriers are required to assure safe operating conditions.

EQUIPMENT SOURCES

There are a number of sources for carrier phone communication systems. A partial listing of manufacturers and their latest models follows. Figures 1, 2, and 3 show sketches of typical units.

- Battery-Powered Mine Trolley-phone,TM Model 73-1901
Femco Division, Gulton Industries, Inc.
Irwin, Pennsylvania 15642
Distributed by National Mine Service Co. (NMS)
- Mine Phone,TM Model 1601
Mine Safety Appliances (MSA)
Pittsburgh, Pennsylvania 15235
- Trolley-Comm,TM Model 219
Pyott-Boone, Inc.
Tazewell, Virginia 24651

This listing is intended only as a guide to current equipment and does not imply selection by the Bureau of Mines.

PHYSICAL LOCATION AND MOUNTING

Carrier phone equipment is installed on all types of tracked vehicles from the small individual personnel carrier to the largest mine locomotive. The seating position of the vehicle operator or the motorman varies considerably, depending on the design of the vehicle frame, the track gauge, the minimum height of the coal seam, and the direction in which the vehicle is traveling.

Three commonly used vehicles found on coal haulage systems are locomotives, portal buses, and utility cars. Each of these vehicles has a different seating arrangement for the driver (see Figure 4).

MICROPHONE-SPEAKER LOCATION

The microphone-speaker assembly is the only part of the carrier phone that interfaces directly with the vehicle operator. Thus, it must be located so that he can reach it easily. The speaker volume control must also be within easy reach. The speaker should also be pointed directly at the operator to provide the best reception. The microphone on most models is connected to the speaker housing with a 1-1/2-foot coiled cord that will extend to approximately 5 feet. The noise-canceling type microphone must be held close to the mouth. This restricts the location of the speaker to within a distance of 5 feet from the operator's mouth.

The location of the microphone hanger is determined by the maximum reach of the smallest operator, which is approximately 2-1/2 feet. Another consideration is the relaxed length of the coiled cord which restricts the distance between the speaker housing and the hanger to less than 1-1/2 feet. These considerations further reduce the distance between the speaker and the operator's head to not more than 4 feet. If the microphone hanger is not conveniently located, it will not be used by the operator, and the microphone and cord will suffer unnecessary damage from mistreatment.

Vehicles without dual controls require the operator to assume two different positions in front of the same controls so that he can observe the track ahead of him. This further complicates the positioning of the microphone-speaker assembly. It is sometimes helpful to use two microphone hangers for this type of installation so that the microphone is convenient no matter which way the vehicle is traveling.

Entanglement of the microphone cord with other vehicle controls, thus causing an unsafe operating condition, should also be considered when locating the microphone-speaker assembly. The microphone should also be mounted in an area that will protect it from falling debris and/or dripping water.



TRANSCEIVER LOCATION

Once a suitable place for the microphone-speaker assembly has been determined, the transceiver location can be considered. The first restriction on its location is the length of the cables running between the different assemblies. Table 1 indicates these cable lengths for three currently available models. A second consideration is the trolley power circuit connection.

TABLE 1
CABLE LENGTHS OF VARIOUS MANUFACTURERS

(feet)

<u>Cable</u>	<u>Mode</u>	<u>Manufacturer/Model</u>		
		<u>Femco 73-1901</u>	<u>MSA 1601</u>	<u>Pyott-Boone 219</u>
Microphone to speaker (coiled cord)	Retracted	1-1/2	1*	1
	Extended	6	5*	5
Speaker to transceiver		7-1/2	15	11
Transceiver to charger or resistor box		N.A.	10	6
Charger to battery		N.A.	5-1/2	N.A.
Transceiver to trolley power connection		3	5	11-1/2

*Plus 6 feet of straight cord

Temperature-sensitive electronic circuits are located inside the transceiver assembly. Therefore, it should be protected from temperature extremes such as those produced by load resistor banks and the vehicle's drive motors. For reliable operation, the ambient operating temperature range that the transceiver is exposed to should be restricted to -40 to +140°F.

It is important that installation of the transceiver does not increase the minimum roof clearance of the trolley above the critical height. Approximately six inches of clearance should be left between the vehicle and the surfaces on which the connectors and/or fuses are mounted. If possible, the connector-mounting surfaces should be protected from dirt and moisture. Sufficient clearance should be allowed to permit removal of access covers and open-hinged panels so that adjustments can be reached and plug-in modules can be changed.



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POWER CONDITIONING UNIT LOCATION

The purpose of the power conditioning unit is to convert the trolley voltage (a nominal 300 VDC or 600 VDC) to 12 VDC to power the transceiver electronics and to recharge the battery. The circuit generally used in this unit contains a large series dropping resistor that under normal operating conditions dissipates several hundred watts. The high temperature associated with this power dissipation would be harmful to the sensitive transceiver circuitry; therefore, it is a separate unit that can be located so that it will not heat up the transceiver. When only the series dropping resistor is contained in this unit, it is called a resistor box. It is also referred to as the battery charger by some manufacturers; in this case, it would contain the dropping resistors and the charging circuits.

The main consideration when locating this unit is its heat dissipation and its relationship to the heat-sensitive transceiver. The heat is dissipated into the ambient air and into the structure on which it is fastened; therefore, it is important to follow the manufacturer's mounting instructions carefully. The mounting surface should be a massive structural part of the vehicle that can absorb the heat transferred from the unit. If it is a horizontal surface, a minimum of 3 inches should be allowed on all sides and, if possible, nothing should be mounted above the unit. If it is a vertical surface, a minimum clearance of 3 inches above and below the unit should be provided for proper air circulation. The power unit should never be mounted below the transceiver and, if possible, a minimum separation of 1 foot in all other directions should be provided.

BATTERY LOCATION

A 12-volt lead acid automotive-type storage battery is most often used as an external emergency power source with trolley phones. When locating this type of battery, the prime considerations should be its weight and the accessibility of the fill caps for servicing.

The battery should be mounted upright on a structural member of the vehicle that can safely support its approximate 40 pounds. Access to the battery caps for periodic checking of the specific gravity of the electrolyte and its level is essential. Some spilling of the electrolyte is unavoidable. Therefore, the battery should be kept away from materials that are susceptible to corrosion by sulfuric acid.

Another restriction on battery location is the cable length between the battery and the charger. These cables and the battery terminals need protection to avoid a short circuit, or a short to the vehicle frame, thus causing an unsafe condition. A high-energy arc from a battery short circuit could burn the skin or cause eye damage to the vehicle operator.

The ideal ambient temperature range for the battery is 60 to 80°F. Low temperatures reduce capacity, but prolong battery life; high temperatures give some additional capacity, but reduce total battery life. Temperatures above 125°F can actually damage some of the battery components and cause early failure.



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MECHANICAL MOUNTING

Once the location of the carrier phone components has been determined, the next step is the mechanical mounting of each subassembly. Welding or bolting is the most common means of fastening the components to the body of the vehicle. The orientation of the subassembly with respect to the vehicle is not critical in most cases, except for the upright position requirement of lead acid batteries. Also, the preferred mounting for Femco's Model 73-1901 transceiver is with the connectors facing upward. This takes maximum advantage of the internal shock-mounting arrangement.

Most of the carrier phone components are supplied with mounting plates that can be tack-welded to the vehicle. This provides a permanent mounting surface with tapped holes or threaded studs onto which the subassemblies are fastened. This arrangement also provides an easy means of interchanging subassemblies for maintenance purposes.

Caution:

- *Remove the subassembly from the mounting plate during the welding operation.*
- *Keep all electrical cables and other non-metallic materials away from the welding area.*

This will prevent the carrier phone components from being damaged by the heat generated from the welding operation.

If welding equipment is not available for the installation, the components may be bolted directly to the vehicle. This requires drilling clearance holes or drilling and tapping holes into the vehicle's frame. Table 2 gives the manufacturers' recommended thread size and the number of holes required for the different subassemblies.

After the mounting plates have been welded in place, or the necessary mounting holes have been prepared, use split lockwashers under all bolt heads to fasten down the assemblies. This will prevent the vehicle's vibration from loosening the mounting hardware.



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TABLE 2

MANUFACTURERS' RECOMMENDED MOUNTING BOLTS

<u>Carrier Phone</u>	<u>Quantity</u>	<u>Size*</u>
Femco Model 73-1901		
Transceiver	4	1/4 - 20
Speaker	2	5/16 - 18
Microphone Hanger	2	8 - 32
Mine Safety Appliances (MSA) Model 1601		
Transceiver	4	5/16 - 18
Speaker	2	3/8 - 16
Battery Charger	4	3/8 - 16
Battery Box	4	3/8 - 16
Pyott-Boone Model 219		
Transceiver	4	1/4 - 20
Speaker	2	1/4 - 20
Resistance Box	4	1/4 - 20

*Diameter-Threads/inch (per American Standards Association).



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ELECTRICAL CONNECTIONS

Once the various subassemblies have been physically mounted to the vehicle and all welding is completed, the final installation task is to make up the electrical interconnections. This consists primarily of inserting cable-mounted plugs into the proper receptacles on the subassemblies and wiring the power cord into the vehicle power system.

For the installer's safety, the trolley shoe should be removed from the trolley line. This disconnects the trolley voltage (300 to 600 VDC) from the vehicle's electrical equipment. The carrier phone battery power (12 VDC) is still present and care should be taken to avoid contact with it. The majority of these phones has a panel-mounted 12-V power fuse that can be easily removed to protect the installer and the equipment from short circuits.

A block diagram of a typical carrier phone interconnecting cable system is shown in Figure 5. The cable connected to the trolley power should be installed last. The other cables may be installed in any order that is convenient.

Caution:

- *Clean and inspect both connector interfaces before mating.*
- *Study the keying arrangement or polarization to prevent jamming and misalignment.*

MICROPHONE CABLE

Depending on the manufacturer, the cable between the microphone and the speaker is either permanently connected, has an in-line connector, or has a receptacle mounted on the speaker housing into which the microphone plug is inserted.

The in-line watertight microphone connector (Figure 6a) is polarized by the use of different sized pins. Pin number one is larger than pins two and three. The three pins are equally spaced in a circle, making it difficult to match up the correct pin and socket to ensure proper mating. Therefore, care should be taken to see that the keying is properly oriented before engaging the contacts.

The plug and receptacle-type microphone connector (Figure 6b) has die-cast aluminum shells that contain the keying arrangement. The receptacle shell has an internal polarizing key that mates with a keyway on the front shell of the plug. As the connectors are brought together, the polarizing keys engage first, thus ensuring proper alignment of the contacts. The plug and receptacle are then drawn up tight by the threaded coupling ring on



the plug. Always inspect and clean the contact faces before mating to ensure reliable operation. If coal particles are left on these faces, they will be crushed into the connector and create low resistance paths between the contacts. The fine threads of the coupling ring supply the mechanical advantage to produce this force without the installer feeling any resistance to his tightening up of the connector.

SPEAKER CABLE

The speaker cable terminates at the transceiver box with a plug and receptacle-type connector similar to the microphone connector discussed above and shown in Figure 6b. On some models, the power cable uses the same connector shell size and keying as the speaker connector and also plugs into the transceiver. The receptacles on the transceiver are clearly marked; the power connector insert uses pins; and the speaker connector insert uses sockets; but none of this prevents mismatching. The speaker plug can be mated with the power receptacle and drawn up tight without undue force. This causes undue stress on the plastic inserts which can lead to connector failure. Therefore, it is very important that the connector legends be read before making up the speaker connector. Fortunately, the power plug will not mate with the speaker receptacle.

POWER CABLE

Caution:

- *Before installing the power cable, the trolley shoe should be removed from the trolley line.*

The trolley feeder voltage (300 to 600 VDC) and its polarity determine the model of carrier phone that should be used for a particular installation. The polarity of the trolley power is determined during the initial design phase of the mine to minimize the destructive effect of electrolysis on adjacent metal structures, such as water lines, reinforced concrete, and existing track rails in neighboring mines. Each manufacturer has his own techniques to compensate for these voltage and polarity variations. Often a resistor box is added or the resistor values are changed, depending on the feeder voltage. To compensate for feeder polarity, rectifier bridges are included in the design, or internal changes to the wiring are required as part of the installation procedure.

The manufacturer's detailed installation instructions should be carefully followed for the particular trolley voltage and polarity of concern. For purposes of this guideline, we will use the nominal 300-VDC system with a positive trolley feeder to illustrate the termination of the power connections. Even with this restriction, there are two types of carrier phone construction to be considered. One has the power-conditioning circuits built into the transceiver; the other has external power-conditioning modules. In the first case, the power cable plugs into the transceiver, and in the second case the power is wired directly into the battery charger. Generally, the power cable is supplied with the carrier phone and consists

of a two-conductor cable with a neoprene jacket. The black conductor is always used for the trolley wire or hot side of the line, irrespective of the polarity of the power system. An in-line fuse holder is generally already connected to this black wire. The white conductor is used for the rail side or ground side of the line. Also, ground studs or terminals are supplied with all cases or chassis to ensure that these metallic enclosures can be properly grounded.

Always make up the ground connection first. This is the white wire in the power cable. Terminate the white ground wire to a permanent connection in the frame of the vehicle. Refer to the Code of Federal Regulations, Title 30, Part 75, Subpart H, for explicit grounding requirements. Remove all paint, rust, or grease that might interfere with a solid low resistance connection. At this time connect all chassis and case grounds, from the lugs or studs provided by the manufacturer, to the vehicle frame ground. Do not rely on the mechanical mounting of the case for a ground connection; always run a separate ground wire to the vehicle's frame.

Next, the black wire in the power cable should be connected to the trolley power circuit ahead of any trolley controls. Generally, this connection is made at the terminal in the speed controller where the wire from the trolley pole terminates.

Power cables with in-line fuses should have a length of black insulated wire from the trolley terminal added to the line side of the fuse connection. A minimum insulation rating of 600 VDC and a minimum wire size of #14 AWG should be used. Before making up the fuse connection, the rubber insulating boot should be slipped over the wire, and approximately 3/4 inch of insulation should be stripped from the end of the wire and crimped to the line side of the fuse holder. The boot should then be slid back over the fuse holder and tightened.

On carrier phones with external power-conditioning units, the power cable exits from the battery charger as a single insulated conductor with an in-line fuse for the trolley power and a case-mounted wire lug for the ground connection. The same installation procedure should be followed as outlined above for the in-line fuse termination. From the chassis-mounted ground lug, at least a #14 AWG white insulated wire should be run to the permanent ground connection on the vehicle's frame.

BATTERY CABLES

The 12-V power fuse and the trolley power fuse should be removed to permit making up the battery connections without a load immediately being placed across the battery.

The lug end of the cables should first be run through the grommet hole in the battery charger and then terminated, according to the manufacturer's instructions. This depends on the polarity of the particular trolley system.



The grounded side of the battery should be connected first. If the system has positive polarity, then the negative side of the battery should be grounded. The negative post is the smaller one, being 0.650 inch in diameter. The larger end of the tapered hole in the negative battery clamp goes on first. The post and clamp are made of lead, as are the internal connections between the post and the battery plates. If too great a torque is applied to the clamping bolt, the internal connections can develop hairline fractures that can cause an intermittent connection. To avoid this, a second wrench should be used to steady the bolt head while tightening the nut.

The larger clamp, 0.750 inch in diameter, should be attached to the positive post, following the same directions as used for the negative termination.



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CABLE PROTECTION

Proper cable protection will reduce the downtime of the communication system, and prevent accidents, such as loose cables tripping up mine personnel when entering or leaving the vehicle. The interconnecting cables should be located, if possible, away from areas occupied by mine personnel or supplies. This will prevent cutting and crushing of the cables caused by shifting loads.

Most of the carrier phone interconnecting cables are manufactured from Type SO multiconductor cord. This is a neoprene jacketed cord designed for hard service use such as in the mining industry. The insulation is rated for continuous operation at 165°F (75°C). It is highly resistant to damage from flexing, abrasion, acids, alkalies and many other chemicals, and should have a long service life if properly installed.

Heavy-duty plastic ties or cable clamps should be used to lash the cord to the frame of the vehicle. If possible the cable should be run under overhanging parts of the frame to protect it from falling debris and/or dripping water. Enough slack should be left to form a drip loop at cable entries to prevent condensate from running down the cord and into the rear of the connector. All holes in the frame through which the cable runs should be grommets. The cables should not be run over sharp edges that might abrade it. Excess cable should be neatly coiled and secured with plastic electrical tape or cable ties and then clamped to the frame. The cable should never be stretched between clamps; this will leave it in tension, causing an elongation of the insulation and the conductor. In addition, the jacket will lose a considerable part of its resistance to mechanical damage, making it vulnerable to cutting, tearing, and abrasion. Tension on the conductor subjects the individual wires in the strand to compression and shear. The small wires will break more easily during bending or flexing under this condition.

FUSE REQUIREMENTS

Fuses provide an intentionally weakened part of an electric circuit, and thereby act as a safety valve in the event of dangerous overloads. This protects both personnel and equipment from potential fire hazards due to overheating of the carrier phone.

Fuses come in many sizes, types, and electrical ratings. Always use a replacement fuse that has the same characteristics as the one specified by the carrier phone manufacturer.

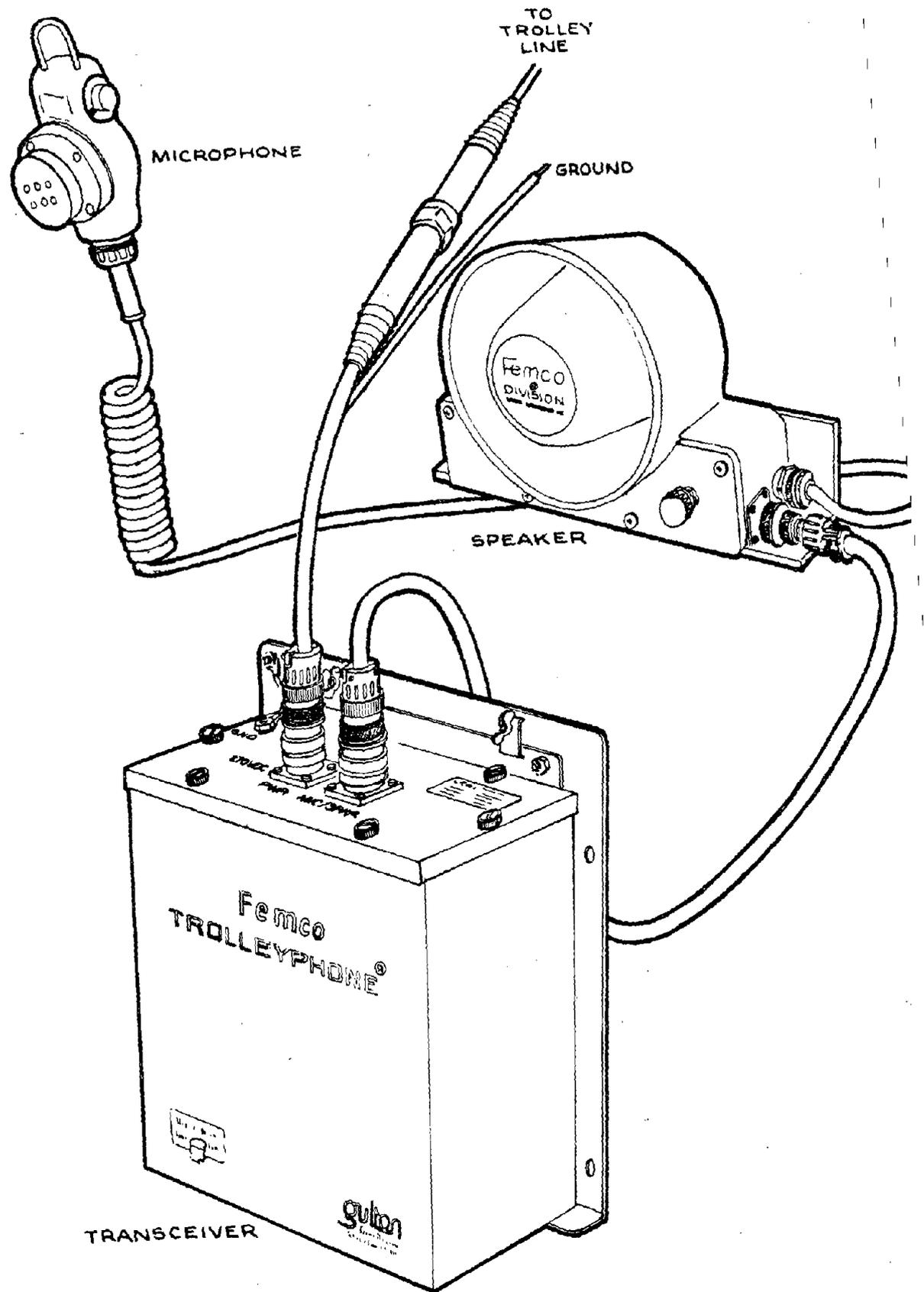
Table 3 lists the trolley line fuse and the battery fuse currently used by carrier phone manufacturers. The ratings specify the fuse manufacturer's interrupt current and maximum operating voltage. The type designation refers to Bussman Manufacturing's fuse classification. Other fuse manufacturers make equivalent products that can be used in these carrier phone fuse holders. Check the current and voltage ratings, type, and size to be sure that you have the proper replacement fuse.

TABLE 3

REPLACEMENT FUSE REQUIREMENTS

<u>Manufacturer, Model Trolley Voltage</u>	<u>Trolley Line Fuse</u>		<u>Battery Fuse</u>	
	<u>Rating</u>	<u>Type*</u>	<u>Rating</u>	<u>Type*</u>
Femco, Model 73-1901				
270 VDC	3 A, 250 V	BAF	5 A, 125 V	MDX
600 VDC	2 A, 600 V	KTK	5 A, 125 V	MDX
MSA, Model 1601				
250/300 VDC	3 A, 600 V	BCF	6 A, 250 V	BAN
550/600 VDC	3 A, 600 V	BCF	6 A, 250 V	BAN
Pyott-Boone				
300 VDC	3 A, 600 V	BBS	5 A, 250 V	AGC

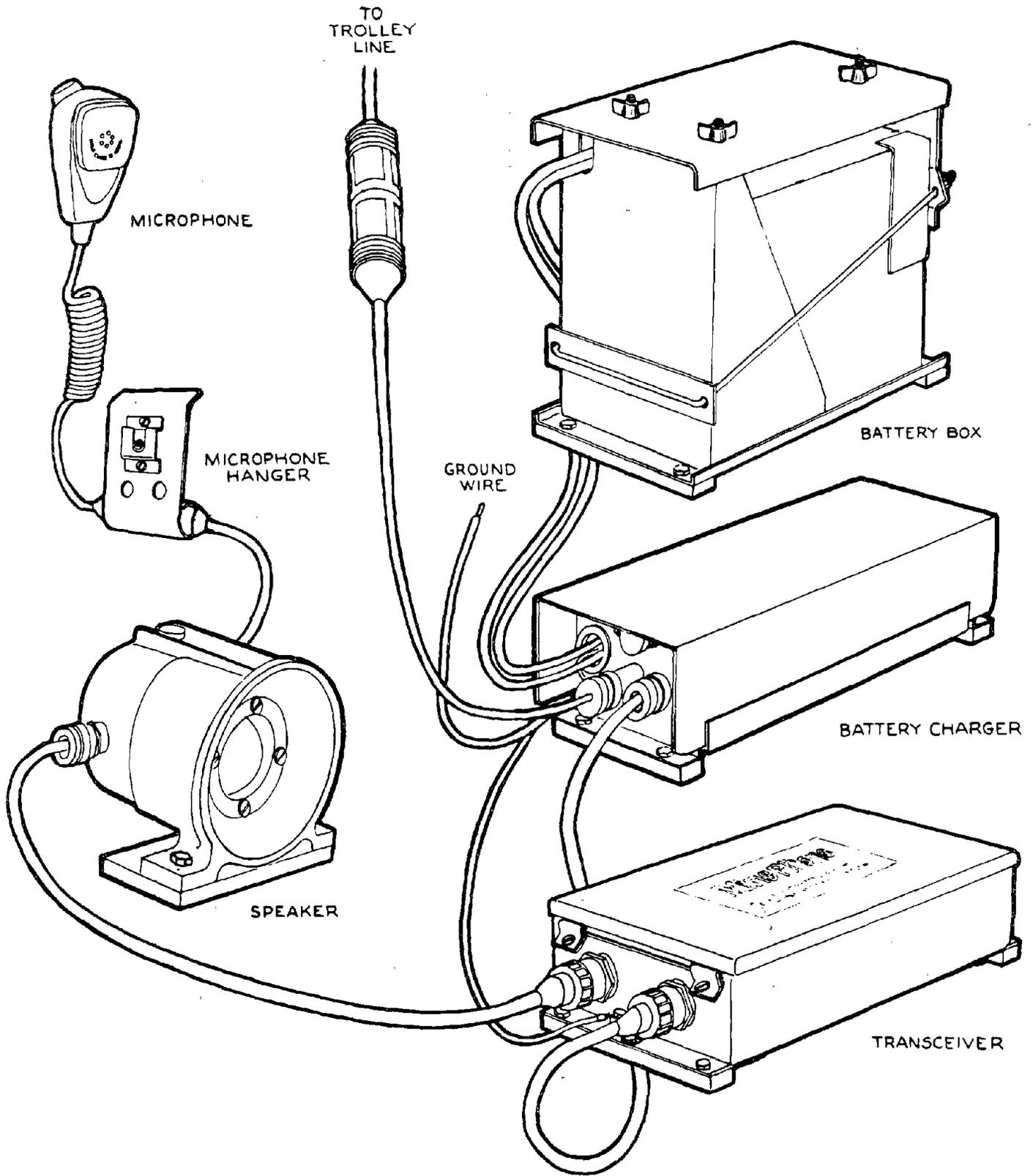
*The type number refers to Bussman Manufacturing's symbol for fuse classifications.



FEMCO TROLLEY PHONE MODEL 73-1901
CARRIER PHONE

FIGURE 1

50

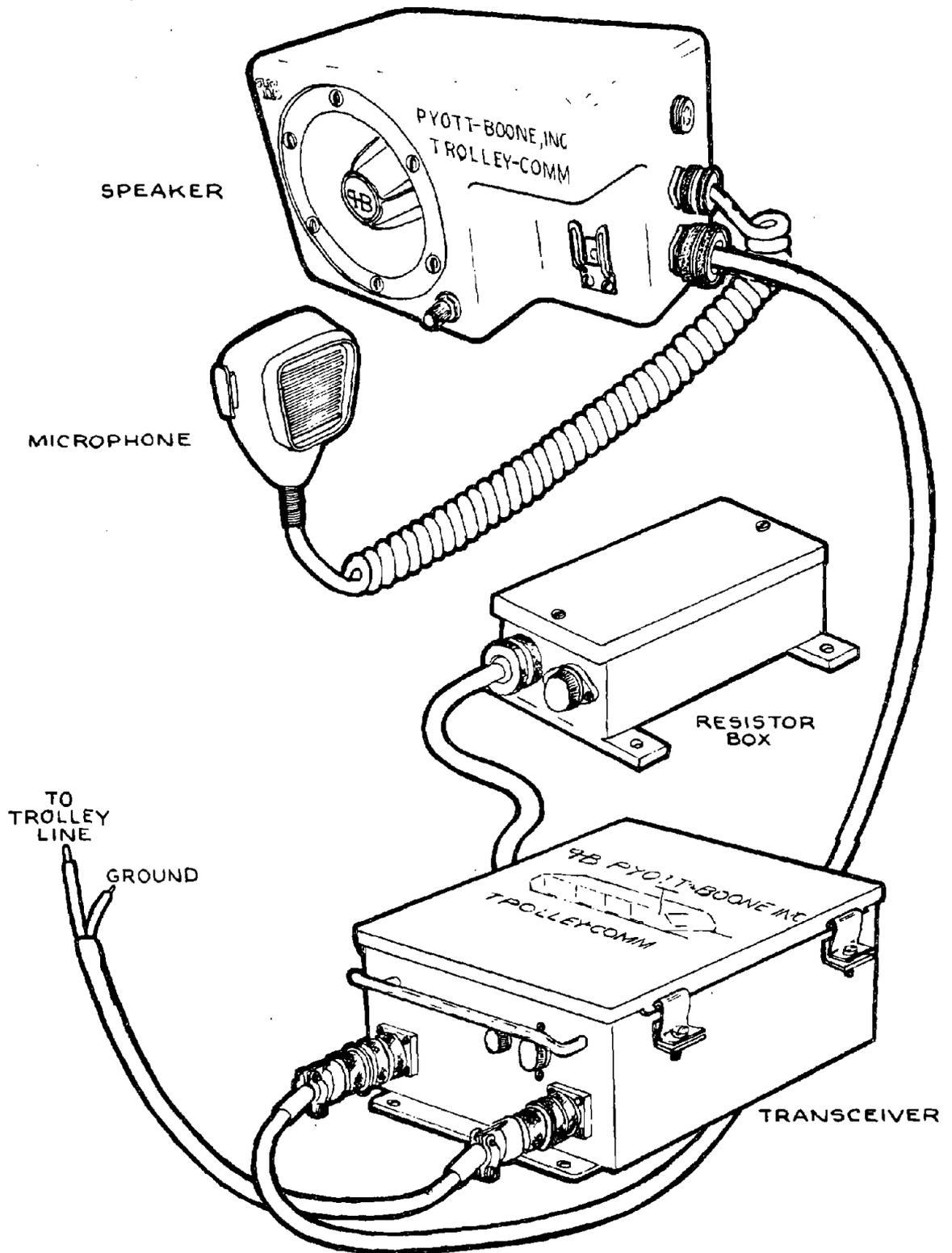


MSA MINE PHONE MODEL 1601
CARRIER PHONE

FIGURE 2



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PYOTT-BOONE TROLLEY-COMM MODEL 219
CARRIER PHONE

FIGURE 3

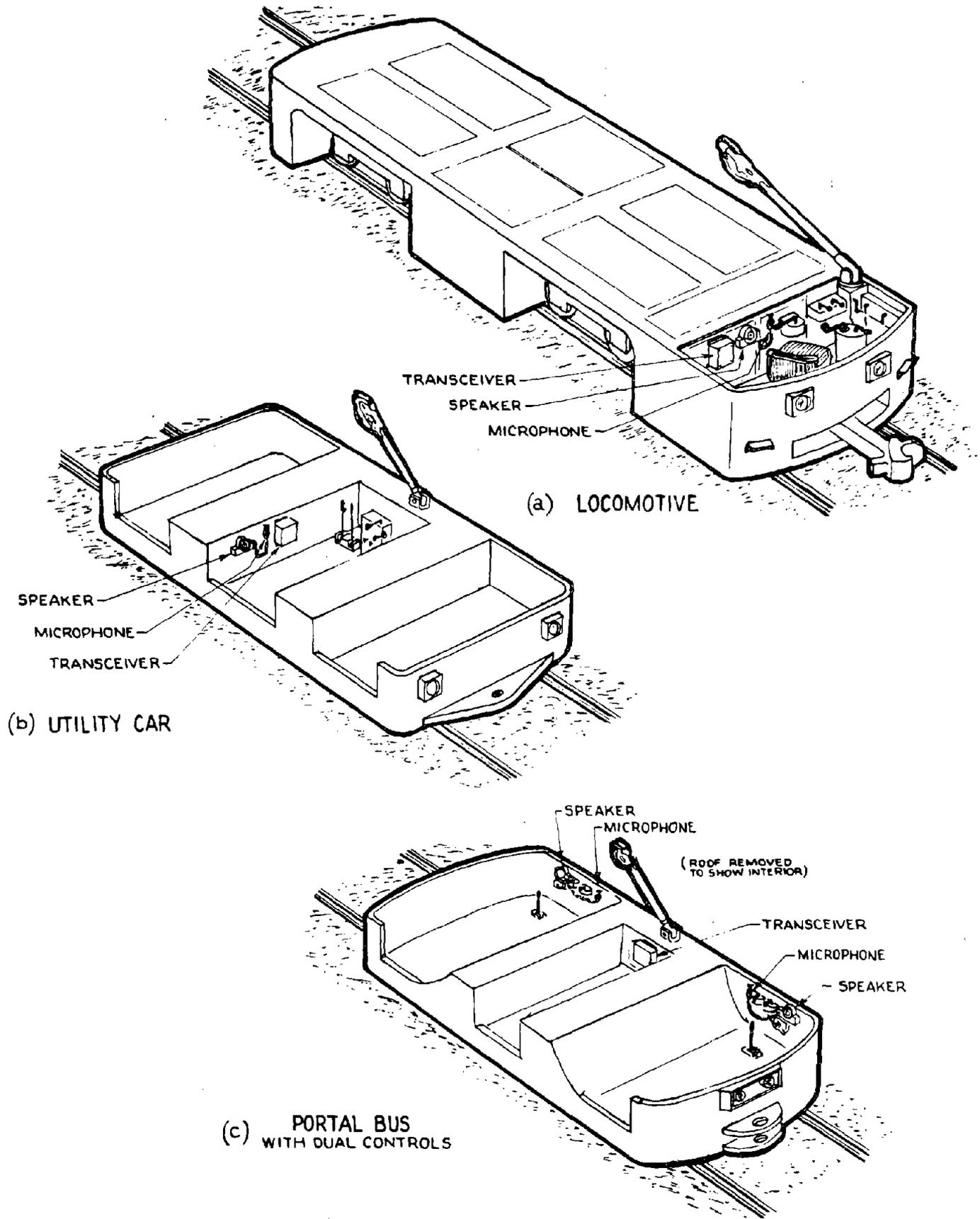
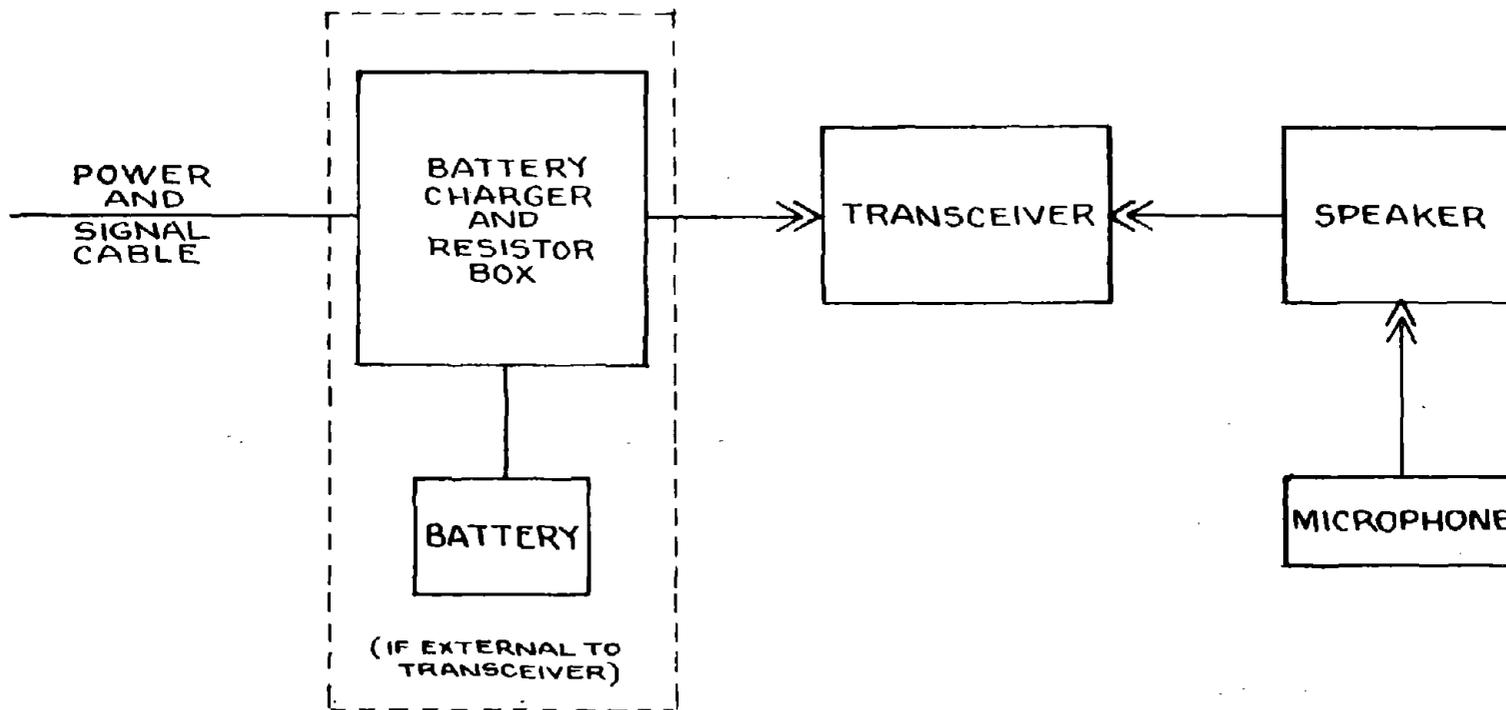


FIGURE 4



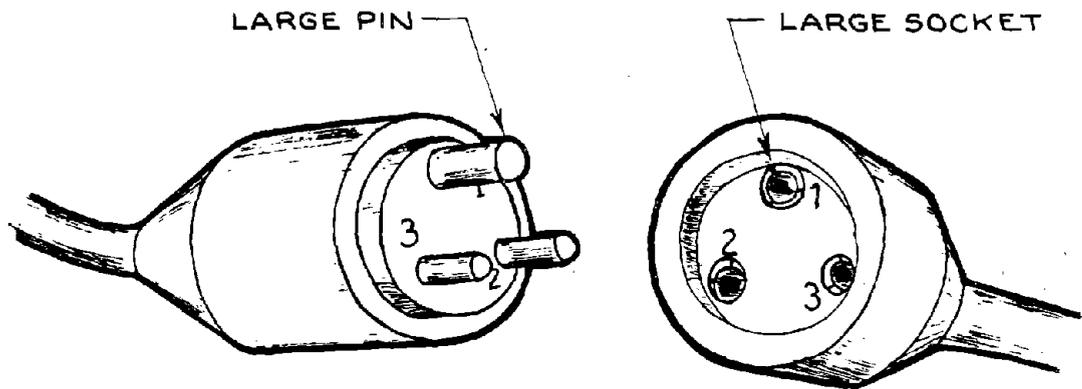


TYPICAL CARRIER PHONE INTERCONNECTING CABLE SYSTEM

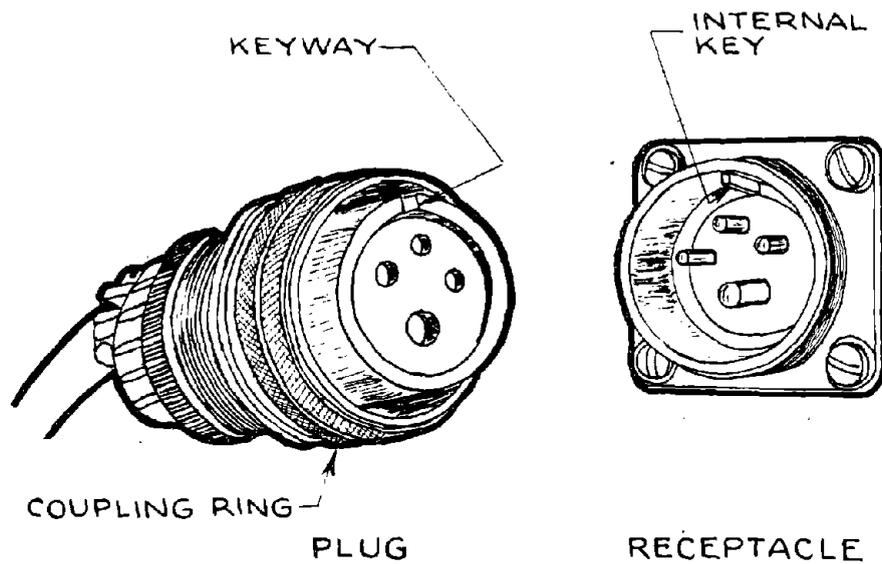
FIGURE 5

Arthur D Little Inc

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(a.) IN-LINE CONNECTOR



(b) CONNECTOR PAIR WITH ALUMINUM SHELLS

TYPICAL CARRIER PHONE CONNECTORS

FIGURE 6

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INSTALLATION OF CARRIER PHONE EQUIPMENT

AT THE DISPATCHER'S ROOM

INTRODUCTION

The primary function of the carrier phone system is to provide a reliable communication network over which the dispatcher can direct all tracked vehicle traffic in the coal mine. The safety and productivity of the mine depends, to a large measure, on the ability of the dispatcher to maintain direct contact with all motormen via the carrier phone system. For this reason the dispatcher's carrier phone installation should be carefully thought out and the workmanship should be of the highest caliber.

There are many state and federal regulations that affect the installation of carrier phones. These include the *Code of Federal Regulations*, Title 30, *Mineral Resources*, Part 75. The major federal regulations that apply to carrier phones are noted below, along with a brief description of the subject matter in each of the relevant paragraphs. The paragraphs of Title 30 cited contain explicit details on these regulations. (This brief description is for reference purposes only).

- *Power requirements* (paragraph 75.1600-2 (c))

If the carrier phone system is the only communication system in the mine, then a means must be provided to permit continued communications in the event the mine's electric power fails or is cut off.

- *Grounding procedures* (paragraph 75.1600-2(d))

Carrier phones must be grounded in accordance with subpart H, paragraph 75.701.

- *Examination, testing, and maintenance* (paragraph 75.512)

Under this statutory provision, frequent examination, testing, and maintenance of electrical equipment are required to assure safe operating conditions.

- *Communication wires and cables; installation; insulation; support.* (paragraph 75.516-2)

This provision deals with the use of insulated J-hooks, the dielectric strength of insulated wires, and the installation of communication wires in track entries.

EQUIPMENT SOURCES

There are a number of sources for carrier phone communication systems. A partial listing of manufacturers and their latest models follows. Figures 1, 2, and 3 show sketches of typical units.

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Pittsburgh, Pennsylvania 15235
- Trolley-Comm, TM Model 219
Pyott-Boone, Inc.
Tazewell, Virginia 24651

This listing is intended only as a guide to current equipment and does not imply selection by the Bureau of Mines.



DISPATCHER'S LOCATION

The trend in modern coal mining is to locate the dispatcher above ground in a separate building or a separate room in the mine office complex. This location provides a continuously manned communications center even if the mine must be evacuated due to emergencies or ventilation failures. The mining laws of West Virginia, since 1974, have required that the dispatcher be located on the surface for all new mines and for existing mines if the dispatcher is relocated, per Article 22-2-37, Part T5.

Underground dispatcher's locations vary greatly, depending on the mine layout and growth. The two most common locations are close by the bottom of the main shaft and in the physical center of the mine topology.

The dispatcher's local environment is generally the same for both surface and underground locations. He normally works in a heated room equipped with a table or desk, which provides him with a writing surface for record keeping; see Figure 4.

The carrier phone equipment is installed on a panel which is mounted on a wall adjacent to the dispatcher's desk. This panel provides one convenient location for all the subassemblies that make up a carrier phone and protects the interconnecting cables from unnecessary flexing and stretching.

The distance between the dispatcher's location and the trolley power distribution system generally determines the type of signal coupling technique used to connect the dispatcher's carrier phone to the trolley line. Once the signal coupling technique is determined, then the type of carrier phone power can be selected.

PHYSICAL LOCATION AND MOUNTING

The carrier phone typically consists of a transceiver assembly, a microphone-speaker assembly, and power conditioning units; these are sometimes an integral part of the transceiver. The mounting of these subassemblies on one wall-mounted panel greatly simplifies the installation.

The panel should be made from at least 1/8-inch thick steel plate if the carrier phone uses a power-conditioning unit or resistor box that contains series dropping resistors. These units require a metallic mounting surface to help dissipate the heat generated by the resistors. Also, most carrier phones are designed with steel mounting plates that are easily welded to a steel panel. If desirable, a minimum of a 1/2-inch thick plywood panel can be used for mounting carrier phones that do not use series dropping resistors.

MICROPHONE-SPEAKER LOCATION

The microphone-speaker assembly is the only part of the carrier phone that interfaces directly with the dispatcher. Thus, it must be located so that he can reach it easily. The speaker volume control must also be within easy reach. The speaker should also be pointed directly at the dispatcher



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to provide the best reception. The microphone on most models is connected to the speaker housing with a 1-1/2-foot coiled cord that will extend to approximately 5 feet. The noise-canceling type microphone must be held close to the mouth. This restricts the location of the speaker to within a distance of 5 feet from his mouth.

The microphone hanger should be mounted to the front of the speaker enclosure or directly below it. The microphone-speaker assembly should be located on the lower part of the panel such that from a seated position the dispatcher can reach the microphone and the speaker volume control. This places the assembly approximately three feet above the floor and within two feet of the dispatcher's seat.

TRANSCEIVER LOCATION

Locate the transceiver on the panel at either side of the speaker assembly, taking into consideration the location of the interconnecting cables. Leave room for the excess cable to be coiled up and secured to the panel.

Temperature-sensitive electronic circuits are located inside the transceiver assembly. Therefore, it should be protected from temperature extremes such as those produced by load resistor banks and room heaters. For reliable operation, the ambient operating temperature range that the transceiver is exposed to should be restricted to -40 to +140°F.

Approximately six inches of clearance should be left around all surfaces on which the connectors and/or fuses are mounted. If possible, the connector-mounting surfaces should be protected from dirt and moisture. Sufficient clearance should be allowed to remove access covers and opening panels so that adjustments can be reached and plug-in modules can be changed.

POWER CONDITIONING UNIT LOCATION

The purpose of the power-conditioning unit is to convert the trolley voltage (a nominal 300 VDC or 600 VDC) or the building AC power to 12 VDC to power the transceiver electronics and to recharge the battery. The circuit generally used in this unit contains a large series dropping resistor that under normal operating conditions dissipates several hundred watts. The high temperature associated with this power dissipation would be harmful to the sensitive transceiver circuitry; therefore, it is a separate unit that can be located so that it will not heat up the transceiver. When only the series dropping resistor is contained in this unit, it is called a resistor box. It is also referred to as the battery charger by some manufacturers; in this case, it would contain the dropping resistors and the charging circuits.

The main consideration when locating this unit is its heat dissipation and its relationship to the heat-sensitive transceiver. The heat is dissipated into the ambient air and into the structure on which it is fastened; therefore, it is important to follow the manufacturer's mounting instructions carefully.

The power unit should never be mounted below the transceiver or the speaker enclosure. Keep the power unit a minimum of six inches away from either side or the top of the transceiver. To ensure proper air circulation around the power unit, a minimum clearance of three inches should be maintained above and below the unit.

If mine personnel can come in contact with the hot surfaces of the power-conditioning unit, due to its panel-mounted location, then a protective grille should be added. This grille should be open at the top and bottom to allow for proper air circulation. If possible, mount the power-conditioning unit at the top of the panel, so that it is more than 6 feet above the floor. This would prevent mine personnel from coming in contact with the hot surfaces, thus eliminating the need for a protective grille.

BATTERY LOCATION

A 12-volt lead acid automotive type storage battery is most often used as an external emergency power source with trolley phones. When locating this type of battery, the prime considerations should be the accessibility of the fill caps for servicing and proper room ventilation to handle the outgassing of hydrogen.

The battery should be mounted upright on a surface that can safely support its approximate 40 pounds. Access to the battery caps for periodic checking of the specific gravity of the electrolyte and its level is essential. Some spilling of the electrolyte is unavoidable. Therefore, the battery should be kept away from materials that are susceptible to corrosion by sulfuric acid.

Another restriction on battery location is the cable length between the battery and the charger. These cables and the battery terminals need protection against short circuits that could cause unsafe conditions. A high-energy arc from a battery short circuit can burn the skin or cause eye damage.

The ideal ambient temperature range for the battery is 60-80°F. Low temperatures reduce capacity, but prolong battery life; high temperatures give some additional capacity, but reduce total battery life. Temperatures above 125°F can actually damage some of the battery components and cause early failure.

The lead-acid battery gives off hydrogen gas toward the end of its charging cycle. The amount of hydrogen gas given off depends on the voltage level to which the battery is recharged. Below 13.8 volts there is very little outgassing because all the energy from the battery charger is absorbed by the battery. Above this voltage level the excess energy disassociates water by electrolysis into its component gases, hydrogen and oxygen.

To minimize the hydrogen outgassing, the battery charger output voltage should be limited to not more than 13.8 volts.



MECHANICAL MOUNTING

Once the location of the carrier phone components has been determined, the next step is the mechanical mounting of each subassembly. Welding or bolting is the most common means of fastening the components to the panel. The orientation of the subassembly with respect to the panel is not critical in most cases, except for the upright position requirement of lead-acid batteries, which requires that a shelf be added to the panel.

Most of the carrier phone components are supplied with mounting plates that can be tack-welded to a steel panel. This arrangement provides a permanent mounting surface with tapped holes or threaded studs onto which the subassemblies are fastened. This arrangement also provides an easy means of interchanging subassemblies for maintenance purposes.

Caution:

- *Remove the subassembly from the mounting plate during the welding operation.*
- *Keep all electrical cables and other non-metallic materials away from the welding area.*

This will prevent the carrier phone components from being damaged by the heat generated from the welding operations.

If welding equipment is not available, the components may be bolted directly to the surface. This operation requires drilling clearance holes or drilling and tapping holes into the panel. Table 1 gives the manufacturers' recommended thread size and the number of holes required for the different subassemblies.

After the mounting plates have been welded in place, or the necessary mounting holes have been prepared, use split lockwashers under all bolt heads to fasten down the assemblies.

If a wooden panel is used for mounting the subassemblies, then clearance holes can be drilled and the units directly mounted to the panel. Once the panel is mounted to a wall, access to the rear of the panel is limited, making subassembly replacement difficult. For this reason a steel panel is preferred when mounting plates that require welding are supplied with the carrier phone.

ELECTRICAL CONNECTIONS

Once the various subassemblies have been physically mounted to the panel and all welding is completed, the final installation task is to make up the electrical interconnections. This procedure consists primarily of inserting cable-mounted plugs into the proper receptacles on the subassemblies and tying the signal and power cords into the proper mine electrical systems.



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TABLE 1

MANUFACTURERS' RECOMMENDED MOUNTING BOLTS

<u>Carrier Phone</u>	<u>Quantity</u>	<u>Size*</u>
Femco Model 73-1901		
Transceiver	4	1/4 - 20
Speaker	2	5/16 - 18
Microphone Hanger	2	8 - 32
Mine Safety Appliances (MSA) Model 1601		
Transceiver	4	5/16 - 18
Speaker	2	3/8 - 16
Battery Charger	4	3/8 - 16
Battery Box	4	3/8 - 16
Pyott-Boone Model 219		
Transceiver	4	1/4 - 20
Speaker	2	1/4 - 20
Resistance Box	4	1/4 - 20

*Diameter-Threads/inch (per American Standards Association).

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A block diagram of a typical carrier phone interconnecting cable system is shown in Figure 5. The cable connected to the trolley power and/or building power should be installed last. The other cables may be installed in any order that is convenient.

Caution:

- *Clean and inspect both connector interfaces before mating.*
- *Study the keying arrangement or polarization to prevent jamming and misalignment.*

MICROPHONE CABLE

Depending on the manufacturer, the cable between the microphone and the speaker is either permanently connected, has an in-line connector, or has a receptacle mounted on the speaker housing into which the microphone plug is inserted.

The in-line watertight microphone connector (Figure 6a) is polarized by the use of different sized pins. Pin number one is larger than pins two and three. The three pins are equally spaced in a circle, making it difficult to match up the correct pin and socket to ensure proper mating. Therefore, care should be taken to see that the keying is properly oriented before engaging the contacts.

The plug and receptacle-type microphone connector (Figure 6b) has diecast aluminum shells that contain the keying arrangement. The receptacle shell has an internal polarizing key that mates with a keyway on the front shell of the plug. As the connectors are brought together, the polarizing keys engage first, thus ensuring proper alignment of the contacts. The plug and receptacle are then drawn up tight by the threaded coupling ring on the plug. Always inspect and clean the contact faces before mating to ensure reliable operation. If coal particles are left on these faces, they will be crushed into the connector and create low resistance paths between the contacts. The fine threads of the coupling ring supply the mechanical advantage to produce this force without the installer feeling any resistance to his tightening up of the connector.

SPEAKER CABLE

The speaker cable terminates at the transceiver box with a plug and receptacle-type connector similar to the microphone connector discussed above and shown in Figure 6b. On some models, the power cable uses the same connector shell size and keying as the speaker connector and also plugs into the transceiver. The receptacles on the transceiver are clearly marked; the power connector insert uses pins; and the speaker connector insert uses sockets, but none of this prevents mismating. The speaker plug can be mated with the power receptacle and drawn up tight without undue force. This causes undue stress on the plastic inserts which can lead to connector failure. Therefore, it is very important that the connector legends be read before making up the speaker connector. Fortunately, the power plug will not mate with the speaker receptacle.

POWER AND SIGNAL CABLE

Before the power and signal cable can be connected, the power source and the signal coupling method must be determined. For a fixed installation of this type either the 115 VAC building power or the 300 to 600 VDC trolley feeder power may be used. Most carrier phone manufacturers provide models designed to operate on 115 VAC or 250-300 VDC or 550-600 VDC, with and without a 12 V battery for backup operation in the event that primary input power is lost.

The guideline entitled, "Converting a Rail Haulage Trolley-wire and Feeder System into a Functional Carrier Frequency Transmission Line," should be used to help determine the type of signal coupling required for the dispatcher's carrier phone. Installation practices for the three most commonly used signal coupling methods, direct coupling, pager phone line coupling, and single dedicated line coupling, will be discussed in this guideline. Special devices, such as carrier repeaters and remote control units, have been designed to overcome the transmission problems associated with some of the larger coal mines. These devices generally require installation assistance from the manufacturer, and are often custom tailored for each installation; therefore, they are beyond the scope of this guideline.

Once the power source and signal coupling method are determined then the proper model of carrier phone may be selected. Table 2 identifies the connection designations for the RF signal and input power used by the various carrier phone manufacturers for their current models. Refer to the manufacturer's installation manual for internal modifications required to separate the RF signal output from the power input if pager phone line coupling or dedicated line coupling is to be used.

For the installer's safety, the input power should be connected last. The carrier phone battery power (12 VDC) is always present on some models, therefore care should be taken to avoid contact with it. The majority of these phones have a panel-mounted 12 V power fuse that can be easily removed to protect the installer and the equipment from short circuits.

SIGNAL CONNECTIONS

The hot side of the RF signal should be made up first using Table 2 to identify the proper connecting point. A 14 AWG copper wire with a minimum insulation rating of 600 V should be used for the pager phone line coupling. This wire is used to bring the RF signal to the junction box in which the .04 microfarad 1600 VDC capacitors are located (see Figure 7).

Another method of signal coupling the dispatcher's phone to the trolley wire is the single conductor dedicated line. This line, if used, would terminate at the hot RF signal connecting point (see Table 2).



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TABLE 2

Power and Signal Connection Designation

<u>Carrier Phone</u>	<u>RF Signal</u>		<u>Input Power</u>	
	<u>Hot</u>	<u>Com</u>	<u>Hot</u>	<u>Com</u>
Femco, Model 83-1901 (Transceiver power connector P1)	P1-C	P1-D	P1-A	P1-B
Mine Safety Appliances (MSA)				
Model 1601 DC Power Vers. (Battery Charger Terminal Board)	3(TEL)	9	2(TR)	9
Model 1601 AC Power Vers. (Battery Charger Terminal Block)	TR	RL	3 prong plug and line cord provided	
Pyott-Boone Model 219* (Transceiver power connector)	F	D	F	D

* At present available only for 300 VDC with direct signal coupling.

A third method of signal coupling called direct coupling involves wiring the hot RF signal connecting point directly to the trolley wire with the in-line holder cable provided with the phone. If the dispatcher's office is remotely located, then a fuse box adjacent to the trolley wire should be used (see Figure 8). If the input power to the phone is to be supplied by the trolley wire (300 to 600 VDC), then the hot power connection (Table 2) is jumpered to the hot RF signal connection with a length of 14 AWG insulated copper wire. Do not install the 3-Amp in-line power fuse until all ground connections are made up.

COMMON CONNECTIONS

The next step is to make up the RF signal common and the case or chassis grounds. The RF signal common should be an all-metallic connection to the rail system, even if the dispatcher is located above ground (Figure 8). Often the rails are bonded to the steel structural members of the main shaft to help establish a good earth ground for the mine. If this is the case, the RF signal common can be wired to the shaft structure at the surface or the hoist house structure, if it is part of this ground network. A #14 AWG insulated copper wire should be used for this purpose.

Again, if the input power is supplied by the trolley wire, then the RF signal common and the power common should be jumpered together.

At this time connect all chassis and case grounds from the lugs or studs provided by the manufacturer to earth ground. Do not rely on the mechanical mounting of the case for a ground connection; always run a separate ground wire to the earth ground. Refer to the Code of Federal Regulations, Title 30, Part 75, Subpart H, for explicit grounding requirements.

The earth ground connection or building ground is generally made up to the metallic water supply pipe or to the structural iron work of the building. In either case the connection should be made close to where the pipe or structure enters the earth to ensure a minimum resistance between the connection and the earth.

POWER CONNECTIONS

The input power to the dispatcher's phone is either supplied from the trolley wire (300 to 600 VDC) or the building wiring (115 VAC). In the previous section on signal connections we discussed the direct signal coupling method using the in-line fuse holder cable and we stated that if the input power is to be supplied by the trolley wire, then the hot power connection (see Table 2) is jumpered to the hot RF signal connection. This covered one combination of signal coupling and trolley wire input power.

If trolley wire input power is to be used with the pager phone line or the dedicated line coupling method, then the in-line fuse holder cable is connected to only the hot input power terminal. The other end of the cable is connected to the trolley wire. Whenever trolley wire input power is used, the common power connection and the common signal connection are jumpered together and wired to the rails. For more details refer above to the paragraph on the RF signal common wiring.

If the carrier phone is not located adjacent to the haulageway, then a wall-mounted fuse box should be used instead of the inline fuse; see Figure 8. Use a current tap to connect a minimum of a 14 AWG copper wire with 600 V neoprene insulation to the trolley wire. Support this wire on insulated J hooks across the roof of the tunnel to keep it out of the way of the trolley pole. Terminate the wire on the line side of the fuse block. Using the same type of wire, make a welded connection to the rail and run this back to the fuse box. Now, two-wire neoprene jacketed-type portable cordage may be used to supply power to the dispatcher's phone.

Connect the black wire of the neoprene cord to the load (hot) side of the fuse block and splice the white wire to the wire from the rail. By locating the fuse box adjacent to the trolley wire, the branch circuit wiring to the dispatcher's phone is protected and can be disconnected by removing the fuse.

Another consideration, when using the trolley feeder for input power, is the polarity of this voltage. To compensate for feeder polarity, either rectifier bridges are included in the design of the phone or internal changes to the phone's wiring are required as part of the installation procedure. The manufacturer's detailed installation instructions should be carefully followed to make certain the carrier phone is compatible with the polarity of the mine trolley power.

If the building wiring (115 VAC) is to be used for the input power, then the hot and common power connections and the chassis ground connection can be wired to the black, white, and green wires, respectively, of a line cord with a three prong plug which can be plugged in any convenient 115 VAC outlet.

BATTERY CABLES

The 12 V power fuse and the trolley power fuse should be removed to permit making up the battery connections without a load immediately being placed across the battery.

The lug end of the cables should first be run through the grommet hole in the battery charger and then terminated, according to the manufacturer's instructions. This depends on the polarity of the particular trolley system.

The grounded side of the battery should be connected first. If the system has positive polarity, then the negative side of the battery should be grounded. The negative post is the smaller one, being 0.650 inch in diameter. The larger end of the tapered hole in the negative battery clamp goes on first. The post and clamp are made of lead, as are the internal connections between the post and the battery plates. If too great a torque is applied to the clamping bolt, the internal connections can develop hair-line fractures that can cause an intermittent connection. To avoid this condition, a second wrench should be used to steady the bolt head while tightening the nut.



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The larger clamp, 0.750 inch diameter, should be attached to the positive post, following the same directions as used for the negative termination.

FUSE REQUIREMENTS

Fuses provide an intentionally weakened part of an electric circuit, and thereby act as a safety valve in the event of dangerous overloads. This protects both personnel and equipment from potential fire hazards due to overheating of the carrier phone.

Fuses come in many sizes, types, and electrical ratings. Always use a replacement fuse that has the same characteristics as the one specified by the carrier phone manufacturers.

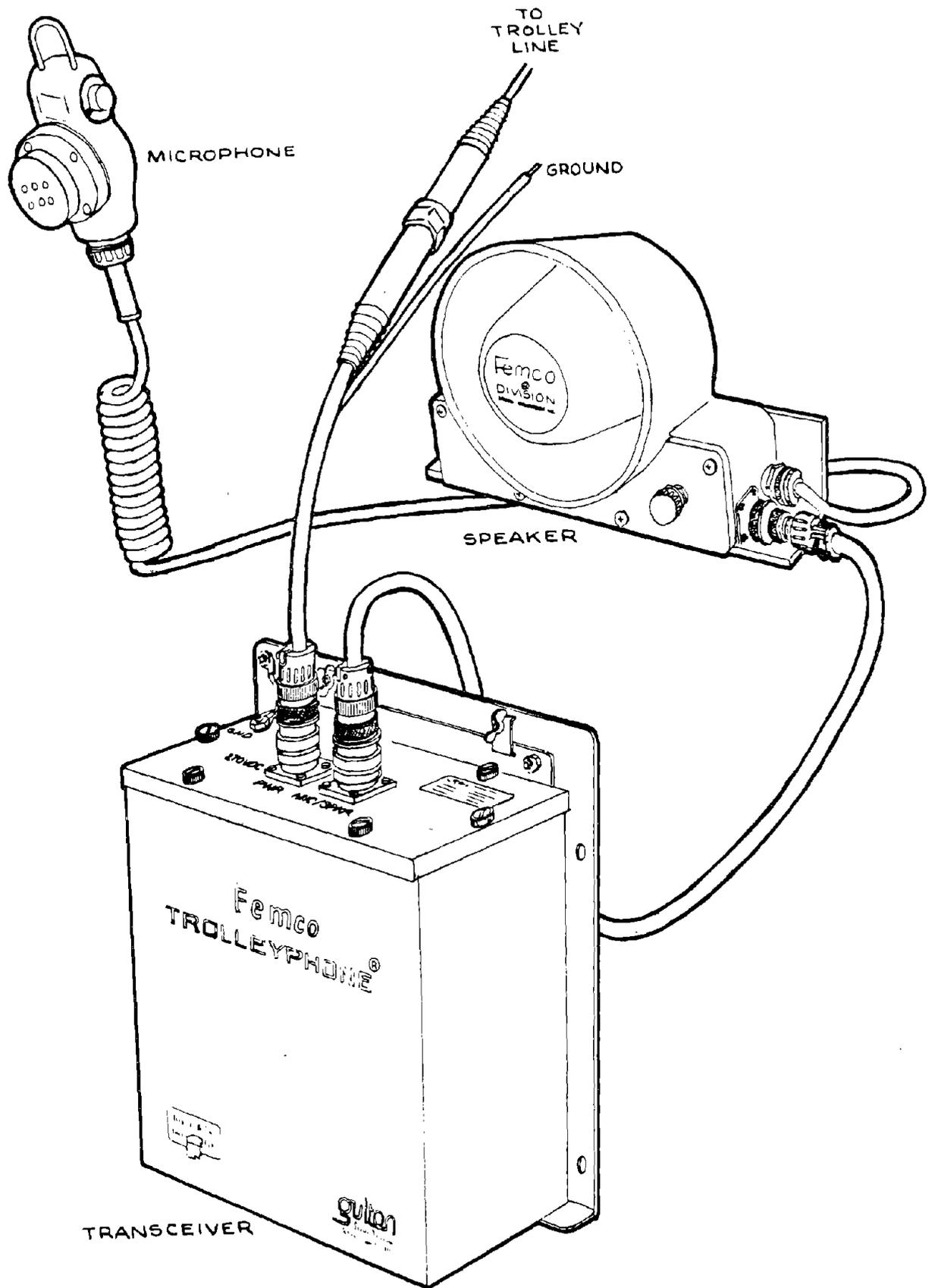
Table 3 lists the trolley line fuse and the battery fuse currently used by carrier phone manufacturers. The ratings specify the fuse manufacturer's interrupt current and maximum operating voltage. The type designation refers to Bussman Manufacturing's fuse classification. Other fuse manufacturers make equivalent products that can be used in these carrier phone fuse holders. Check the current and voltage ratings, type, and size to be sure that you have the proper replacement fuse.

TABLE 3

REPLACEMENT FUSE REQUIREMENTS

<u>Manufacturer, Model</u> <u>Trolley Voltage</u>	<u>Trolley Line Fuse</u>		<u>Battery Fuse</u>	
	<u>Rating</u>	<u>Type*</u>	<u>Rating</u>	<u>Type*</u>
Femco, Model 73-1901				
270 VDC	3 A, 250 V	BAF	5 A, 125 V	MDX
600 VDC	2 A, 600 V	KTK	5 A, 125 V	MDX
MSA, Model 1601				
250/300 VDC	3 A, 600 V	BCF	6 A, 250 V	BAN
550/600 VDC	3 A, 600 V	BCF	6 A, 250 V	BAN
Pyott-Boone				
300 VDC	3 A, 600 V	BBS	5 A, 250 V	AGC

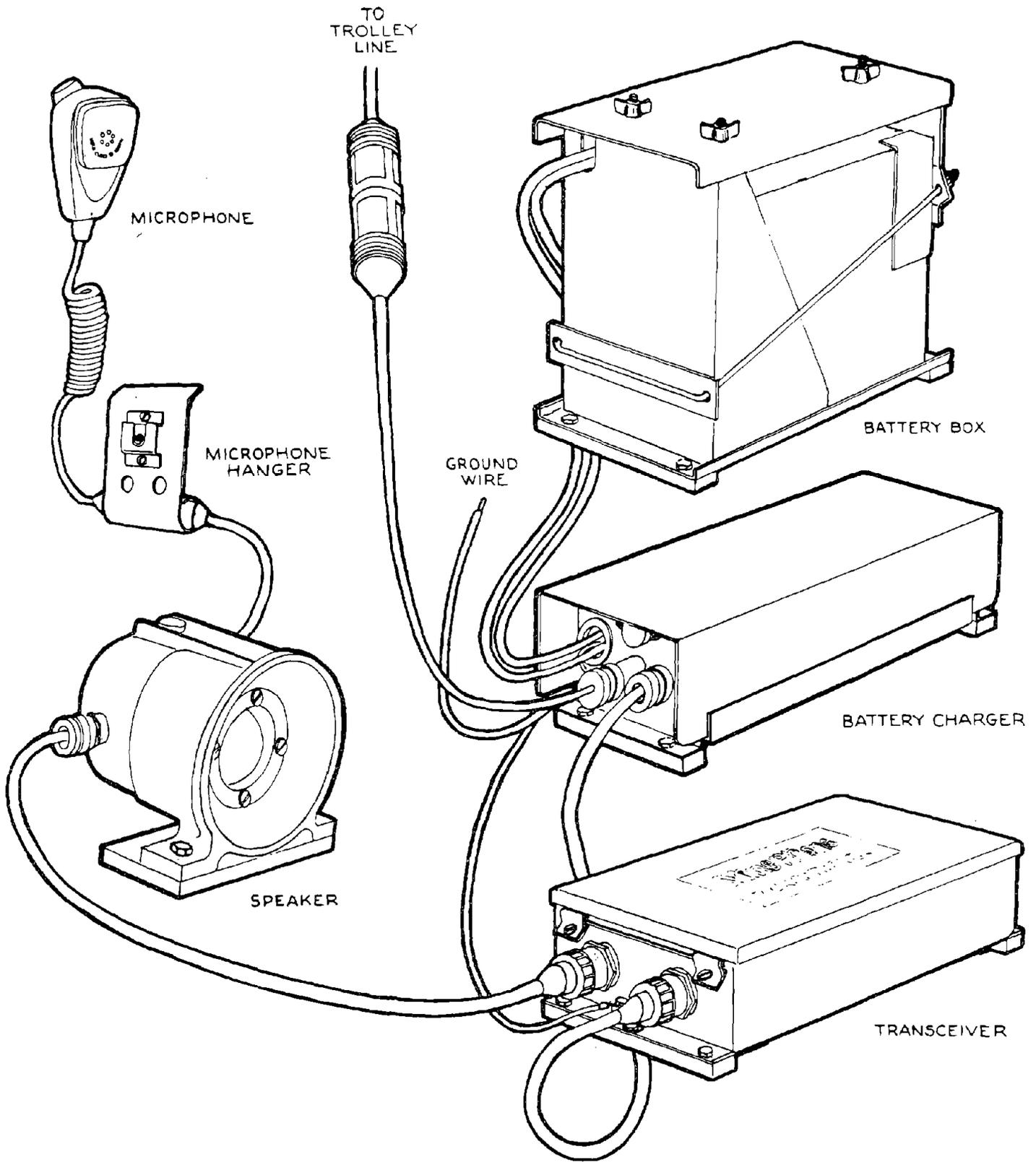
*The type number refers to Bussman Manufacturing's symbol for fuse classifications.



FEMCO TROLLEY PHONE MODEL 73-1901
CARRIER PHONE

FIGURE 1

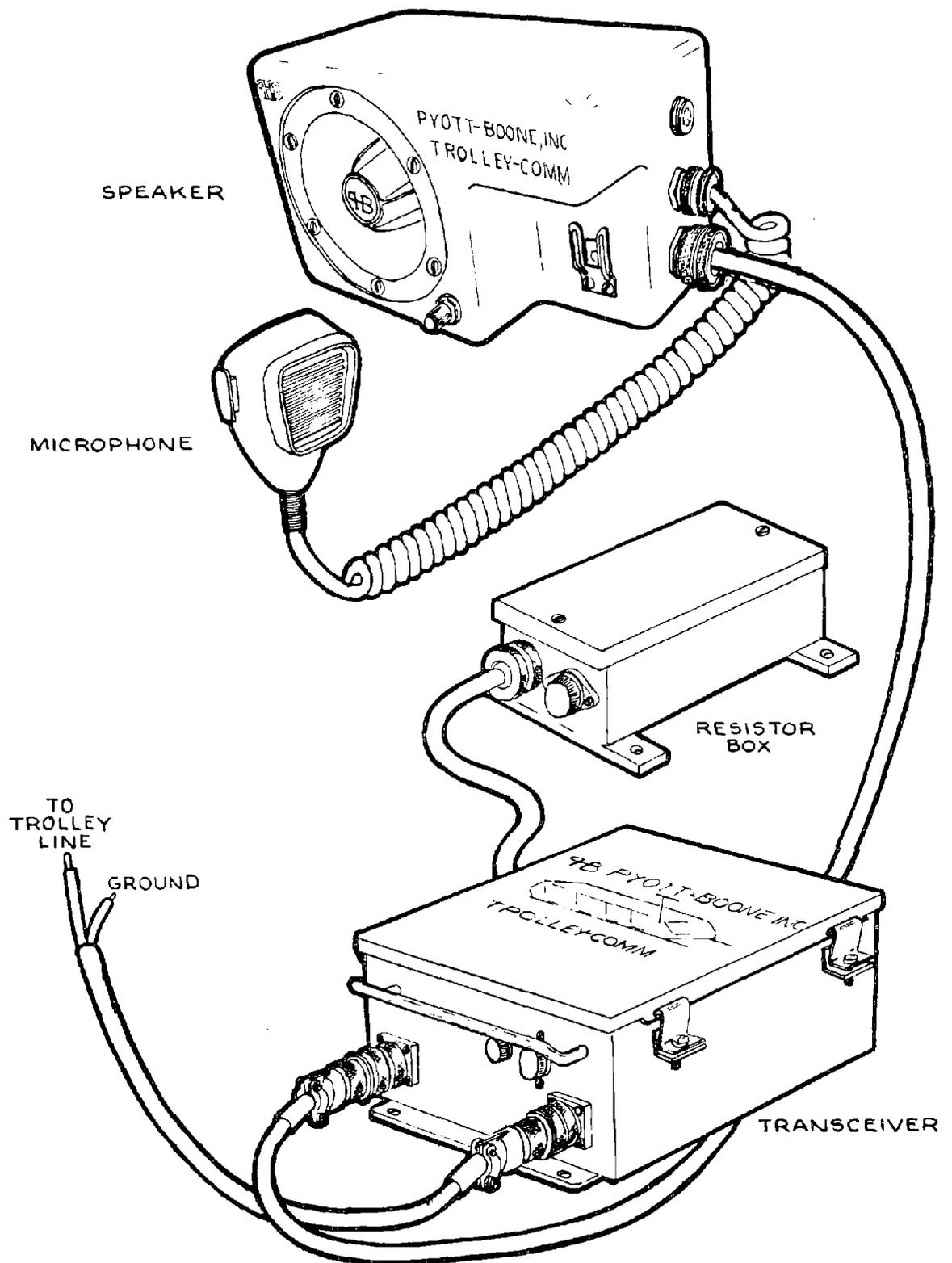
69



MSA MINE PHONE MODEL 1601
CARRIER PHONE

FIGURE 2

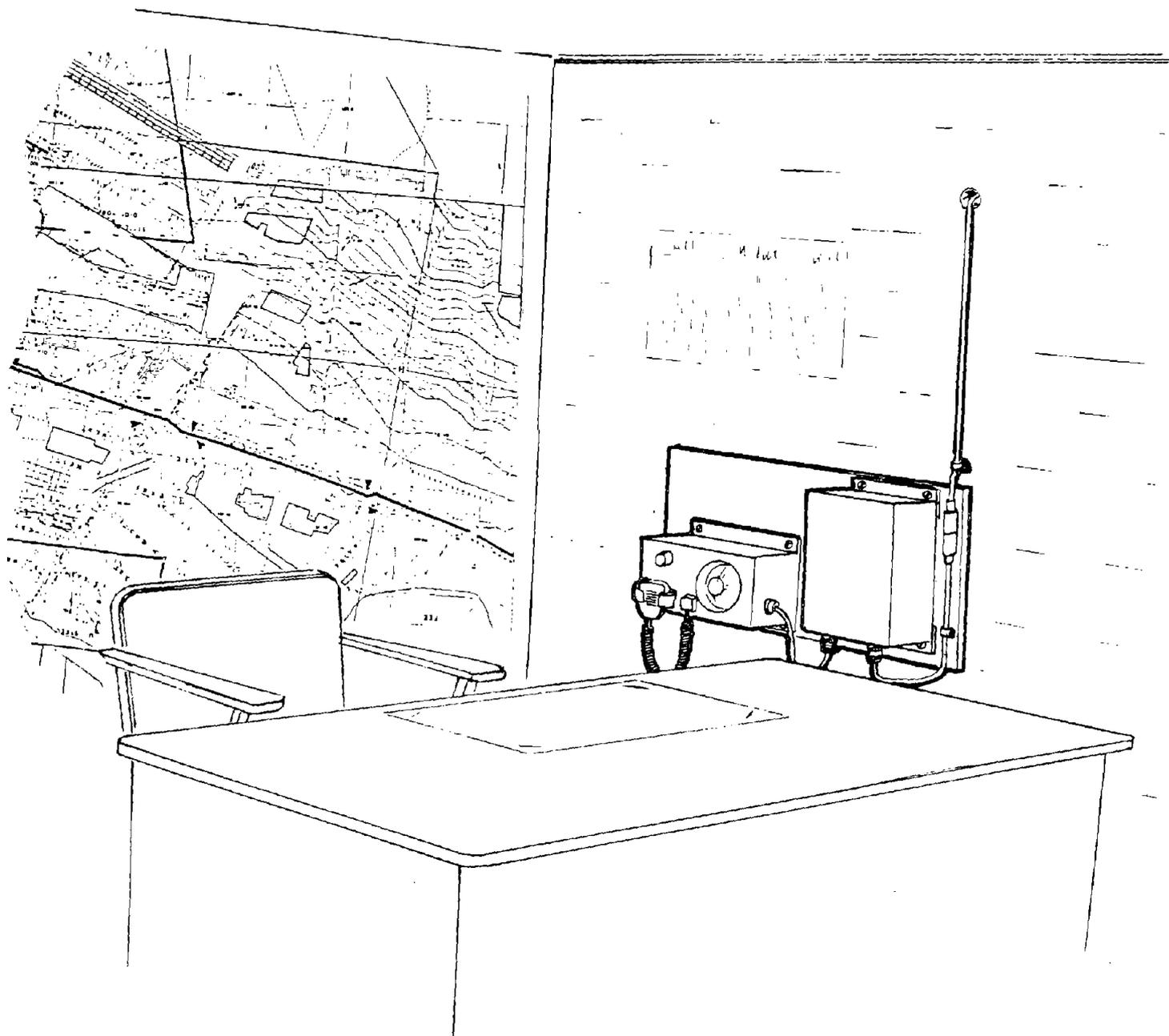
70



PYOTT-BOONE TROLLEY-COMM MODEL 219
CARRIER PHONE

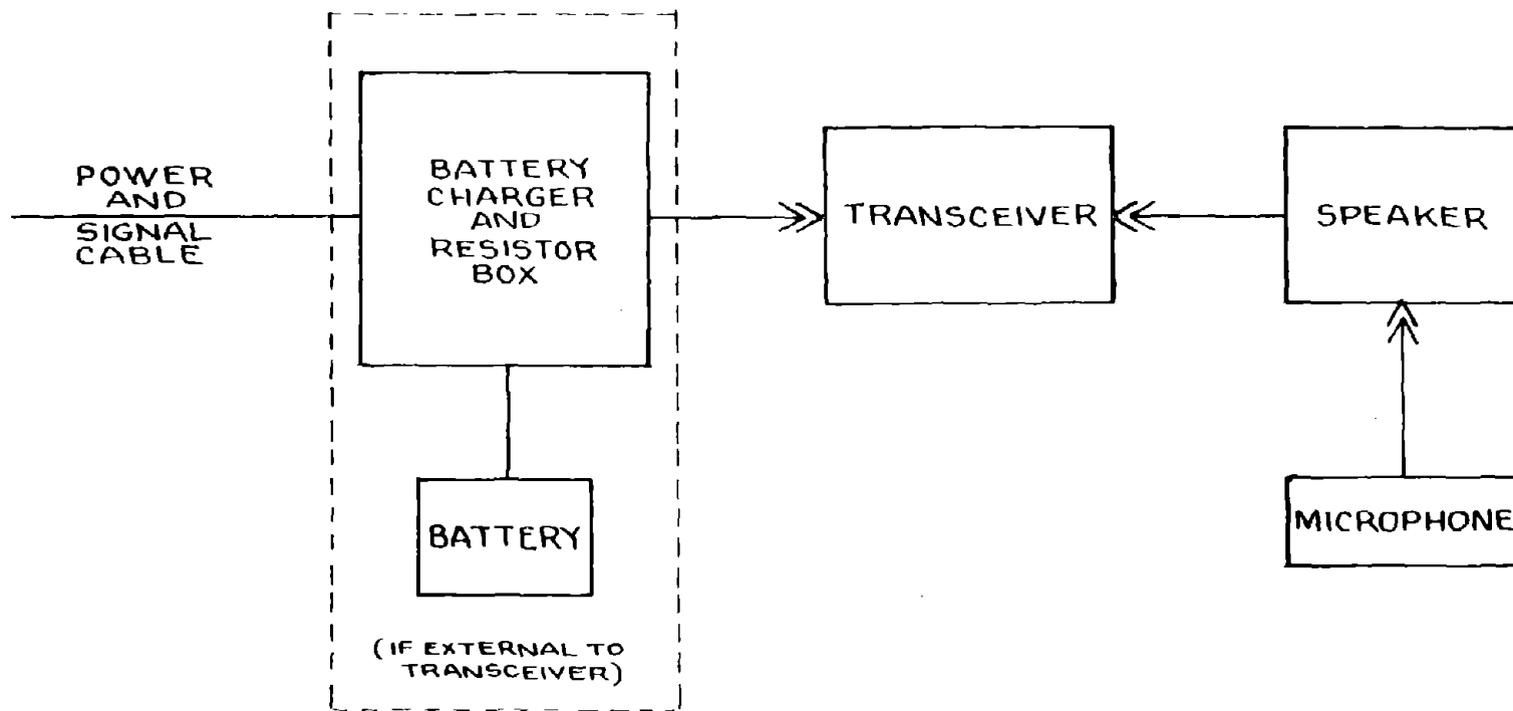
FIGURE 3

Reproduced from
best available copy.



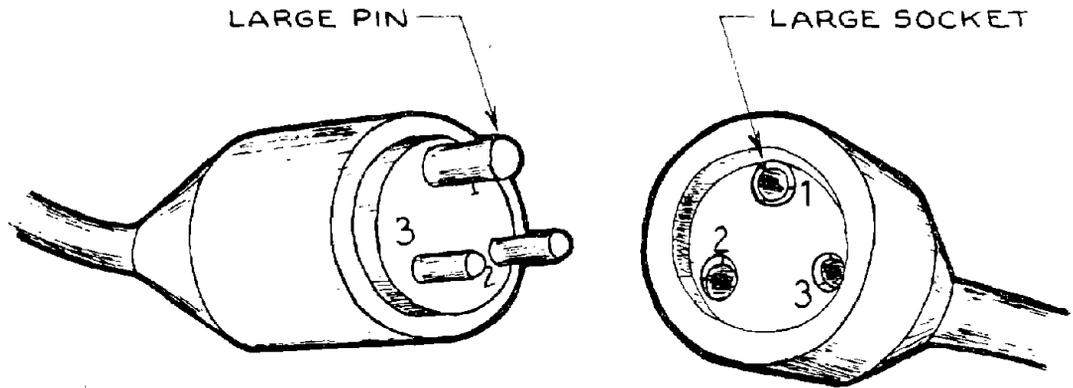
DISPATCHER'S ROOM

FIGURE 4

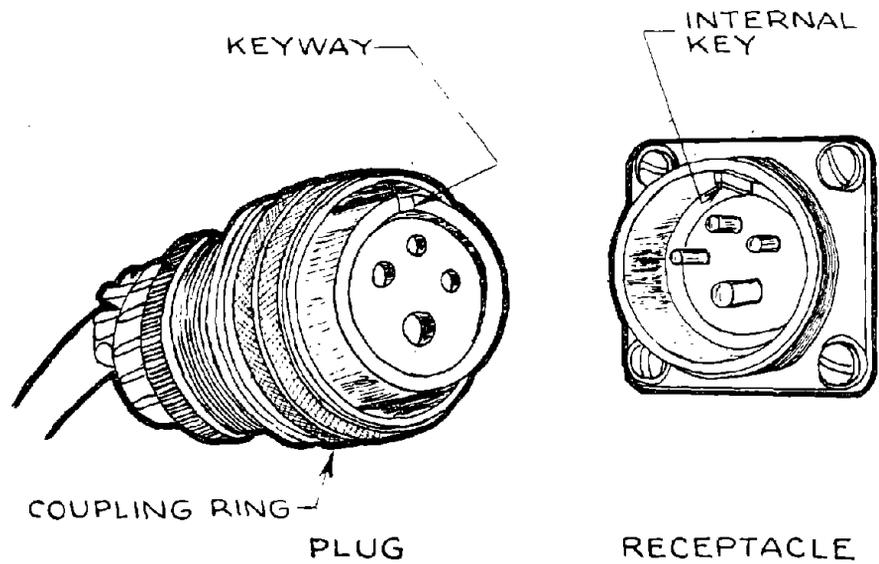


TYPICAL CARRIER PHONE INTERCONNECTING CABLE SYSTEM

FIGURE 5



(a.) IN-LINE CONNECTOR



(b) CONNECTOR PAIR WITH ALUMINUM SHELLS

TYPICAL CARRIER PHONE CONNECTORS

FIGURE 6

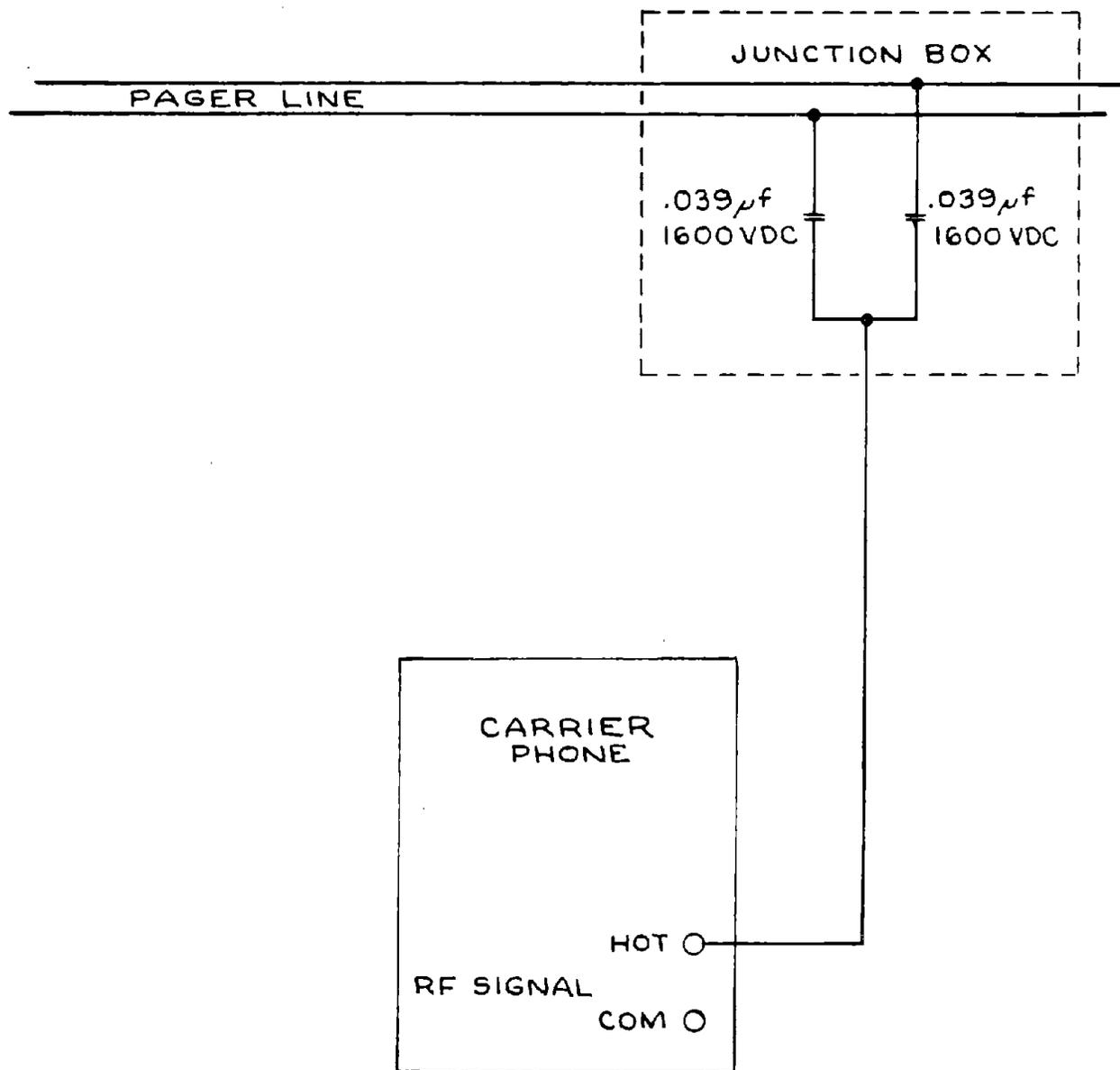
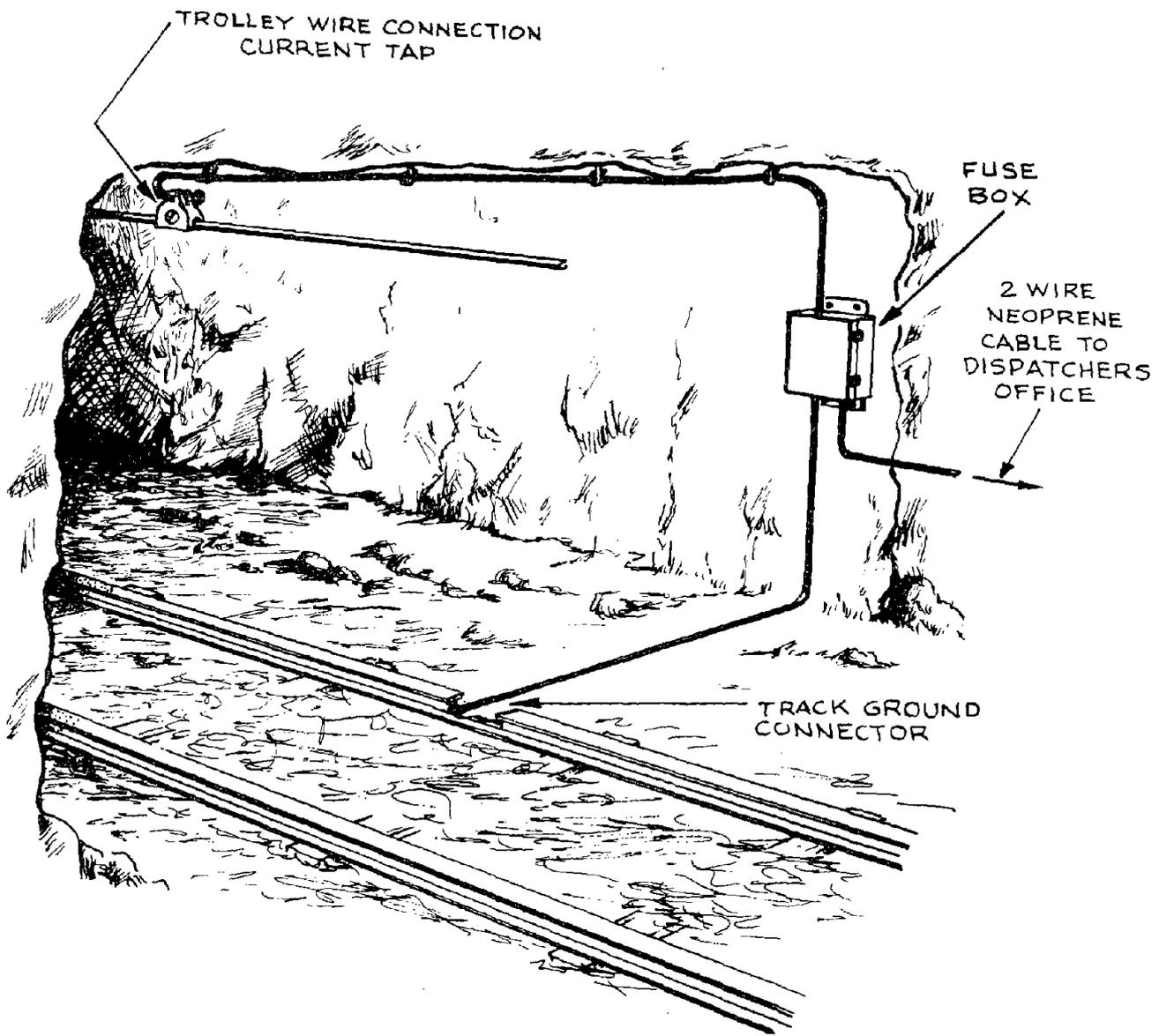


FIGURE 7



TYPICAL CARRIER PHONE CONNECTIONS
TO TROLLEY WIRE AND RAIL

FIGURE 8



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CONVERTING A RAIL HAULAGE TROLLEY-WIRE AND FEEDER SYSTEM
INTO A

FUNCTIONAL CARRIER FREQUENCY TRANSMISSION LINE

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INTRODUCTION

This guideline describes four methods of treating the trolley wire/rail to make it an effective transmission path for trolley carrier phone signals. The guideline treats:

- *Reasons why the trolley wire/rail is often deficient as a transmission path*
- *Means of ascertaining the status of a trolley wire/rail as a transmission path*
- *Four ways of treating the trolley wire/rail to overcome deficiencies.*



WHY THE TROLLEY WIRE/RAIL OFTEN IS A POOR TRANSMISSION LINE FOR CARRIER SIGNALS

Introduction

The trolley carrier phones used for dispatch purposes in electric rail haulage coal mines often show problems in providing coverage over the mine haulage system. The problem is often evidenced as areas of the mine where direct communications between the dispatcher and the vehicle is difficult or impossible. Two major reasons for these difficulties are evident when one considers the factors that determine how well the trolley wire/rail acts as a transmission line for carrier signals: First, characteristics of the trolley wire itself as a two-wire transmission line and second, effects that loads placed across the trolley wire/rail have on transmission. These two factors are considered below.

The Unencumbered Trolley Wire/Rail

Both theory and experiment show that the trolley wire/rail by itself is a relatively low loss transmission line for trolley carrier phone frequencies. In fact, the attenuation rate for such a transmission line is about 2 dB per mile, or a loss in signal of about 20% per mile. A carrier phone pair can tolerate about a 70 dB transmission loss (from 25 volts to 8 millivolts). Thus, on an unencumbered trolley wire/rail transmission line, a distance of 35 miles could be expected for communication range. Actually, such ranges are not achieved; the reasons are noted below.

The Real Trolley Wire/Rail

The real trolley wire/rail can never perform as well as the unencumbered trolley wire/rail for several reasons. The many loads across the trolley wire/rail absorb carrier signal power and reflect carrier signal power. The list of these loads is long and includes rectifiers, personnel heaters, signal lights, vehicle motors, vehicle lights, the carrier phone itself, etc. It is probable that the net signal attenuation rate for a trolley wire/rail with typical loads placed across it is of the order of 10 to 20 dB per mile, and hence a transmission loss of 70 dB yields a useful range as low as 3.5 miles. The problem of obtaining good signal propagation is further aggravated by branches of the trolley wire where the signal splits in a totally uncontrollable way. Lack of termination at the ends of the trolley wire/rail further degrades signal propagation. The moving vehicles represent moving loads on the transmission line and add a further complication to obtaining or predicting good signal propagation. Also, advancing the mine face means that the transmission network changes with time, yielding more uncertainty to the quality of transmission.

The seriousness of the bridging loads can be seen by reference to Table I, where the insertion losses for typical loads are tabulated. Using this table, one can make an estimate of the total signal loss by adding the individual losses (in dB). This procedure will give an estimate only because it does not consider load interactions.



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TABLE I

CHARACTERISTICS OF BRIDGING LOADS

<u>Bridging Load</u>	<u>Estimated Impedance at 100 kHz (ohms)</u>		<u>Insertion Loss* (dB)</u>	<u>Loss in Voltage</u>
Rectifier with minimum setback		2	34.1	51-1
Rectifier with 50-foot setback [†]		9 [†]	21.6	12-1
Rectifier with 100-foot setback [†]		19	15.9	6-1
Carrier phone with 20 Ω receiver		20 Ω	15.6	6.0 - 1
Carrier phone with 100 Ω receiver		100 Ω	6.0	2.0 - 1
Jeep or portal bus motor		500 Ω	1.6	1.2 - 1
44-ton locomotive motor		60 Ω	8.5	2.7 - 1
Vehicle with two 150-watt, 30-volt headlights isolated resistively **	300 V system	60	8.5	2.6 - 1
	600 V system	120	5.3	1.8 - 1
Illumination lights (assumed to be 200-watt load)	300 V system	450	1.7	1.22 - 1
	600 V system	1800	0.5	1.06 - 1
Single insulator		200,000	0.0043	1.0005 - 1
1 mile of insu- lators with 12- foot spacings (440 insulators)		-	1.90	1.2 - 1
1000-watt per- sonnel heater	300 V system	90 Ω	6.5	2.1 - 1
	600 V system	360 Ω	2.1	1.3 - 1
5000-watt personnel heater	300 V system	18 Ω	16.3	6.6 - 1
	600 V	72 Ω	7.6	2.4 - 1

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Notes to Table I

- * This insertion loss is that calculated for an otherwise unencumbered trolley wire/rail having a 200-ohm characteristic impedance, using the formula

$$L = 20 \log_{10} \frac{Z_o + 2R}{2R}$$

where

R is bridging load resistance. (See pages 13 and 14)

For a trolley wire/rail having a large number of loads, the total net transmission loss will in most practical cases be less than the sum of these tabulated losses due to load interaction.

- ** At the trolley wire carrier frequency the bridging impedance of a locomotive or vehicle appears to be dominated by the headlights. Motors have impedances at carrier frequencies that are somewhat larger than these values and therefore the load imposed by the lights only is considered. Newer vehicles with DC to DC converters that supply the light circuits have appreciably less effect.

- † The bridging impedance of a setback rectifier is higher in value than one with minimum setback due to the feed wire inductance. These figures assume a feed wire inductance of 0.3 microhenrys per foot and a frequency of 100 kHz. The values of Z will be somewhat less, but not significantly for 88-kHz operation.



DETERMINING THE STATUS OF THE TROLLEY WIRE/RAIL AS A TRANSMISSION LINE

Introduction

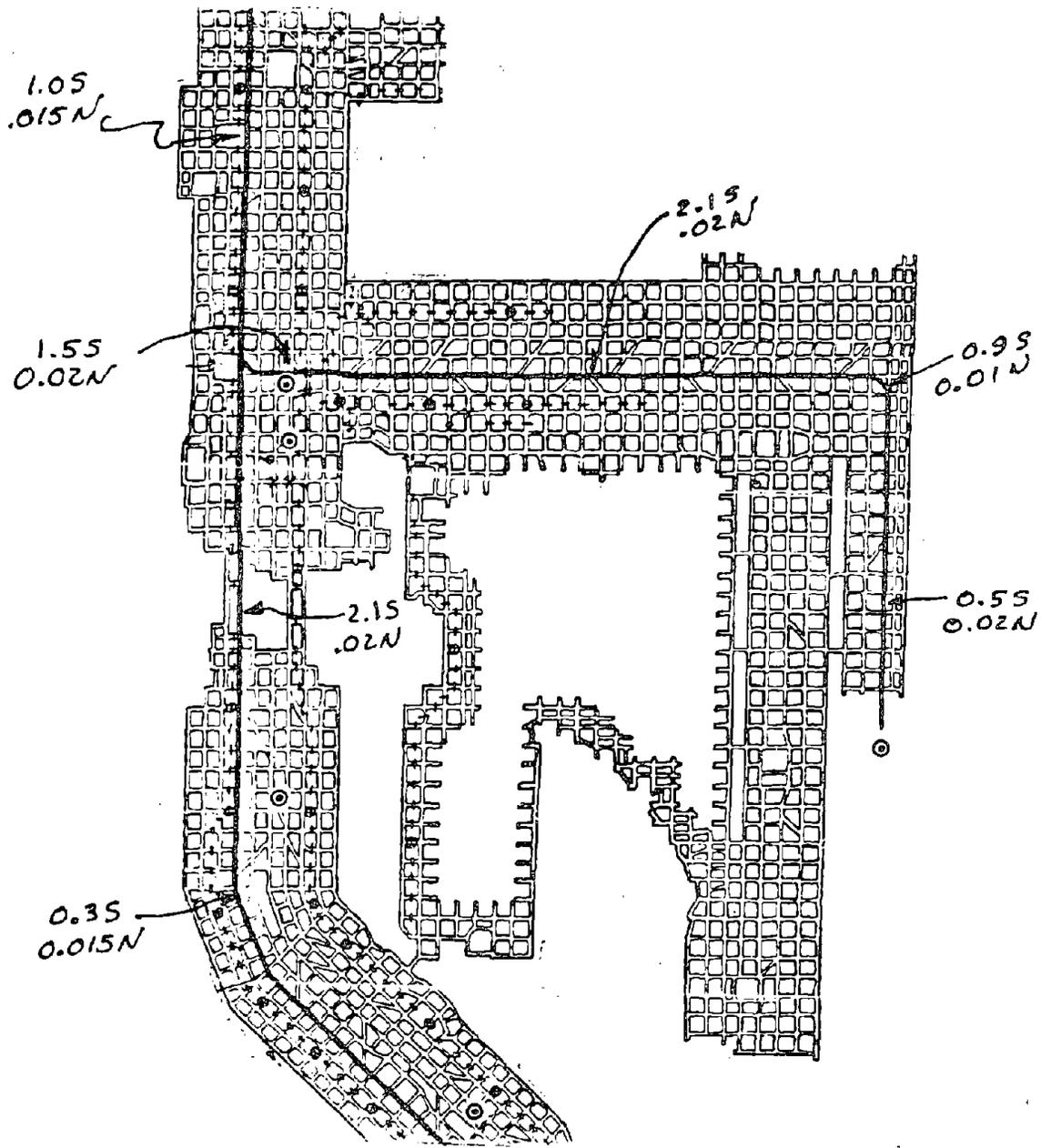
The way to determine the status of the overall transmission system is to map the signal and noise strengths throughout those regions of the mine which are covered by the trolley carrier phone system. Such mapping requires a tuned signal measuring device, typically not available in most mine maintenance shops.

The mapping is preferably carried out by measuring the signal strength produced by the dispatcher's transmitter at various points along the rail haulage system where vehicles operate. A satisfactory way of conducting the measurements is to place a suitable tuned voltmeter aboard a mine vehicle (such as a jeep) and progressing throughout all those regions of the mine where dispatcher-to-vehicle communication is desired. At appropriate places along the rail haulage - for example, at 2000 or 3000 foot intervals - the received dispatcher's signal and the background noise are both measured. These values are noted on a mine map for future reference as the mine expands, or as carrier phone problems occur. Except under extremely unusual conditions, the signal strength map produced in this manner will also indicate the level of signal that a vehicle transmitter at the measuring position would produce at the dispatcher's location.

An example of a portion of a mine map annotated with such readings is shown in Figure 1.



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EXAMPLE OF SIGNAL LEVEL MAP

FIGURE 1

Equipment Descriptions

The equipment for making such a signal level map must be battery-operated, easily portable, and easy to use and read. There are two such units commercially available; the Sierra Model 127C tuned voltmeter* and the Rycom** Model 3115 subscriber carrier test set. These voltmeters are general-purpose, battery-operated instruments appropriate for many tasks other than the mapping of trolley carrier signal levels. For this reason careful attention to the tuning of the instrument to the precise frequency used in the mine must be effected, and careful attention must be paid to the attenuator settings and meter indications. The appearance of the two instruments is shown in Figure 2.

Specifications of the Sierra Model 127C and the Rycom Model 3115 are listed in Table II.

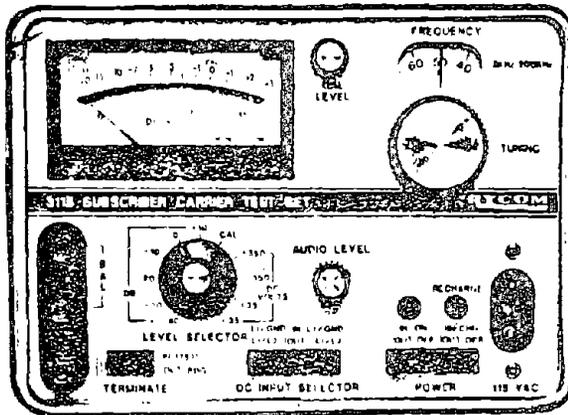
* L.S.I./Sierra Electronics, 3885 Bohannon Drive, Menlo Park, California 94025 - Telephone 415-321-5374.

** Rycom Instruments, 9351 East 59th Street, Raytown, Missouri 64133 Telephone 816-353-2100.

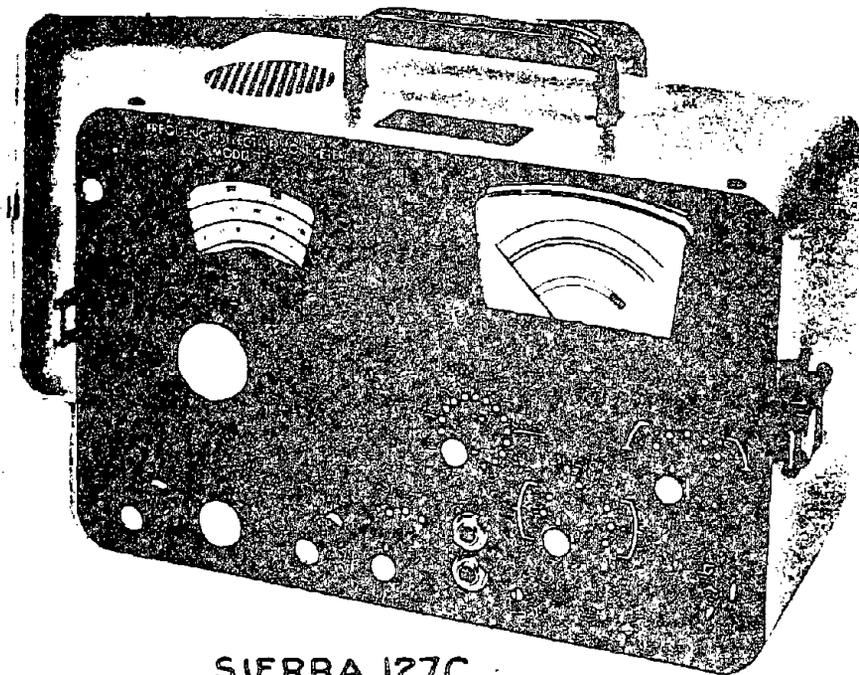


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RYCOM 3115



SIERRA 127C

TUNED VOLTMETERS

FIGURE 2

TABLE II

KEY SPECIFICATIONS OF THE TUNED VOLTMETERS

	<u>Sierra 127C</u>	<u>Rycom 3115</u>
Frequency Range	2 to 350 kHz	3 to 200 kHz
Accuracy		
Frequency	+ 1 kHz	+ 1 kHz
Level	+ 1 dB	+ 1 dB
Selectivity		
Standard (250 Hz)		
3 dB bandwidth	250 Hz	1000 Hz
35 dB bandwidth	600 Hz	
60 dB bandwidth	1000 Hz	4000 Hz
Ranges (full scale)	1 mV to 10V	-37 dB to + 13 dB (3.7 mV to 1.65V) to + 53 dB* (165.V)
Intermediate Frequencies		
1st 1F	1305 kHz	
2nd 1F	330 kHz	
Power Requirements	6 zinc-carbon or 7 NiCd recharge- able "D" size cells	2 GEL cells Globe 610
Voltage	9V nominal	12V
Battery Life (zinc-carbon)	100 hours	5 hours continuous
Temperature Range	-10° to 50°C	-10°C to 55°C
Dimensions		
Width	12 inches	7 1/4 inches
Height	7 1/2 inches	5 1/4 inches
Depth	7 1/2 inches	7 3/4 inches
Weight	15 lb.	6 lb.
Cost	\$1,695	\$895

*With model 3069
40dB fixed
attenuator

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Method of Using the Tuned Voltmeters for Carrier Signal Level Mapping

The simple and straightforward procedure of measuring the dispatcher's signal level from a jeep or vehicle moving about the mine can best be accomplished by connecting the trolley wire voltage on board the vehicle to the input of the tuned voltmeter. Because of the hazards associated with the high voltage of the trolley wire, either a nominal 300 or 600 volts, dc, either instrument has to be properly isolated so that personnel operating the instruments are not subjected to this voltage through error in operation. Therefore, it is important that a capacitor and a fuse are connected in series with the instrument to ensure that the potentially lethal voltage of the trolley wire does not inadvertently reach an operator. Thus, the entire set of measurements may be made safely without removing this instrument from its connection to trolley wire voltage. A diagram showing a possible way of connecting the instrument is shown in Figure 3. (A 0.001 microfarad 1000-volt capacitor and a 1-amp fuse can be used for this purpose.)

Method of Taking Data and Tabulating Results

To make a measurement the vehicle is moved from the dispatcher's office to predetermined regions of the mine, where the vehicle is stopped. The operator then asks the dispatcher for a 5-second long transmission of unmodulated carrier. The response on the indicating meter is noted, together with any attenuator setting, so that an absolute value of voltage (in volts rms) can be noted on the corresponding position on the mine map. It may be necessary when starting measurements to switch the range knobs of the instruments to make sure that the instrument's response is on scale rather than high and off the scale. In this event, perhaps two transmissions will be required before on-scale readings are obtained.

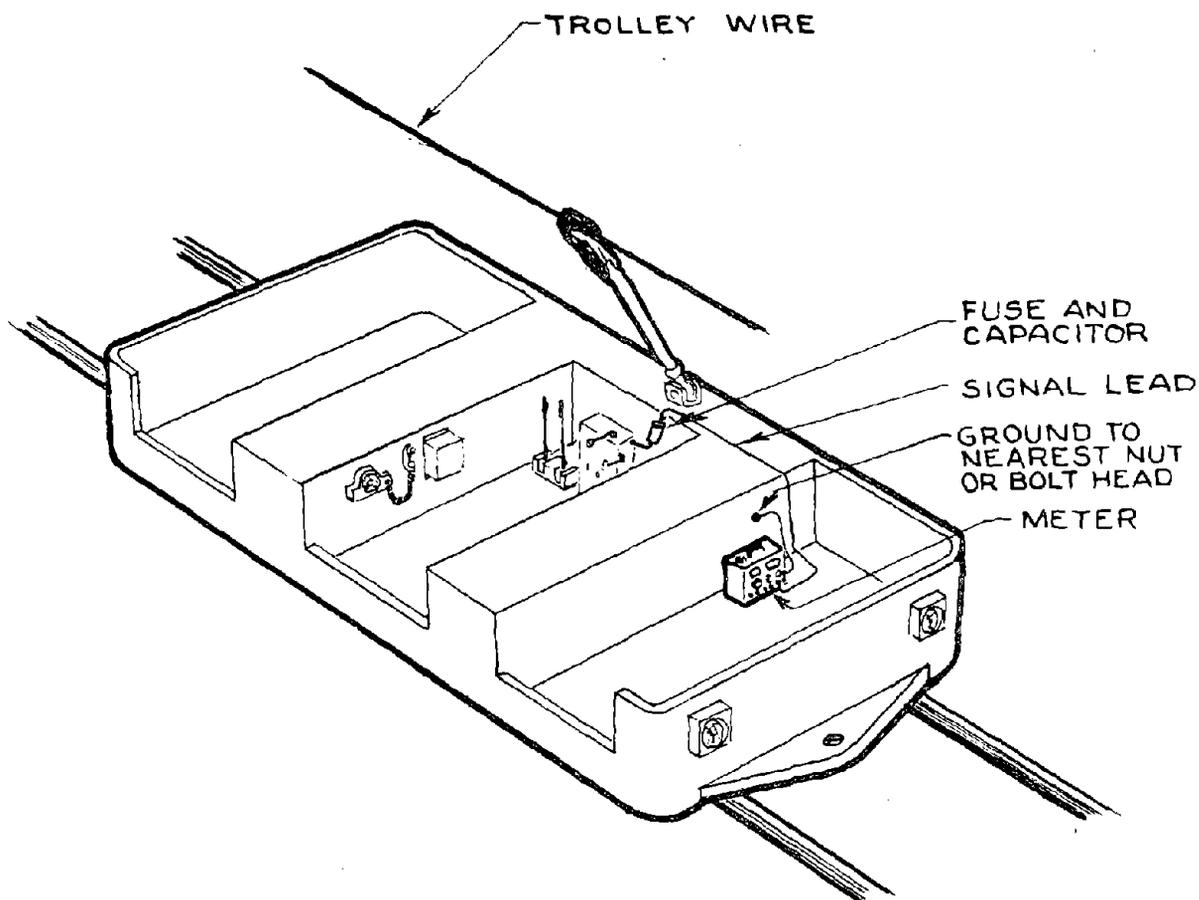
Similarly, after the transmission is over the sensitivity of the instrument should be increased and the noise level at the particular position noted again in volts or millivolts rms. When the operator of the vehicle asks the dispatcher for a transmission, a large level of signal is applied to the meter. For this reason, one must be careful of the range settings to avoid instrument damage.

Use of Information from the Signal-Level Map

The signal-level map will reveal regions of the mine where the dispatcher signals received are weak and thus may cause difficulties in carrier communication. The mine map will also reveal regions where excessive noise is the main cause of poor communications.

The signal-level map will also be extremely useful should carrier communications deteriorate with time, or with the installation of new equipment, or as advancement of the mine occurs. One can refer back to the original signal levels and determine why communications have degraded.





INSTRUMENT CONNECTIONS

FIGURE 3

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FOUR METHODS TO IMPROVE CARRIER SIGNAL PROPAGATION

Introduction

The signal propagation difficulties noted above can be attacked in several ways to extend carrier signal propagation on the trolley wire/rail. Presented below are four methods that have proven useful for this purpose.

Removal of Bridging Loads

The most straightforward way of treating the trolley wire/rail to make it into a functional carrier signal transmission line is to physically remove from the trolley wire/rail all of the bridging loads that are the prime culprits in impeding carrier signal propagation. However, for practical reasons, this method is severely limited. The alternative to physically removing the offending loads is to isolate the loads at the carrier frequency which is described later. Here we treat what can be done in the strict sense of physical removal.

The steps in this process are:

1. Identify the bridging loads. List all the bridging loads across the trolley wire/rail. Consult Table I of this guideline to estimate the seriousness of the impediment the carrier signal propagation that each load represents.
2. Determine which loads can be removed from the trolley wire/rail and be operated from mine ac power. In some instances none of the loads can be so treated and efforts to improve signal propagation must be relegated to other treatments, as described in these guidelines. In any event, certain critical loads including rectifiers, vehicles, lights, motors and carrier transceivers cannot be so treated.

Isolate Loads at the Carrier Frequency

The method discussed above is unlikely to yield a substantial lessening of signal attenuation, and the second method of treating the offending loads should be considered. This method involves adding passive circuit elements in series with the particular load. The added elements must show low resistance for DC currents and a high impedance at the carrier frequency. The circuit components are typically an inductor in parallel with a capacitor that form a tuned circuit.



General

A simple Thévenin-equivalent circuit may be used to determine the loss of voltage on the trolley wire produced by a bridging load. This Thévenin-equivalent circuit is shown in Figure 4a. The voltage V_0 is the voltage found on the wire before the attachment of the load R_L .

The voltage on the bridging load when it is attached is

$$\frac{V_0 2R_L}{2R_L + \frac{Z_0}{2}}$$

The ratio of the loaded voltage to the unloaded voltage is thus:

$$\frac{V_{\text{loaded}}}{V_{\text{unloaded}}} = \frac{2R_L}{Z_0 + 2R_L}$$

This ratio is plotted in Figure 5 for a Z_0 of 200 ohms. This plot illustrates the way that the received signal level behaves near such a bridging load, and clearly shows the improvement in received signal level that can be achieved for the various bridging loads by raising their impedance. Approximate ranges for various types of such bridging loads are shown on the horizontal axis of this plot. Clearly, rectifiers, heaters, and vehicle lights are the bridging loads that most seriously degrade received signal levels, and are the ones that should be treated first to improve received signal levels.

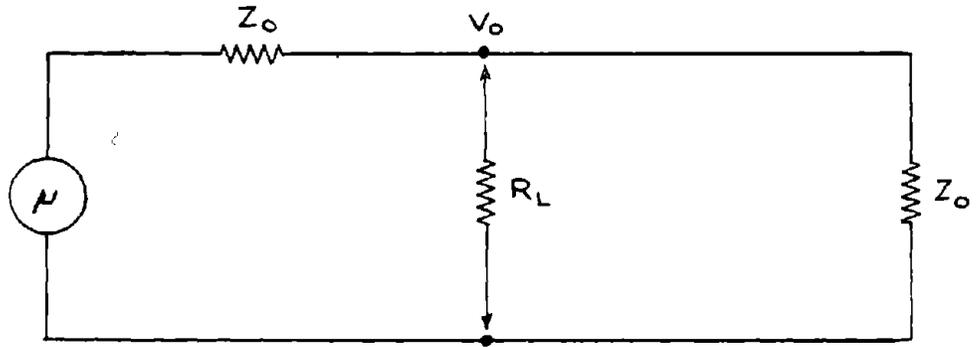
We treat below the ways by which the impedances of each of these bridging loads may be raised to increase the received signal level throughout a mine.

Rectifiers

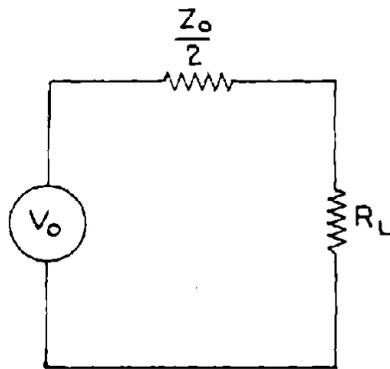
There are three means of raising the effective carrier frequency impedance of a rectifier. The most practical means depends on where the rectifiers are installed. If the rectifier is located relatively far from the rail, that is, beyond 40 feet, then the feed wires represent sufficient inductance that they can be resonated, thereby raising the effective impedance as seen by the trolley wire/rail. If the rectifier setback is short, less than 40 feet, two techniques can be used to raise the effective impedance: (1) a fixed high-current inductor can be added in series with the rectifier and that inductor can be tuned to raise the effective impedance seen by the trolley wire/rail; or (2) the inductance of the trolley wire/rail can be used to resonate short sections of the trolley wire/rail near the bridging load to raise the effective bridging impedance. The ways of applying each of these means are described below and illustrated in Figure 6.



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- a. TRANSMISSION LINE WITH BRIDGING LOAD R_L
 ABOUT TO BE ATTACHED
 (LINE CHARACTERISTIC IMPEDANCE IS Z_0)

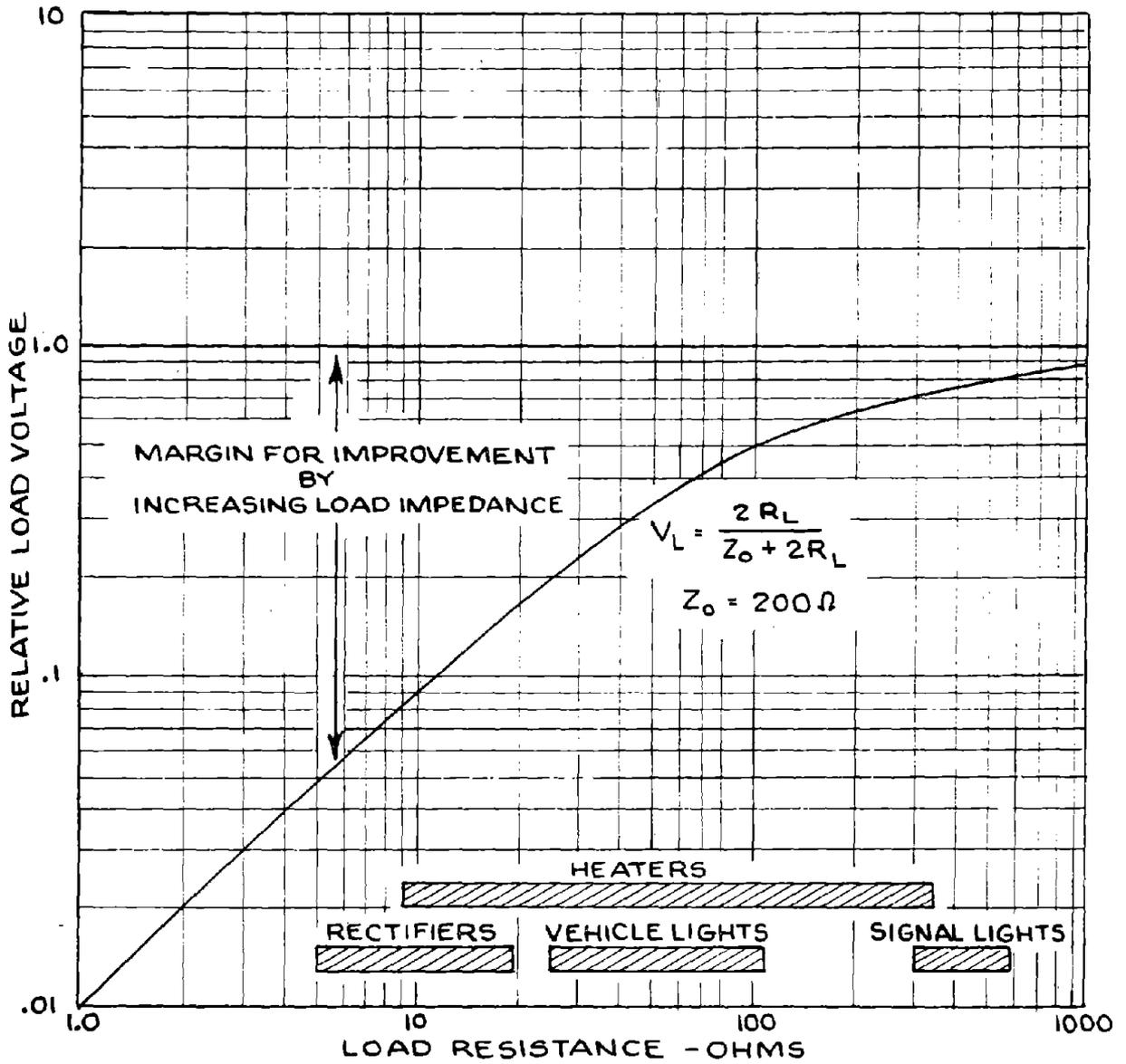


- b. EQUIVALENT CIRCUIT FOR LOAD VOLTAGE COMPUTATION

CIRCUITS REPRESENTING BRIDGING LOAD

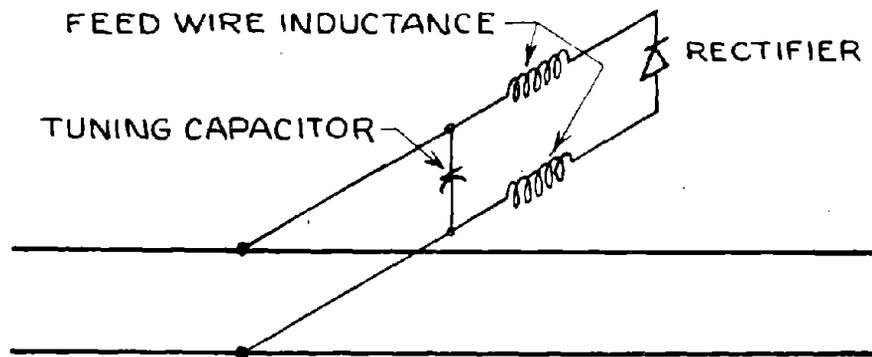
FIGURE 4

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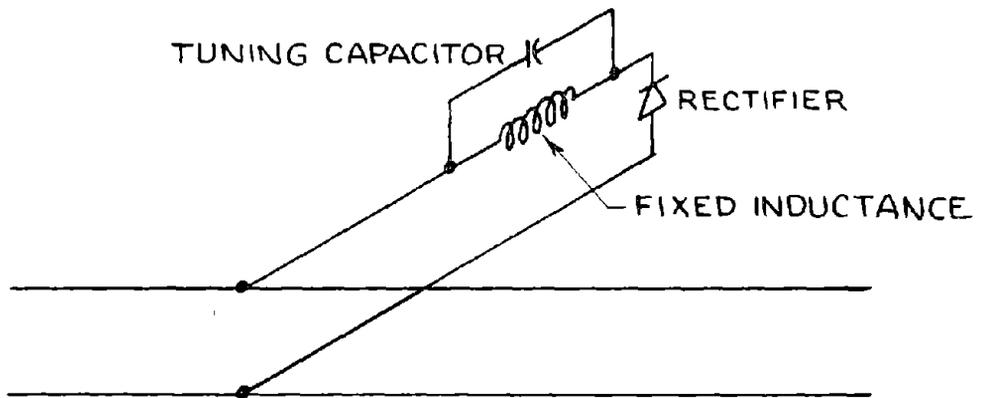


LOAD VOLTAGE AS A FUNCTION OF LOAD RESISTANCE

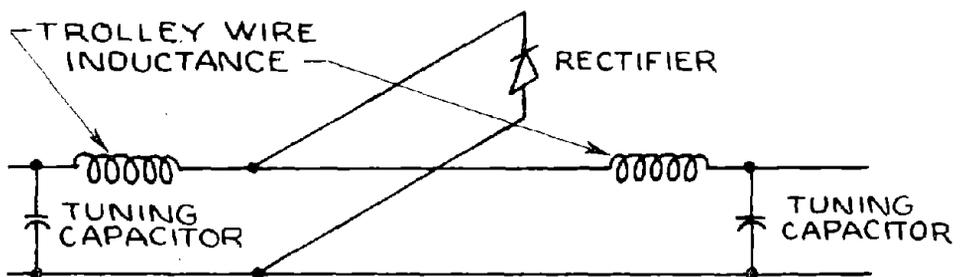
FIGURE 5



a. RESONATING THE FEED WIRE INDUCTANCE



b. RESONATING AN ADDED FIXED INDUCTANCE



c. RESONATING THE TROLLEY WIRE /RAIL INDUCTANCE

REPRESENTATIONS OF MEANS OF RAISING
THE IMPEDENCE OF BRIDGING LOADS

FIGURE 6

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Tuning the Feed Wires

Several steps are required to tune the rectifier feed wires, as noted below:

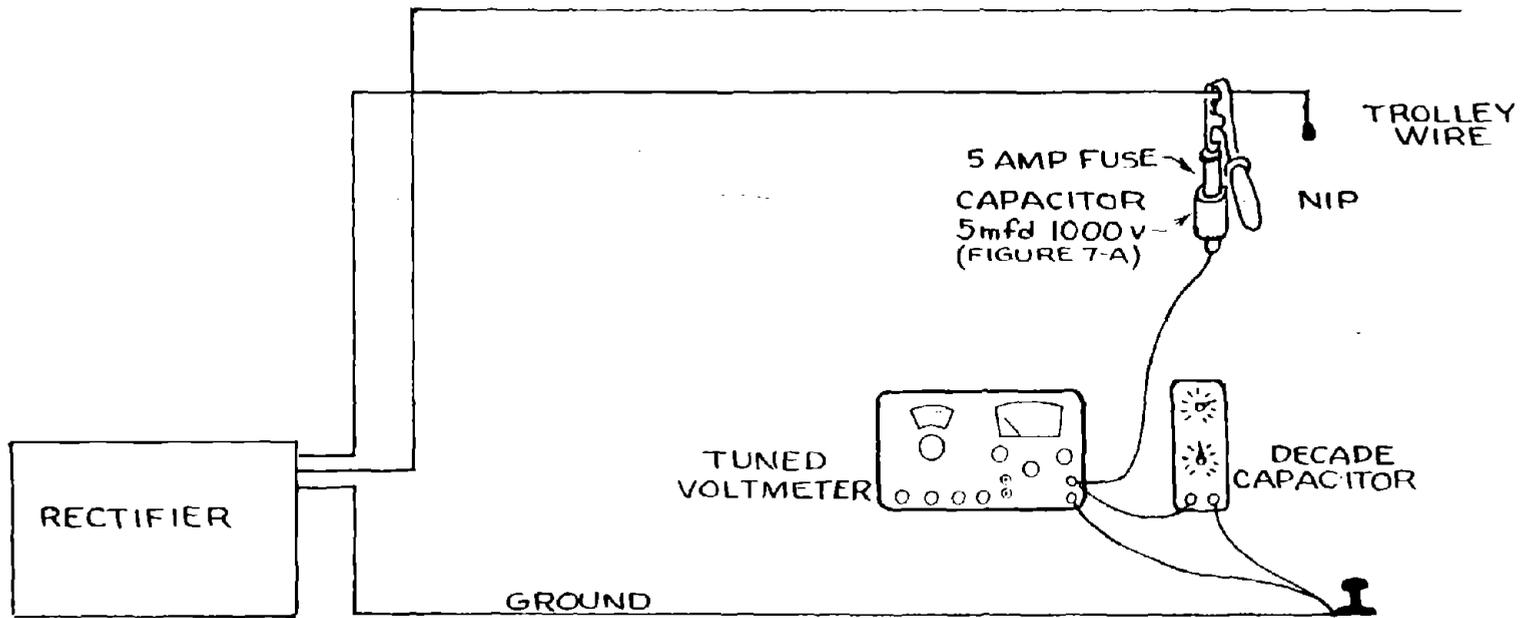
- Attach a 1000-volt, 1- μ F or larger, oil-filled capacitor directly across the plus and minus terminals inside the rectifier. (This capacitor serves to reject rectifier-generated interference in the carrier frequency band.)
- At the far end of the feeder wires, as near to the trolley wire/rail as practical, install the temporary test set shown in diagram (Figure 7). This test set is comprised of a decade capacitor, isolating and protection devices and a tuned voltmeter. Usually two feed wires are run from the rectifier to this point. Only one need be treated.
- The dispatcher is called from a jeep parked nearby and asked to key on his transmitter for 20 seconds or so. The decade capacitor is switched through its range of operation and left at the position of maximum signal, as indicated by the tuned voltmeter. This value of signal should be larger at this setting than at its off position. The two values - the voltage when the decade capacitor is off and the maximum value - should be logged, preferably on a mine map. There should be an appreciable increase in voltage for this condition, at least 1.5 to 1, and in some instances up to 10 to 1. The value of the capacitance that produced the maximum voltage should be noted from the value indicated on the decade capacitor; a capacitor of that value should then be installed in a permanent fashion, as shown in Figure 8. When this installation has been made, a final check, using the tuned voltmeter, should be made to ascertain that the originally indicated increased voltage is obtained.
- For this test it is important, of course, that the tuned voltmeter be tuned to the precise transmission frequency of the dispatcher. A preliminary test can easily ascertain that this condition has been met by sweeping the tuning dial of the tuned voltmeter through values near the transmitted frequency and leaving it at the position where maximum response is indicated.

The Use of an Added Inductor

When the setback is short, an added inductor made up of a coil of feeder wire may be used to provide a series inductance that can be tuned. Because feeder wire is expensive, a coil in the so-called "Brooks" form, which yields the maximum inductance per length of wire should be used.



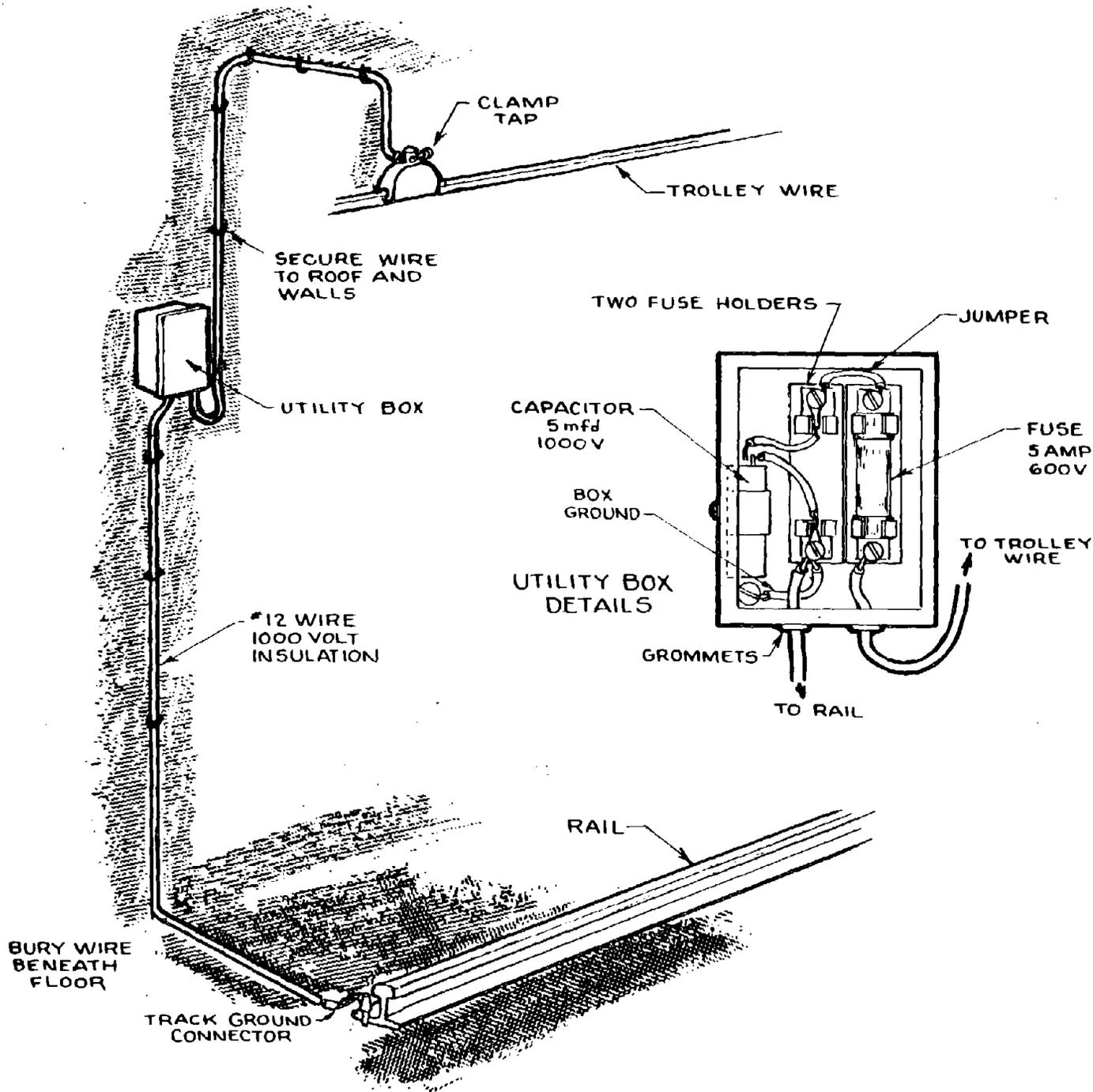
95



TUNED VOLTMETER: SIERRA MOD 127C
 DECADE CAPACITOR: 2 DECADES .01 → .1
 .1 → 1.0

TEST CONFIGURATION FOR TUNING FEED WIRE

FIGURE 7



PERMANENT INSTALLATION OF TUNING ELEMENTS FOR FEEDER WIRE

FIGURE 8

The approximate form is shown in Figure 9. A reasonable bending radius for the typical 1 MCM cable used for such feeder wires is 2 feet,; therefore this dimension is approximately fixed. Four turns of the corresponding diameter yield an inductance of approximately 25 μ H. Such a value is adequate for tuning most rectifiers. The coil should be installed in the room in which the rectifier is located, and should be kept a few feet away from the coal to prevent added losses at the carrier frequency. The exact value of inductance is unknown, so that the coil will have to be tuned in much the same manner as discussed previously for resonating the feeder wires.

Figure 10 illustrates the test setup. The dispatcher is called and asked for a 20-second transmission. The decade capacitor is switched through its positions and left at the position that yields the maximum voltage. The received voltage with the capacitor in the "off" position and the maximum voltage should be tabulated, preferably on a mine map. When the best capacitor value has been found in this manner, the test set is removed and a capacitor of the value found during the test is permanently attached to the coil, as shown in Figure 11. When completed, a last test is made to verify that the improved signal reception is obtained.

Tuning the Trolley Wire/Rail

Several steps are required to tune the trolley wire/rail, a treatment that can be applied should the rectifier setback be short, and should it be impractical to install a fixed inductor in series with the rectifier feed wires. The steps are described below:

Step 1: Locate a position about 80 feet along the trolley wire/rail from the place where the rectifier feed wires attach to the trolley wire/rail. Install the test set as illustrated in Figure 12. Request the dispatcher to transmit for about 20 seconds. Switch the capacitor through its values to find a maximum signal level, as indicated on the tuned voltmeter. Note the value with the capacitor in the "off" position and the value of maximum signal and tabulate these values on a mine map. Remove the test fixture and install permanently a capacitor of the indicated value. Request another transmission to verify that the signal improvement observed during the test was maintained after permanent installation.

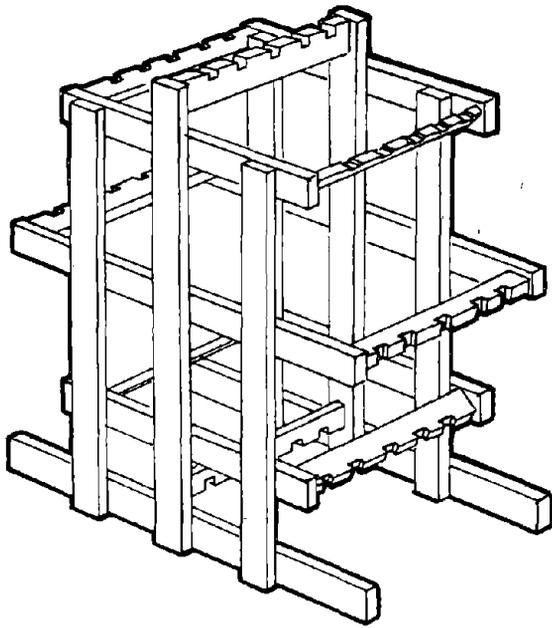
Step 2: Repeat the same procedure as in Step 1, but at a place in the opposite direction along the trolley wire/rail, that is, 80 feet or so on the other side of the feed point. Keep records as before.

Step 3: Return to the first point and measure and record the signal level for a dispatcher's transmission.

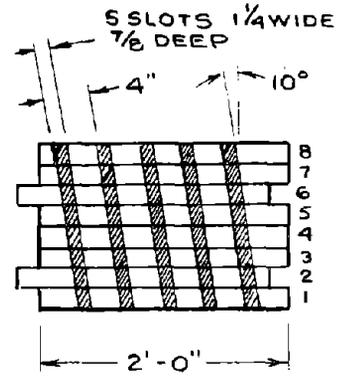
Warning

These procedures are undertaken with the trolley wire energized; therefore they are extremely hazardous. Extreme caution must be exercised to avoid

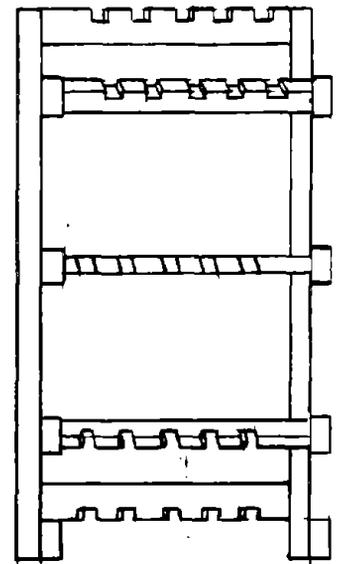
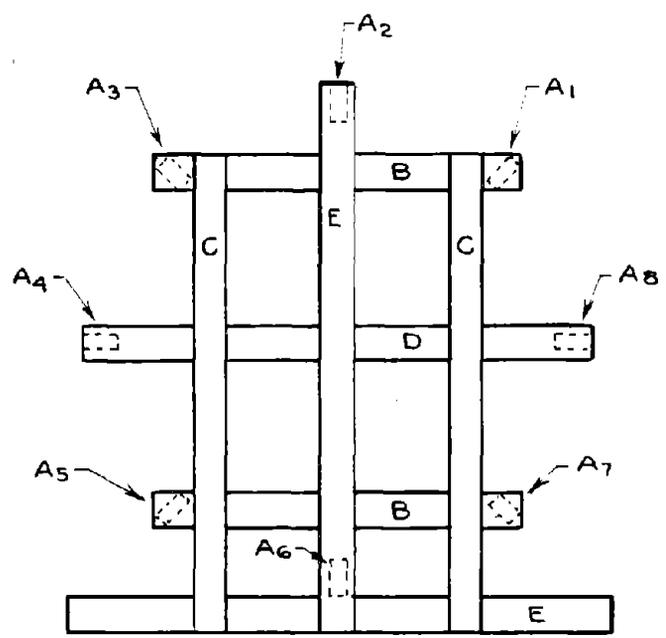




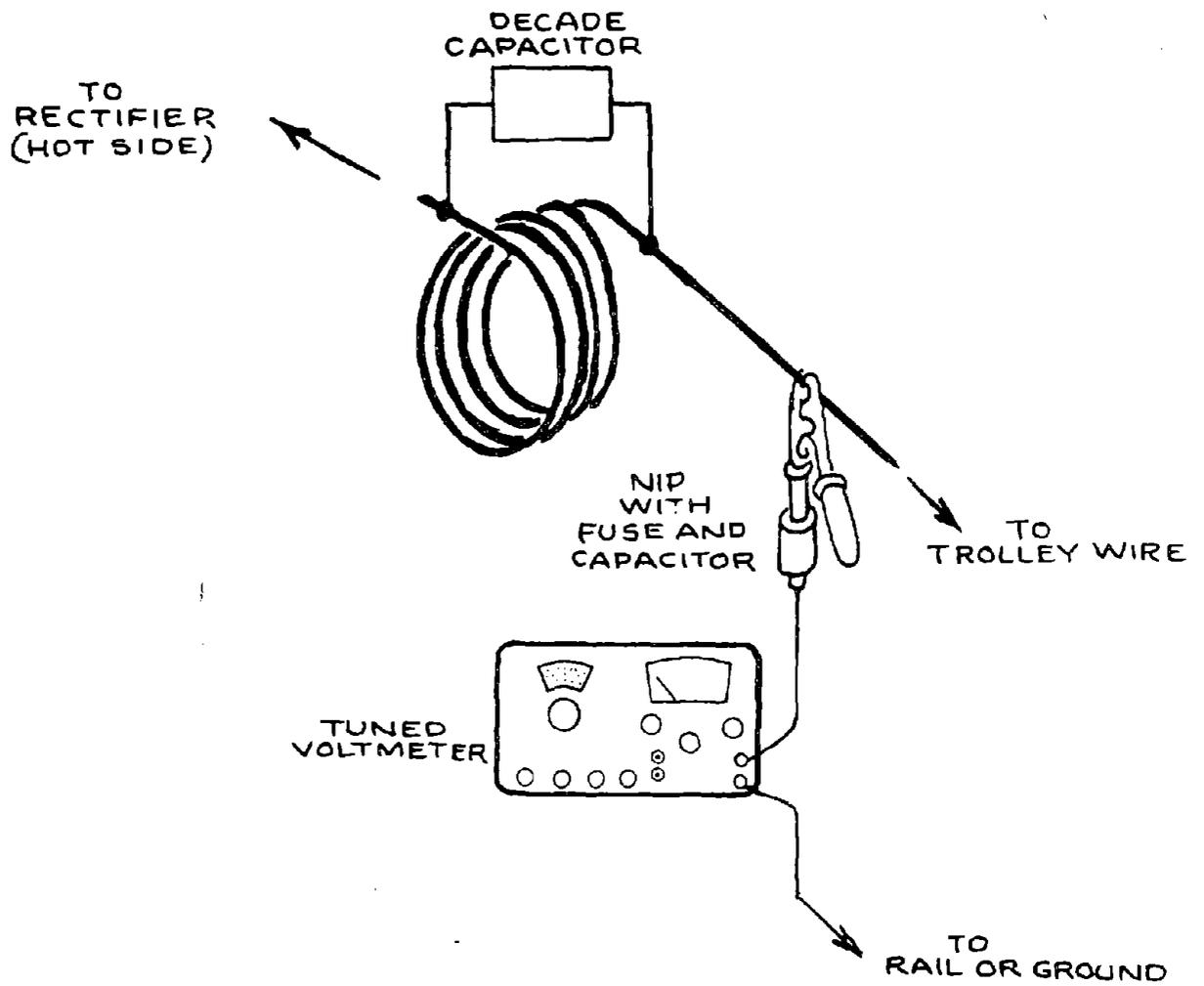
NOTES:
 MATERIAL: 2x4 LUMBER
 DIAGONAL BRACING, OMITTED FOR
 EASE OF DRAWING, IS REQUIRED.



- 8 PIECES A, THRU A₈
- 4 PIECES B @ 3'-0"
- 4 PIECES C @ 3'-11"
- 2 PIECES D @ 4'-2"
- 4 PIECES E @ 4'-5"

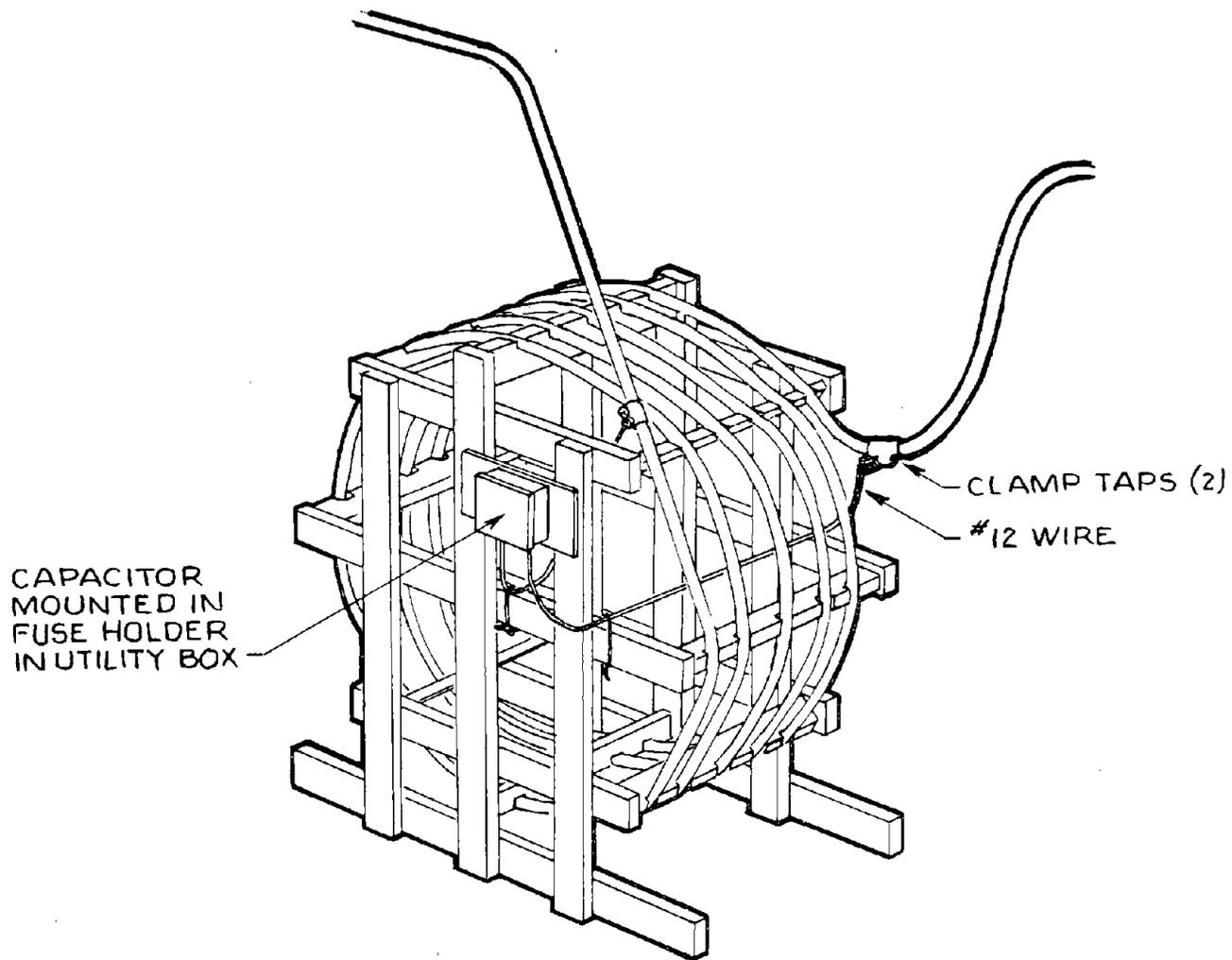


COIL FORM
 FIGURE 9



TEST SET-UP FOR
TUNING FIXED INDUCTANCE

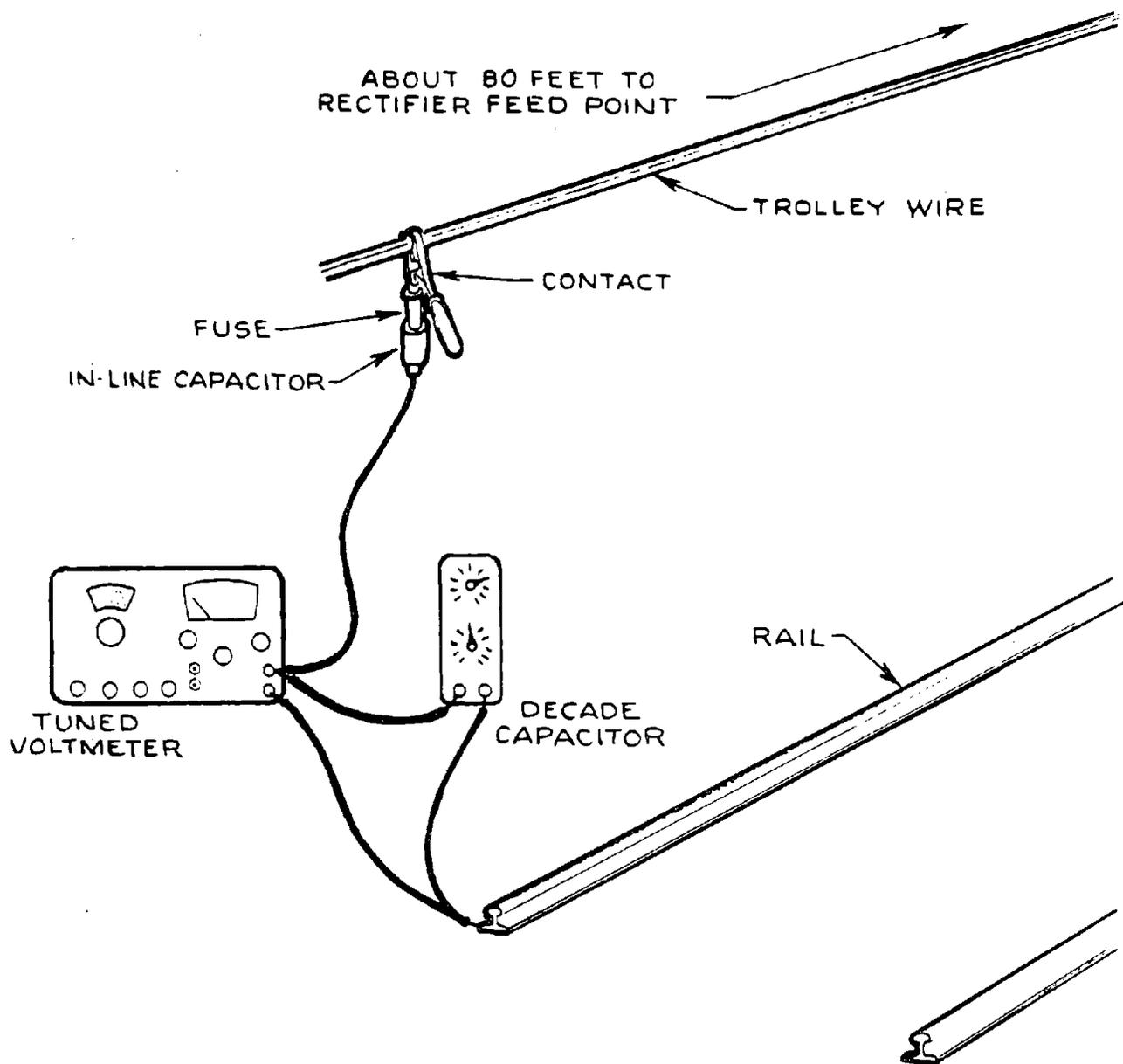
FIGURE 10



PERMANENT ATTACHMENT OF TUNING CAPACITOR TO FIXED INDUCTOR

FIGURE II

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TEST SET-UP FOR
TUNING TROLLEY WIRE/RAIL

FIGURE 12

potentially lethal shock. The fuses used in the test leads serve only to protect equipment and do not in any way reduce the shock hazard to personnel. Only personnel thoroughly familiar with electrical work on trolley wires should conduct the test procedures.

Note: The permanent connection of capacitors should be done with power removed from the section being worked on.

Heaters

Personnel heaters with a wide range of wattage ratings are used; however, 1000 watts is likely to be the lowest, and each heater of this rating, or higher, poses a significant signal loss to the carrier system. Such heaters will range in resistance from 360 ohms for a 1 kW unit on a 600-volt line to 18 ohms for a 5kW unit on a 300-volt line. Current will range from 1.5 to 17 amperes for corresponding conditions. Unlike rectifier currents, these heater currents are sufficiently low that commercial inductors can be used untuned to provide isolation of heaters, thereby avoiding the step of individually tuning each isolator.

To raise the impedance level to 300 ohms using an untuned inductance, requires an inductor of 500 μ H. While it would be convenient to find a single inductor usable for all such loads, the wide range of direct currents that must be handled, 1.5 to 17 amperes, makes such a condition unlikely. It is more reasonable to consider three different values, one for 1 through 5 amperes, another for 5 through 10 amperes, and finally, one for 10 through 20 amperes. Examples of such inductors are shown in Table III.

The procedure for treating personnel heaters is described below: Locate the heater element. Measure the carrier frequency voltage at this load, using the tuned voltmeter and a dispatcher's transmission. Note this value on a mine map. Disconnect the heater and permanently attach the appropriate inductor in series with the element. Reconnect the heater and measure the voltage produced across the heater and inductor in series, using the tuned voltmeter and a dispatcher's transmission. An improvement in voltage of 1.2/1 to 10/1 can be expected. Note the new received voltage on the mine map. Repeat this procedure for each personnel heater.

Vehicle Lights

Mine vehicles, including locomotives, jeeps, and portal buses, all draw substantial power from the trolley wire. Much of this power is used for motive purposes. Motors represent a relatively high impedance at trolley carrier frequencies, particularly for jeeps and portal buses and, to a lesser extent, for locomotives. However, a part of the power is used for headlights on the vehicles. Most conventional vehicles use 150-watt, 32-volt, PAR-type lights for this purpose. The difference between 32 volts and the trolley voltage is taken up with a ballast resistor. A single light circuit of this type presents a resistance of about 50 ohms on a



TABLE III

EXAMPLES OF INDUCTORS AVAILABLE
THROUGH ELECTRONIC SUPPLY HOUSES

<u>Manufacturer</u>	<u>Model</u>	<u>DC Current Rating (AMPS)</u>	<u>Inductance (μH)</u>	<u>Untuned Impedance at 100 kHz (OHMS)</u>
Dale	1H5-100	5	100	62
Dale	1H10-50	10	50	31
J. W. Miller	5256	2	500	315
J. W. Miller	D-7825	2	600	378
J. W. Miller	D-7825-5	5	100	62
J. W. Miller	D-7826	5	570	357
J. W. Miller	D-7827	10	370	292
J. W. Miller	D-7829	20	135	84



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300-volt circuit and about 110 ohms on a 600-volt circuit. Some vehicles use two lights at a time and some only one. Thus, the bridging loads represented by the vehicle lights range from 110 to 25 ohms in value. These values are sufficiently low that treatment is desirable.

The procedure for treating vehicle lights is described below:

Insert a 10-ampere inductor in series with the light circuit of each vehicle. Make sure that the inductor is only in series with the light circuit and is not in series with the motor or trolley phone circuits. Because of the variable conditions faced by the vehicles, it is not of much utility to check the before and after carrier frequency voltages found on vehicles, but the tuned voltmeter could be used for this purpose if so desired.

Other Loads

Other loads can also adversely affect propagation on the trolley wire/rail; e.g., signal and illumination lights. As noted earlier, an individual light bulb, or a string of such lights, does not impose much insertion loss. However, if there are many such units, the aggregate effect could be substantial. A way to estimate whether such lights affect propagation significantly is to count the number of lights on the trolley wire/rail between the dispatcher and the farthest place in the mine. Approximate values of loss versus number of lights are given in Figure 1. If the total loss is less than 6 dB, only marginal improvements will result from treating these lights. If the loss is more than 6 dB, consideration should be given to treating the lights.

It would be a rather unusual situation to find lights that really represented a significant impediment to propagation on a trolley wire/rail. However, when marginal signal levels exist, the lights could well make the difference between marginal and fully usable signal levels.

The most effective way to treat such lights would be to take them off the DC line and operate them from the AC system. This practice is being used in some of the newer mines. In old mines, where AC power is not available, little can be done. In some instances, the power rating of the lights could be reduced, thereby raising the value of the bridging impedance. Fixed inductors could also be used, but would only have small effects because the light strings (typically three: 100-watt, 115-volt lights in series in a 300-volt system) already have a fairly high resistance (approximately 300 ohms for the example above).

Other Miscellaneous Loads

Other loads are comprised of such equipment as pumps and other motor-driven devices. However, these devices generally have high enough impedances and are placed so infrequently that they result in minimal loading effects.



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Extending Carrier Phone Coverage Using an Auxiliary Line

The auxiliary line used to extend trolley carrier phone communication range is either a wire specially installed for this purpose or the pager phone line used in common mode. Better success will be found using the specially installed wire because it serves only for the purpose of extending carrier signal propagation. The phone line has branches, bridging loads and routes that may hinder its use as a carrier line. In addition, because it is a two-wire line, carrier signals placed on it in a common mode fashion can be converted to differential mode and attenuate more rapidly than is desired.

We treat here first the use of a special purpose wire, then the use of the pager phone line.

Use of the Special Purpose Wire:

The procedure for developing a system based on a special purpose line is divided into the following steps:

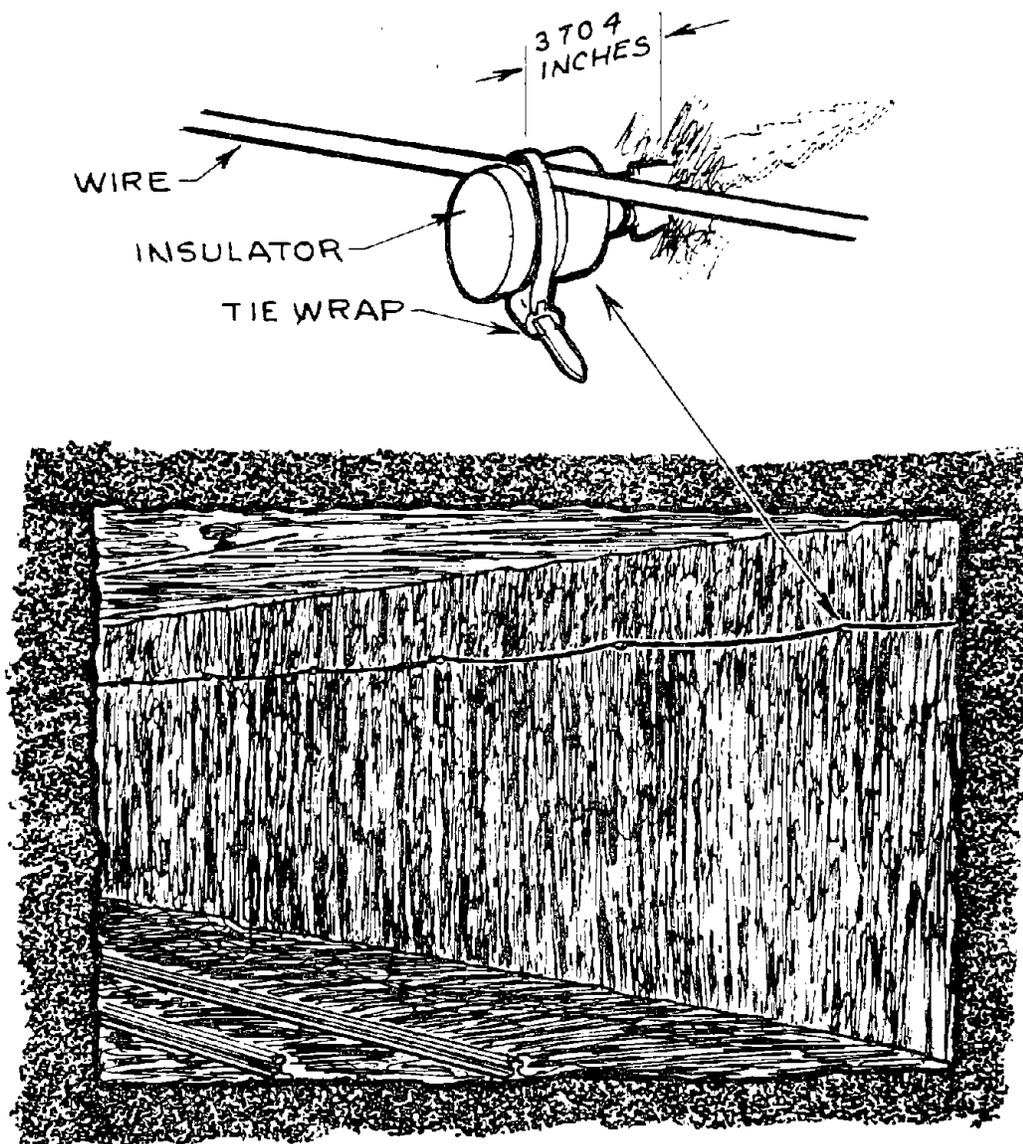
Step 1. Routing: Ascertain from a mine map the coverage desired, considering that the dispatcher position is the key position. Mark out on this map a route for a single line that runs in the same entryway as the trolley wire/rail to which communication is desired. Avoid branches on this route. If necessary, use a second or third such route to cover all regions of the mine. Short sidetracks need not be covered initially. If a branch on the route will cover the desired region with less length of wire, use a branch, but minimize the number of branches.

Step 2. Installation: Install the wire, #10 or #12 wire is well suited to the task. Copperweld construction is recommended for strength and integrity. This wire must be insulated and also held away from the rib or roof by a distance of three or more inches. Installation should be on the wide side and the wire located for least exposure to damage. Figure 13 illustrates a possible installation. At the far ends of each line the wire is terminated by a 200-ohm 10-watt resistor to the rail, as illustrated in Figure 14. If branches are used, signal splitting resistors must be included, as illustrated in Figure 15.

Step 3. Connection of Transmitter: Upon completion of the installation of the special purpose wire, the dispatcher's transmitter should be directly connected to the end or ends of the wire that converge on the dispatcher's station (the return wire of the transmitter should go to earth or to the rail). It is now necessary to determine the signal level that this wire carries into the mine. The signal level can be measured at intervals of one to three thousand feet along the routes. A tuned voltmeter such as the Sierra Model 127C is appropriate for this purpose and is used to measure the voltage

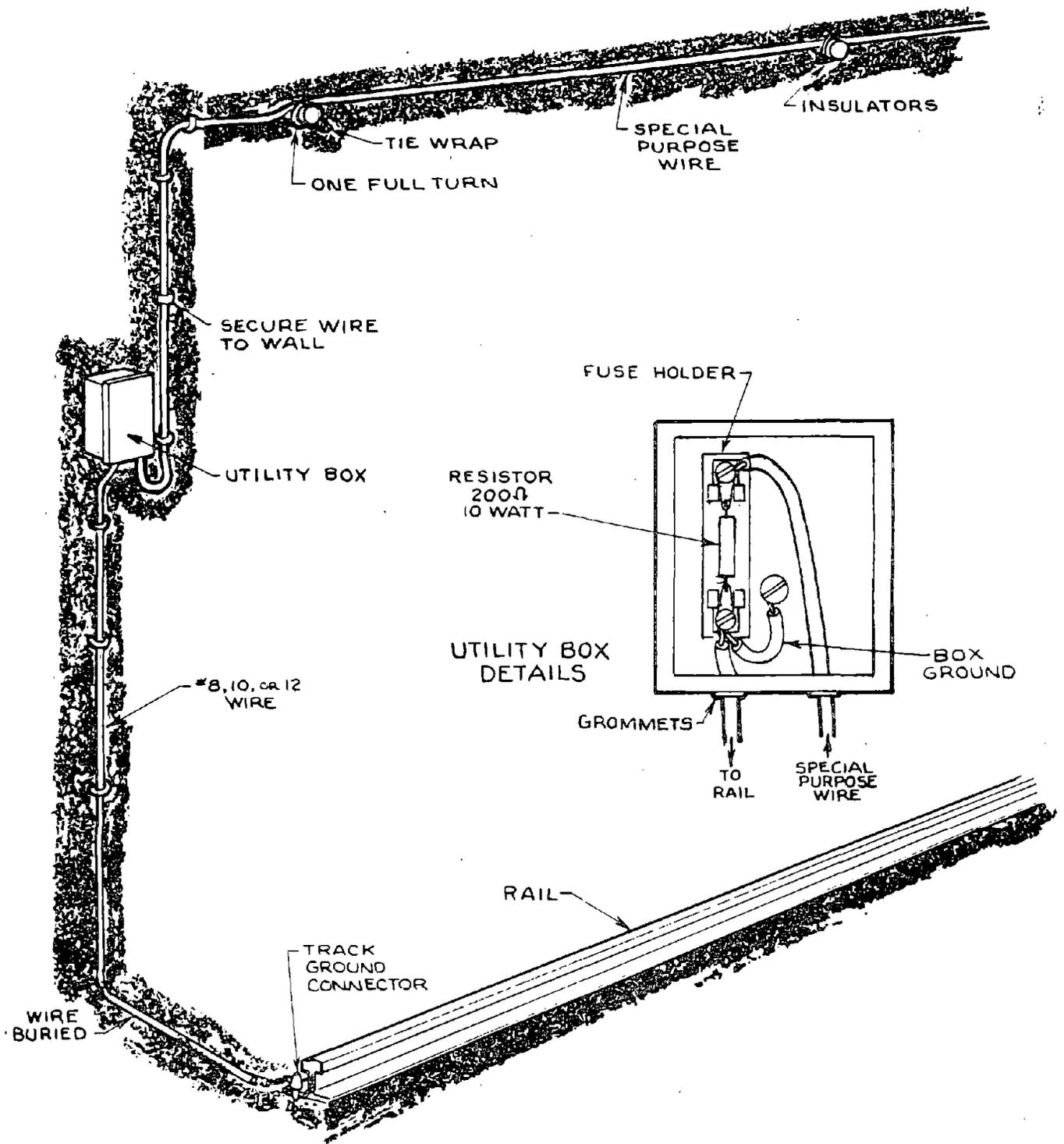


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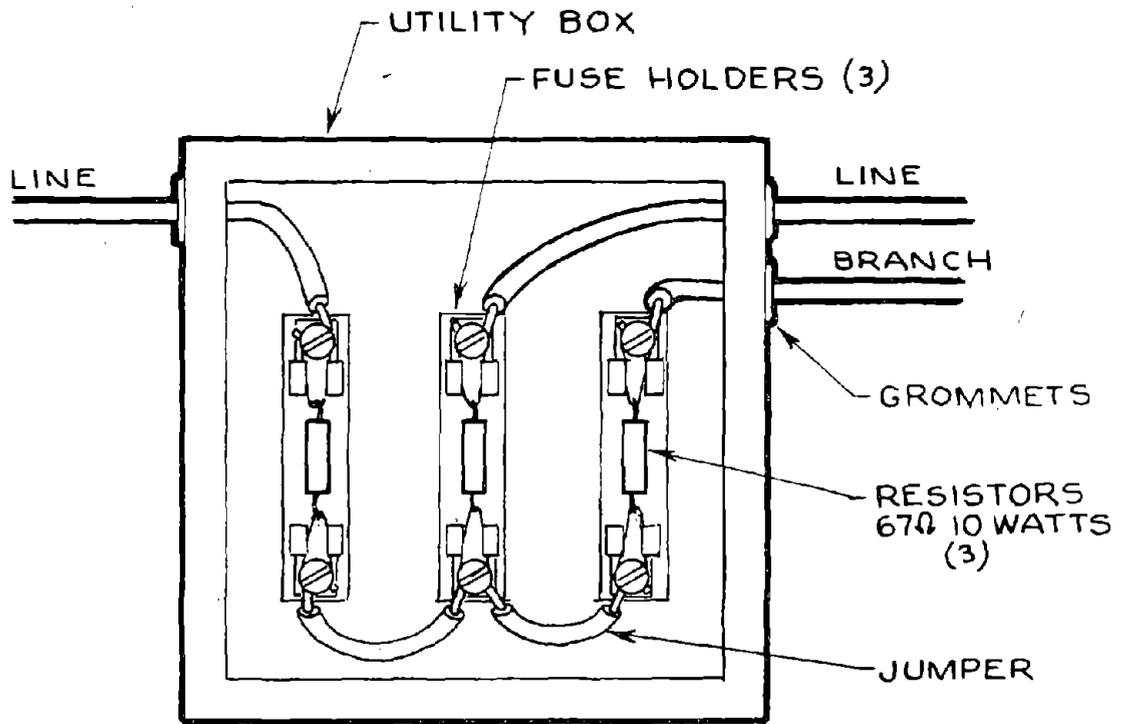
INSTALLATION OF SPECIAL WIRE

FIGURE 13



TERMINATION OF THE SPECIAL PURPOSE WIRE

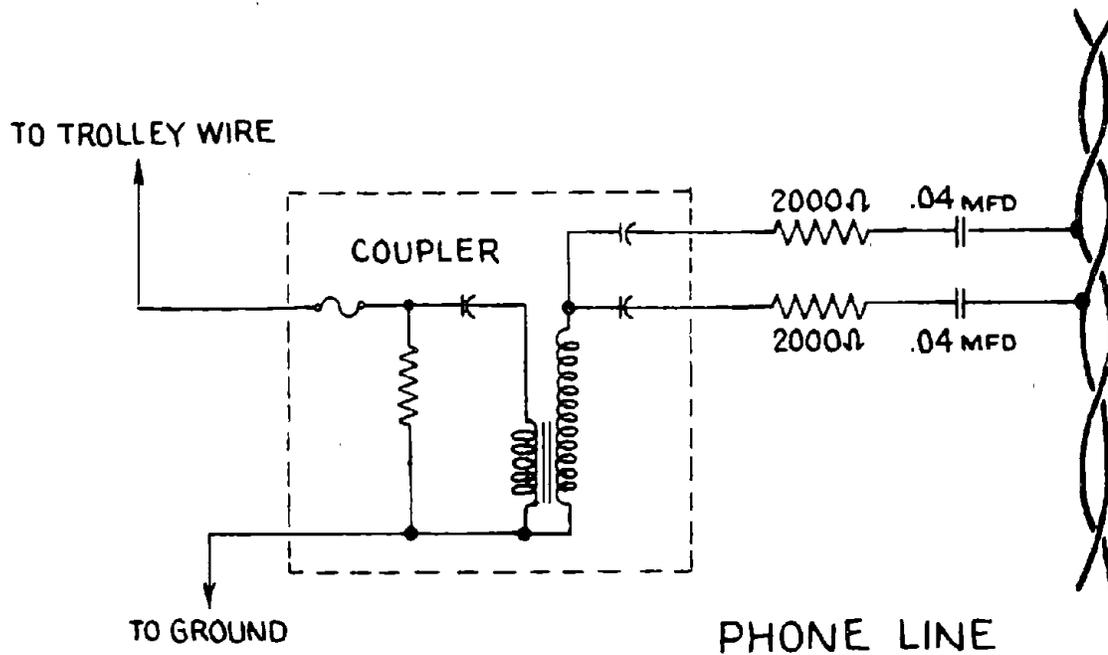
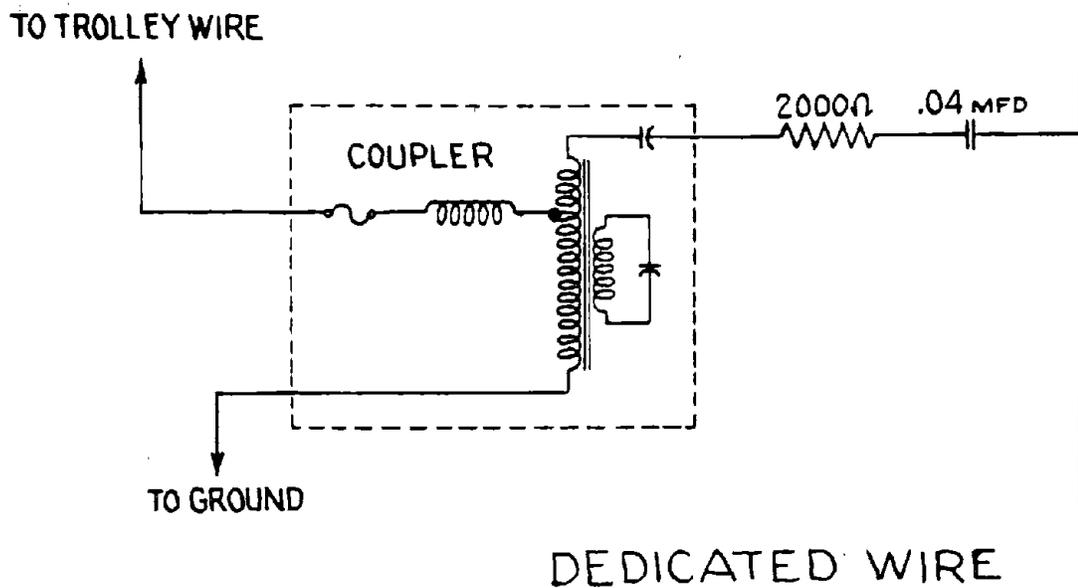
FIGURE 14



SIGNAL SPLITTER

FIGURE 15

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ADDING RESISTORS TO COUPLING NETWORKS

FIGURE 16



noted before that the use of several lines is preferred to placing branches on a line. (When more than one line is used, they should be run in separate entryways.) However, in some instances when the routes are short, considerably less than 10 miles, resort can be made to branches on such a special purpose wire. The reason that branches are undesirable is that a branch reduces the signal level by 2 to 1 (6 dB). On short runs, such a loss can be tolerated, but on runs approaching 10 miles, such a loss may be too much. Signal splitting may be accomplished, as illustrated in Figure 15.

Use of the Pager Phone Line:

The pager phone line may be used to provide a carrier signal path. There are several problems encountered with the use of such lines:

- The route is established and cannot be readily moved.
- Branches are normally present and signal-splitting cannot be controlled.
- Termination possibilities are limited.
- Common mode* signals can change to differential mode and be strongly attenuated.
- Trolley wire noise may be coupled to the lines.
- Hazardous dc voltage of the trolley wire may be connected to the phone line.

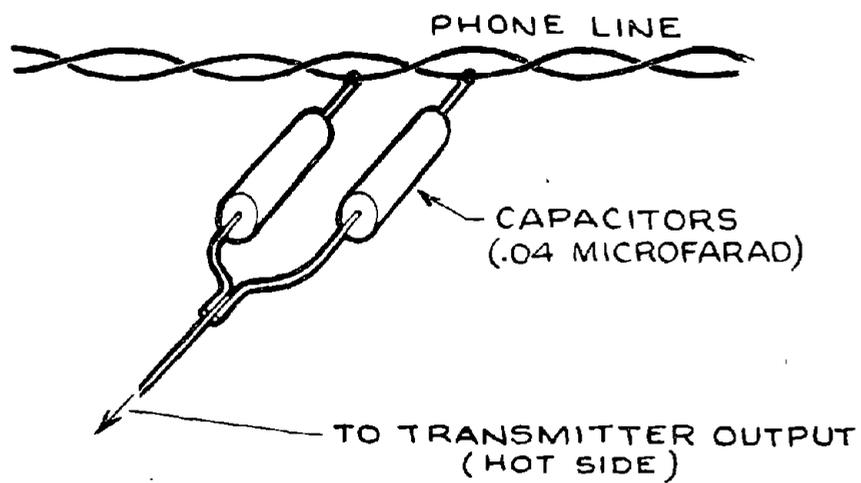
Despite these drawbacks, the phone line is available and can be used. The procedure is quite similar to that of the special purpose wire, but is changed as described below.

1. Connection to the dispatcher's transmitter: There are two wires in the phone line. These are driven in common mode by means of the connection illustrated in Figure 17. The two coupling capacitors have impedances of approximately 33 ohms at 100 kHz, but represent 1000 ohms at 3000 Hz, which is the upper end of the telephone band.

* For our purposes, common mode signals are signals that exist in common on the two wires of the phone line with respect to the rail. These signals have no differential value, that is, no difference in voltage is found between the two wires of the phone line. Thus, common mode signals do not appear on telephone-line loads. It is the common mode signals on the phone line that help extend carrier frequency coverage. An unfortunate fact is that at the carrier frequencies of concern, those near 100 kHz, the phone line can convert common mode signals to differential mode and thus effectiveness in extending carrier frequency can be lost.

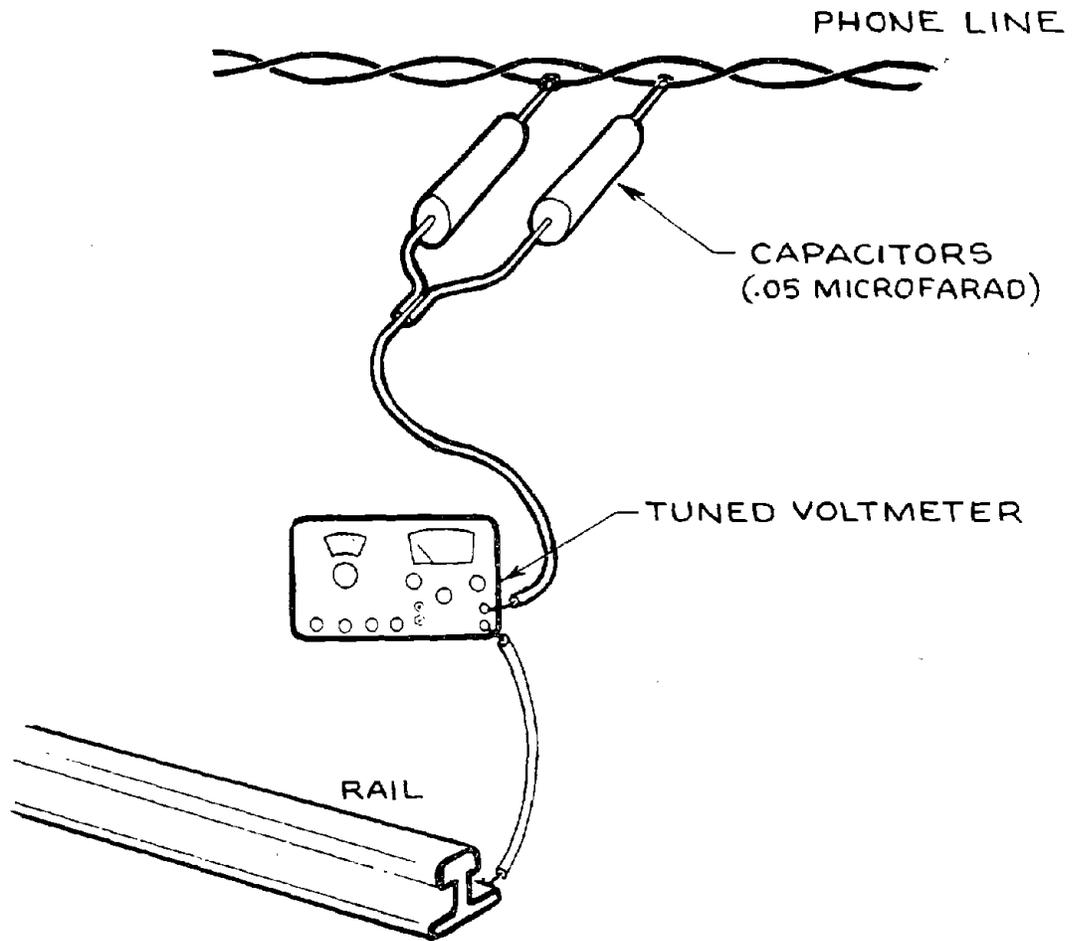


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COUPLING TRANSMITTER TO PAGER TELEPHONE LINE

FIGURE 17



MEASUREMENT OF PHONE LINE VOLTAGE

FIGURE 18

2. Mapping the signal levels on the phone line: The carrier voltage on the phone line is mapped in the same way as for the special purpose wire. The signal must be abstracted for the measurement in common mode using the arrangement illustrated in Figure 18. The measurements are conveniently made at each place where a phone is connected and the wires are available. If it is found that the pager phone line provides a signal level throughout the desired regions of the mine of at least 1 volt in the extreme regions, then the phone line can serve as an effective way of extending the carrier phone coverage. Branches and unterminated line ends can interfere drastically with this expectation due to standing wave effects. If it is found that the signal level is adequate then the next step may be undertaken.

3. Mapping the trolley wire/rail signal level: The trolley wire/rail signal voltage should be mapped. Again, in regions near the dispatcher's office where carrier signal levels on the phone line are high, it can be anticipated that useful levels of carrier signals will be found on the trolley wire/rail. At more remote regions, the level may be less than sufficient (approximately 10 millivolts).

4. Use of signal couplers of the phone lines: Sparing use of signal couplers should be made for the reasons already cited. If there are regions in the extremities of the mine that have marginal signal levels on the trolley wire/rail, couplers may be used to raise the levels. Couplers are applied as illustrated in Figure 16. Again, the couplers should apply a signal level to the trolley wire/rail about 30 dB below that of the phone line, hence, when the phone line has a 1-volt signal level, about 30 millivolts should appear near the coupler on the trolley wire/rail.

5. Mapping the trolley wire/rail voltage: When the installation of couplers has been completed, the signal level on the trolley wire/rail should be remapped and placed on file for future reference.

The Use of a Remote Transceiver

Those familiar with the often difficult problems of obtaining adequate signal levels from a dispatcher's position to the far reaches of an extensive coal mine know how difficult it can be to obtain and maintain adequate communication coverage on the carrier phone system. The examples given in previous sections of this document show only too well the obstacles in obtaining extensive range. Frequently the dispatcher is located at one of the extremities of a coal mine complex. In this instance the communication range must be extensive in order that the dispatcher be able to reach all motormen in the mine system. In some instances a convenient way of solving the dispatcher's problem is to make use of a remote transceiver for his station. The use of a remote transceiver immediately permits the location of that transceiver at the



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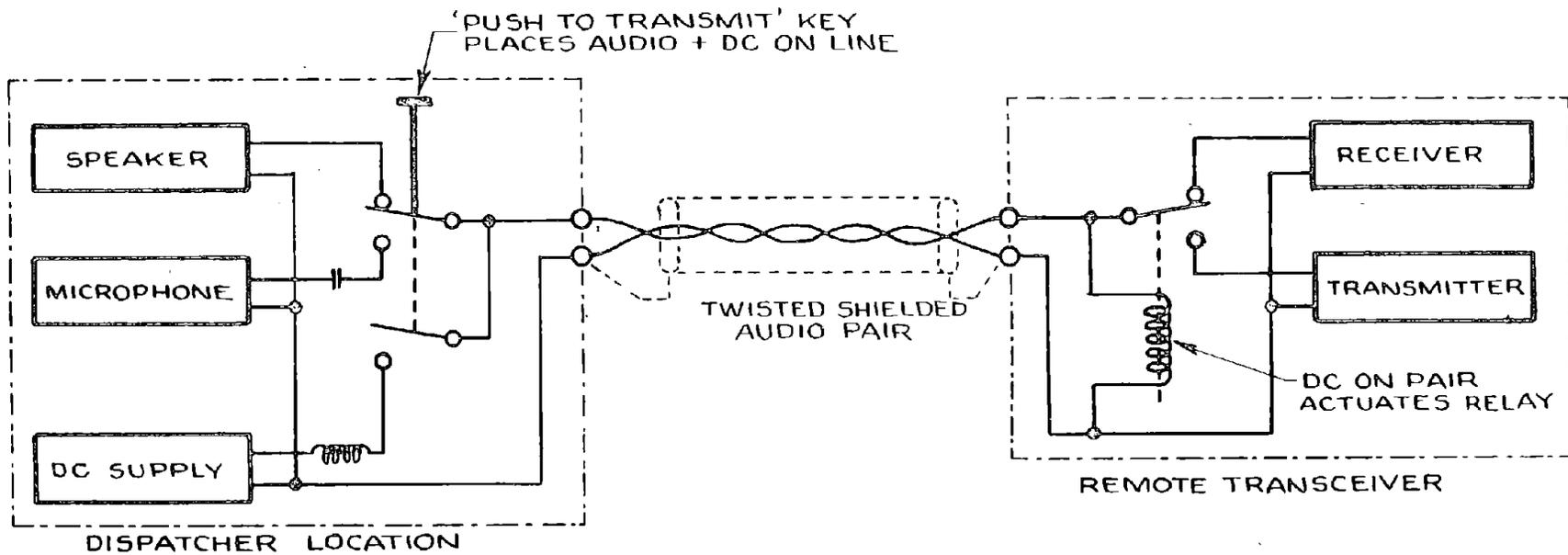
most favorable place for reaching all parts of a mine complex. The location of such a remote transceiver is likely to be near the center of the rail haulage system of the mine, although, in certain circumstances, moving it somewhat away from such a center might produce more favorable results.

As an example of what might be achieved by this means, consider a dispatcher's position for which the signal attenuation is 80 dB from his position to the farthest reach of the mine. This attenuation would imply that an initial 25-volt rms signal provided by the dispatcher's transmitter would be reduced to 2.5 millivolts at the farthest reach of the mine. This level of signal is marginal for many mines and thus the dispatcher would have marginal communication to those motors in the far reaches of the mine. If the dispatcher's position were moved to the center of such a mine, the signal attenuation should drop to one-half, or 40 dB, from this central position to the extremities of the mine. Such a small value of attenuation would provide signal levels of 250 millivolts at the extremes of the mine, one hundred times bigger than that would result if the dispatcher's transmitter were located at an extremity of the mine.

Such a substantial improvement in signal levels throughout the mine would change an otherwise marginal operation into a completely adequately performing communication system. Insofar as the dispatcher is concerned, his operation would remain the same. He would have the carrier phone speaker and microphone located at his dispatching position. The control and audio signals in both directions would be transmitted from his position through a twisted shielded pair to the remote transceiver. Thus, it would be necessary to run an audio cable for whatever distance was necessary to reach the center of the mine. In mines where multi-pair cable is used, it may be that a pair is available for this purpose. If not, the expense and inconvenience of installing such a cable would be justified to assure adequate coverage for the dispatcher's communication system. A block diagram is shown in Figure 19.



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FUNCTIONAL DIAGRAM OF REMOTE TRANSCEIVER

FIGURE 19

PERFORMANCE CHECKOUT OF A MINE TROLLEY PHONE SYSTEM

INTRODUCTION

Vehicle-mounted carrier phones provide voice communication between fixed stations and vehicles operating on the same track haulage system, as well as between vehicles. The trolley wire and the track, which distribute the DC power to drive the vehicle, are also used as the transmission path for this communication system. The carrier phone typically consists of a transceiver assembly, a microphone-speaker assembly, and power-conditioning units; these are sometimes an integral part of the transceivers.

There are many state and federal regulations that affect the installation of phones on vehicles. These include the *Code of Federal Regulations*, Title 30, *Mineral Resources*, Part 75. The major federal regulations that apply to carrier phones are noted below, along with a brief description of the subject matter in each of the relevant paragraphs. The paragraphs of Title 30 cited contain explicit details on these regulations. (This brief description is for reference purposes only.)

- *Power Requirements* (paragraph 75.1600-2 (c))

If the carrier phone system is the only communication system in the mine, then a means must be provided to permit continued communications in the event the mine's electric power fails or is cut off.

- *Grounding Procedures* (paragraph 75.1600-2 (d))

Carrier phones must be grounded in accordance with subpart H. paragraphs 75.701-2,4,5.

- *Examination, testing, and maintenance* (paragraph 75.512 and paragraph 75.1600-2 (e))

Under this statutory provision, frequent examination, testing, and maintenance of electrical equipment found on locomotives and personnel carriers are required to assure safe operating conditions. Also immediate repairs are required on faulty equipment.



EQUIPMENT SOURCES

There are a number of sources for carrier phone communication systems. A partial listing of manufacturers and their latest models follows.

- Battery-Powered Mine Trolley-phone, TM Model 73-1901
Femco Division, Gulton Industries, Inc.
Irwin, Pennsylvania 15642
Distributed by National Mine Service Co. (NMS.)
- Mine Phone, TM Model 1601
Mine Safety Appliances (MSA)
Pittsburgh, Pennsylvania 15235
- Trolley-Comm, TM Model 219
Pyott-Boone, Inc.
Tazewell, Virginia 24651

This listing is intended only as a guide to current equipment and does not imply selection by the Bureau of Mines.

Figures 1, 2 and 3 show sketches of typical units and Figures 4, 5, 6, 7, 8 and 9 are photographs of the various units in an open condition to show more detail of the parts and connectors.

Each of the units above is supplied with an instruction manual and/or maintenance manual. These manuals are devoted to the details of the unit supplied and contain many useful hints for trouble-shooting and performance specifications. It is of the greatest importance for concerned persons to make reference to and be familiar with the details given in each individual instruction and maintenance manual.

Since each of these three designs is intended to perform the same service of communicating over the trolley wire in the mine, certain maintenance procedures, test procedures and performance requirements can be adopted and applied to all trolleyphones.

SUGGESTED TEST EQUIPMENT

Test equipment required for maintenance and performance checkout of mine trolleyphone systems may be divided into two groups. The first group is portable equipment to be used to check out the operation of the trolleyphone while it is still installed in the vehicle and may be used for routine maintenance or diagnostic work on the phone system in the vehicle in order to locate a faulty unit causing malfunctions of the equipment on the vehicle. This equipment is intended to be used either in the maintenance shop when a vehicle is brought to the shop for routine maintenance or repair of malfunctioning equipment or to repair a malfunctioning trolleyphone on a vehicle remote from any maintenance facility.

The second group is for use in the maintenance area for detailed fault finding inside the trolley phone and for a thorough performance checkout of the unit before installation in a vehicle.

Group 1 Test Equipment

- a. A multimeter - the most useful instrument for trouble shooting a mine phone system is a multimeter or universal test meter. This meter can be used for measuring voltages in and around the unit, power consumption, power output and fuse checking. In order to give useful results for transmitter power output measurements, the meter should be capable of operating with frequencies of at least 100 kHz. A meter such as the Triplett¹ 630 ABL, Simpson² volt-ohm milliammeter 270 series 3, or equivalent has such a capability. (Superscripts refer to manufacturer's address list, Page 9.)
- b. Spare fuses - fuses provide an intentionally weakened part of an electric circuit, and thereby act as a safety valve in the event of dangerous overloads. This protects both personnel and equipment from potential fire hazards due to overheating of the carrier phone.

Fuses come in many sizes, types, and electrical ratings. Always use a replacement fuse that has the same characteristics as the one specified by the carrier phone manufacturer.

Table 1 lists the fuses currently used by carrier phone manufacturers. The ratings specify the fuse manufacturer's ratings for interrupt current and maximum operating voltage. The type designation refers to Bussman Manufacturing's fuse classification.

TABLE 1

REPLACEMENT FUSE REQUIREMENTS

<u>Manufacturer, Model</u> <u>Trolley Voltage</u>	<u>Trolley Line Fuse</u> <u>Rating</u> <u>Type*</u>	<u>Battery Fuse</u> <u>Rating</u> <u>Type*</u>	<u>Transmitter Fuse</u> <u>Rating</u> <u>Type*</u>	<u>Convertor Board</u> <u>Rating</u> <u>Type*</u>
Femco, Model 73-1901				
270 VDC	3A, 250V BAF	5A, 125V MDX	2A, 250V ABC	1/2A, 250V ABC
600 VDC	2A, 600V KTK	5A, 125V MDX	2A, 250V ABC	1/2A, 250V ABC
MSA, Model 1601				
250/300 VDC	3A, 600V BCF	6A, 250V BAN		
550/600 VDC	3A, 600V BCF	6A, 250V BAN		
Pyott-Boone				
300 VDC	3A, 600V** BBS	5A, 250V AGC		

*The type number refers to Bussman⁴ Manufacturing's symbol for fuse classification.

**Two required, one for transceiver and one for resistor box.

Other fuse manufacturers make equivalent products that can be used in these carrier phone fuse holders. Check the current and voltage ratings, type, and size to be sure that you have the proper replacement fuse.

A blown fuse generally indicates that some part of the circuit of the trolleyphone has become defective, but occasionally a temporary external overload condition can cause a fuse to blow, hence it is a useful practice to change a blown fuse one time to see if the unit can be brought back into service. Should the fuse blow again, then a more detailed trouble shooting process should be attempted.

- c. A Substitute Unit--each trolleyphone consists of a number of different units interconnected by cables. To facilitate trouble shooting on the vehicle, a fully operational spare set of the type used in the mine should be maintained so that initial trouble shooting can be performed by substitution of the individual units.
- d. Battery Maintenance Equipment--Two different types of battery are used in mine trolleyphones. Both types are lead-acid systems but one type is the conventional wet cell such as is used commonly in automobiles. The other type is called a 'gel/cell'^R.

The test meter described as item (a) can be used to measure the voltage on these batteries.

A specific gravity hydrometer, distilled water for topping off the wet battery, electrolyte for replacing spillage, and petroleum jelly for prevention of corrosion on battery terminals is also required.

In order to recharge batteries which have become discharged, a battery charger is also needed. For the wet battery any commercially available 12 volt battery charger can be used. For the 'gel/cell' a special type of battery charger is required to limit the charging current as the battery becomes charged in order to allow maximum life for the battery. For the 4.5 ampere hour 12 volt gel/cells normally used in mine phones the Globe "gel/cell" GRC 12750M charger or equivalent is recommended. This unit is available from Globe Union.³

^R A trademark of Globe Battery Division, Globe Union, Incorporated, 5757 North Green Bay Avenue, Milwaukee, Wisconsin 53201.

Group 2 Test Equipment

- a. An audio signal generator--to be used for providing a modulation signal. Typical equipment specifications:

Frequency Range - 200 Hz to 200 kHz. Accurate within 10% of dial setting.

Amplitude Response - Flatness of 1 dB over entire range (1 kHz reference).

Attenuation - Adjustable from 0 dB to 70 dB.

Harmonic Distortion - Less than 1% over the frequency range.

Hum and Noise - Less than 0.1% of rated output.

Maximum Output Voltage - 5 V rms open circuit;
2.5 V rms into 600 Ω .

Output Impedance - 600 Ω , single ended.

The Tektronix⁵, SG502 Wavetek⁶ 110, Hewlett Packard⁷ 200CD, 651B or equivalent meets or exceeds most of these specifications.

- b. A function generator--to be capable of generating a frequency modulated carrier signal.

Typical equipment specification:

Frequency Range - 50 kHz to 200 kHz.

Output Amplitude - Up to 10 V p-p across a 50 Ω load, low distortion. May be reduced to less than 1 mV p-p by means of an optional 1000X attenuator.

The Tektronix⁵, FG503 or Wavetek⁶ 111VG or equivalent meets or exceeds most of these specifications.

The 1000X attenuator is available as Tektronix⁵ 067-0529-00 or equivalent.

- c. A digital counter--to accurately measure the output-frequency of item b.

Typical equipment specification:

Display - 5 digits, LED's.

Display Accuracy - ± 1 count \pm time-base accuracy (\pm trigger error in period mode only).

Frequency - AC coupled: 10 Hz to at least 1 MHz.

Frequency (max. resolution) - kHz Positions: 0.1 Hz, 1 Hz and 10 Hz.

Sensitivity - 20 mV rms (56.6 mV p-p).

Triggering Level - Adjustable.

Trigger Source - Internal (rear connector interface) or external (front panel BNC).

Maximum voltage - 250 V (DC and peak AC) at 500 kHz or less.

Impedance - 1 M Ω paralleled by approximately 20 pF.

Internal Time Base

Crystal Frequency	1 MHz
Stability (0°C to 50°C) after 1/2-hour warm-up	Within 1 part 10^5
Long-term Drift	1 part or less in 10^5 per month
Setability	Adjustable to within 1 part in 10^7

Display Time - Variable from about 0.1 s to about 10 s. Detent position at cw position of DISPLAY TIME knob provides a HOLD mode.

The Tektronix⁵ DC504, Hewlett Packard⁷ 5381A or equivalent meets or exceeds most of these specifications.



- d. An oscilloscope - to be used to measure carrier levels, noise levels, receiver sensitivity, distortion, frequency response, and squelch.

CRT	8 x 10 divisions, 0.25"/div. P31 phosphor
Vertical (Y) axis	Dual-trace, 1 MHz; 1 mV to 20 V/ div. alt., chop, and ch. 1 minus ch. 2 modes
Horizontal (X) axis	Triggered sweep 2 μ sec/div. to 0.5 sec/div. with 10X magnifier, 2.5X variable, normal, p-p auto, ext/int trig, single sweep, external horizontal input, variable trigger hold off.

The Tektronix⁵ SC502, Hewlett Packard⁷ 1220A or equivalent meets or exceeds most of these specifications.

BNC-BNC cables are available as Tektronix⁵ 012-0057-01 or equivalent.

Items a, b, c and d are available in a single portable package as Tektronix⁵ part number F5150-N1. If an oscilloscope is already available, items a, b, and c are available in a single bench package as Tektronix⁵ part number F5030-N1.

- e. A non-inductive dummy load to check the transmitter output. These units are normally available in 50 Ω or 75 Ω units. Two units of 50 Ω at 25-watt rating can be connected in parallel to produce the 25 Ω impedance more typical of a trolley line than if a single 50 Ω unit was used.

These are available as Bird Electronics⁸ model number 8080 or equivalent, or from Pyott-Boone, Inc.

- f. Tunable Voltmeter - to measure carrier voltages in the presence of system noise.

Frequency range:	50 - 200 kHz
Bandwidth:	8000 Hz or smaller
Range:	1 mV to 10 V
Power:	Battery

The Sierra Model 127C meets these specifications.



TEST EQUIPMENT MANUFACTURERS' ADDRESSES

1. The Triplett Electrical Instrument Company
Bluffton, Ohio
2. Simpson Electric Company
5200 W. Kinsie Street
Chicago, Ill. 60644
3. Globe Battery Division
Globe Union Incorporated
5757 North Green Bay Avenue
Milwaukee, Wisconsin 53201
4. Bussman Manufacturing Division
McGraw-Edison Company
St. Louis, Missouri 63107
5. Tektronix Incorporated
Beaverton, Oregon 97005
6. Wavetek
9045 Balboa Avenue
San Diego, California 92123
7. Hewlett-Packard
1820 Embarcadero Road
Palo Alto, California 94303
8. Bird Electronic Corporation
30303 Aurora Road
Solon, Ohio 44139
9. L.S.I./Sierra Electronics
3885 Bohannon Drive
Menlo Park, California 94025

ROUTINE MAINTENANCE

Trolleyphone reliability can be increased if a simple program of routine maintenance is performed by the person responsible for the operation of the trolleyphones. Such a program involves the following steps.

Cables

Approximately once per month all cables in the trolleyphone installation should be inspected for any signs of kinking, chafing, cracking, wear, stretching or other signs of physical abuse. Particular attention should be paid to cable glands at the entry or exit points to the various units comprising the trolleyphone, where the cable goes around sharp corners, in the vicinity of holding cleats which may be clamping the cable too tightly causing potential damage, and across the areas where the cable is exposed to physical damage from outside sources, such as boots or falling objects. If a cable is found to suffer from any of the damage described, it should be replaced immediately, a task which will be most conveniently accomplished by replacing the trolleyphone unit to which the offending cable is attached. Obviously, if the offending cable can be unplugged from the unit to which it is attached, then the cable only need be replaced.

It is mandatory that the ground leads and connections be thoroughly inspected and observed to be in good condition, since considerable hazard may exist to the operator or equipment if a ground connection is broken.

Trolleyphone Units

Each of the trolleyphone units should be examined for any external physical damage. All fixing screws must be tight. All connectors and externally accessible fuses should be checked for proper seating.

Microphone

The microphone in the trolleyphone is the most delicate piece of equipment and most liable to abuse by handling or being dropped. The microphone should be examined for evidence of physical abuse. The keying action of the key to operate the transmit relay should be observed by operating the key and listening for the transmit relay inside the transmitter (in units where such a relay is used) to produce a sharp click as the microphone key is depressed. Finally, the microphone transmit quality should be assessed by transmitting a test count to a remote unit where the operator of the remote unit will judge the quality of the sound he receives and report back to the unit being tested so that the receiving quality of the unit being tested may also be assessed.



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Batteries

There are two different types of battery systems used in the trolleyphones. One is a conventional car battery type of wet lead acid cells and the other is a 'gel/cell.' Both types of battery should be tested once a month to insure that they are being maintained in a proper state of charge and that the electrolyte is properly maintained. Note that the 'gel/cell' is also of a lead acid construction; its so-called 'dry' electrolyte system cannot be adjusted since the cell is sealed in such a way as to prevent any electrolyte loss. Over-charging of either of the battery types causes considerable electrolyte loss and both types of battery can be dried out if over-charged for a long period of time.

CAUTION: The electrolyte loss on overcharging also happening to a lesser extent during a normal charge cycle, results in the emission of hydrogen and oxygen from the cells in a ratio which is explosive. Slow emission of such a hydrogen and oxygen gas mixture in the units using 'gel/cells' can create a hazardous mixture of such gases inside the trolleyphone units. Some of the units are vented to prevent a pressure build-up inside the transceiver box containing the 'gel/cell,' but this is insufficient ventilation to prevent possible build-up of a hazardous atmosphere inside the trolleyphone box. Thus, the boxes of the transceiver units in the trolleyphones using 'gel/cells' should only be opened in a well ventilated area where there are no possible sources of ignition of the hydrogen and oxygen mixture, before it is sufficiently diluted by the surrounding air to become harmless. Also, the wet lead acid battery of the MSA units should be placed in a well ventilated area in the vehicle to prevent build-up of pockets of dangerous hydrogen oxygen mixture liberated by the battery when charging or overcharged.

Wet Cell Maintenance

The car-type wet cell lead acid battery as is used on the MSA units is housed in a separate container which, as previously mentioned, should be in a well ventilated area and easily accessible for this routine maintenance program. Each week the level of the electrolyte in each cell should be checked and the electrolyte restored to its proper level by the addition of distilled water. The electrolyte should read a specific gravity of 1.275 on a battery testing hydrometer, when the battery is fully charged and the cell voltage should be measured to be between 2.2 and 2.4 V on the testmeter. Since in normal operation the battery is under continuous charge, the specific gravity and voltage of a battery in good condition should be around the stated values. Values significantly less than this are symptoms of problems either with the battery or the battery charger and should be investigated.

If electrolyte is lost from the battery due to spillage, then a batch of electrolyte should be premixed to the same specific gravity as that of the cell from which the spillage took place. This cell may now be filled to its normal level with the premixed electrolyte.

The terminal posts on the lead acid batteries should be examined each month and cleaned from any corrosion. Petroleum jelly may be used to coat these posts to prevent corrosion. Also, any corrosion of the battery box must be scraped clean and petroleum jelly used to prevent any further corrosion.

Finally, if a vehicle equipped with the MSA trolleyphone is to be taken out of service for some time, then both battery leads should be disconnected to prevent deep discharge of the battery while the unit remains in standby mode. Again, petroleum jelly should be applied to the battery posts and the terminals to prevent any corrosion.

Any battery found to be in a weak condition should be removed for recharging and replaced by a fully charged battery. Should any particular vehicle show repeated problems with the battery, then the battery charger should be removed for check out.

'Gel/Cell' Maintenance

It is not possible to service the electrolyte in a 'gel/cell' since it is sealed into the cell at the factory. Note, however, that even though the 'gel/cells' are sometimes called 'sealed' batteries, they do vent small amounts of hydrogen and oxygen during the charging process which will increase to much larger amounts to be released if the battery is overcharged. Normally, the battery should be charged by what is called a taper-charge process. This means that when the battery is in a discharged condition then the battery charger can apply a comparatively large amount of current to build the charge up in the battery quickly. However, as the battery charge increases, the charging rate should decrease until a point when the battery may be deemed to be almost fully charged when the charging current should fall to zero or maintain a very small trickle charge. This is the function of the special battery charger designed for bench charging of 'gel/cells.'

Each of the two types of trolleyphones using 'gel/cells' has this taper-charge type of battery charger built into it to maintain the cells at a fully charged state, without the hazard of overcharging.

The important parameter to measure for proper 'gel/cell' maintenance is the battery voltage. A nominal 12 V gel/cell is fully charged when it reads 13.80 V across the terminals. This should be the voltage reading when the cell has been fully charged by the operation of its own internal battery charger. Any voltage higher than 13.80 is an indication that the battery is being overcharged, thereby suffering a considerable loss of life due to the drying out of the electrolyte. This also causes generation of dangerous quantities of hydrogen and oxygen gas mixtures as the cell vents. If this is the case, the trolleyphone battery charger should be examined for malfunction.

Alternatively, if the trolleyphone has been left on with the standby current drain, without any battery charging from the trolley wire, it is possible for the battery to become moderately discharged or deeply discharged. A moderately discharged battery can be removed for recharging on the special battery charger described in the equipment list, and generally will not suffer any significant harm. However, if the battery is deeply discharged and stored in this condition for a time without being recharged, the battery may develop a condition where it cannot be recharged and should be replaced.

The battery voltages may be most easily measured in the case of the Pyott-Boone trolleyphone by opening the front cover on the case and measuring directly across the battery terminals with the test meter. This is shown on Figure 8. In the case of the Femco unit, it is not necessary to take the unit apart for routine battery voltage checks. Battery voltage may be measured between sockets B(-) and G(+) on the MIC/SPKR connector. Simply disconnect the MIC/SPKR connector from the transceiver box and insert the test probes of the test meter into the sockets on the transceiver connector labeled B and G and a battery voltage reading can be obtained.

TROUBLESHOOTING ON THE VEHICLE

When an operator reports a malfunctioning trolleyphone, initial diagnosis of a problem can be carried out using only the equipment suggested in Group 1. The repairman may either take his equipment to the faulty vehicle, or the faulty vehicle may be returned to the test and maintenance area.

First, the battery voltage should be checked to make sure the battery has not become discharged. Methods of measuring the battery voltage have already been described in section on routine maintenance. If the battery is found to be good, all external fuses in the unit should be checked. If a faulty fuse is found, it should be replaced with a unit of the proper rating as shown on Table 1 and attempts should be made to operate the unit. If the fuse blows again, then the unit is faulty. It is possible that replacing the blown fuse with a new one will cause the unit to operate properly since a transient overload could have caused the original fuse to blow.

If these steps fail to make the unit operational, then repair by substitution is the most expedient way of getting the vehicle into operation again. Substitution should be in the order of items considered to be more or less vulnerable. Thus, the process should be carried out in the following order:

1. Change the microphone assembly and test for normal operation.
2. Change the transceiver assembly and check for normal operation.
3. Change the loudspeaker unit and check for normal operation.
4. Where relevant, change the battery charger box and check for normal operation.

By these steps, the faulty unit can be isolated and replaced. The faulty unit may then be returned to the repair area for a more detailed examination, including an overall performance checkout after the fault has been isolated and repaired.

On 300 V systems, a test can be made of the transmitter power output onto the trolleyline. A simple method of measurement in the field makes use of the testmeter with the range selector switch set to 50 V AC scale. The black meter lead should be plugged into the common (-) terminal of the meter and the free end connected to the ground. The red lead must be plugged into the meter "output" jack and connected to the trolley wire. The trolley pole must be in contact with the wire. A reading of 15 V or more when the transmitter is keyed indicates normal operation provided the test is made at least 200 feet from the nearest power rectifier that supplies the trolley wire. This test cannot be performed on 600 V DC systems since this voltage will over-stress some components inside the multimeter. In this case, the unit should be returned to the repair shop for a standard bench test. It should be noted that the meter will respond to ripple present on the trolley wire, thus a base reading of up to 10 volts will be shown even with the transmitter off.



TROUBLE SHOOTING AND PERFORMANCE CHECKOUT

IN THE SERVICE SHOP

Since each of the three major manufacturers product lines are significantly different in circuitry details, the best guideline for trouble shooting is to follow the manufacturer's step by step trouble shooting procedure as detailed in his manual. All of the equipment from Group 1 will be available in the test area plus the test set described in Group 2. This equipment will allow all the tests described in the manufacturer's literature and other performance tests described later in this guideline to be carried out by a qualified repairman.

RF Transmitter Power (Figure 10)

For this performance checkout on the laboratory bench, at least two of the non-inductive transmitter loads, that is, Group 2, category e, should be connected in parallel with coaxial cables and connectors. The oscilloscope should also be connected by means of a coaxial cable in parallel with these two loads. The trolleyphone should have all of its units connected together. The trolley wire lead from the trolleyphone should be connected to the center or hot connection of the coaxial cables feeding the loads and the oscilloscope and the ground connections should be commoned through the whole circuit. Under battery power, the transmitter may now be keyed and the output voltage of the transmitter power amplifier measured on the oscilloscope. (In the case of the Pyott Boone unit the toggle switch should be set to the emergency position.)

When the transmitter is keyed, the oscilloscope should show a sine wave at the carrier frequency with an amplitude of 70 V peak to peak showing that the load is absorbing 25 watts of RF power from the transmitter. During this test, the transmitter frequency may also be checked by connecting the frequency counter across the load resistor and operating the transmitter. The counter will directly indicate the transmitter frequency in kilohertz.

Some variation in the RF output voltage is to be expected since there will be slight differences from one unit to another. However, the output voltage should not be less than 50 volts peak to peak.

The effect of line loading can also be determined during this test. If two more 50 ohm transmitter loads are connected in parallel across the first two, the transmitter will now be driving the load of some 12 1/2 ohms. Under these conditions, a reduction in output voltage over the previous measurement is to be expected. It will be normal if the output voltage goes to half the previous value as measured, but it is an indication of trouble if the output voltage is less than this.



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During the whole of this task, battery voltage should be monitored since it is the sole source of energy for the transmitter output. The battery voltage should not fall below 12 volts. If it does, the battery should be replaced with a fully charged battery and the original battery should be recharged.

Receiver Sensitivity (Figure 11)

Measurement of the receiver sensitivity requires all the capabilities of the test set instruments specified in Group 2. The audio signal generator is used as a source of modulating signals for the function generator which provides the carrier signal. The counter is used to measure accurately the frequency of the carrier signal. The oscilloscope is used to measure the amplitude of the signal applied to the receiver input and also the amount of frequency deviation. Thus, the output of the signal generator is connected to the voltage control input of the function generator. The function generator should be set to produce sine waves. The output of the function generator is fed to the input to the counter, the input of the oscilloscope, and also to the input to the 1000X attenuator. The output of the attenuator is connected to the hot trolley lead of the trolleyphone on the bench and the ground lead is made continuous from the trolleyphone ground to the attenuator, oscilloscope, etc.

If the trolleyphone is a 100 kHz unit, the frequency on the function generator should be set at 100 kHz and set at an output signal level capable of being measured on the oscilloscope and the frequency generator. The frequency may now be finely adjusted by careful movements of the frequency control knob to be exactly 100 kHz, as shown on the counter.

Initially, the frequency on the audio signal generator should be set to 400 hz. By adjusting the sweep rate on the oscilloscope to show ten cycles of the carrier wave from the function generator and observing the output of the function generator, the amplitude on the audio signal generator may now be increased to adjust the frequency modulation index. It will be noticed that the sine wave at the extreme right hand side of the oscilloscope display now becomes blurry because the signal is becoming frequency modulated. A frequency deviation of 3% which is the maximum frequency deviation to be produced by a carrier phone can be set by advancing the output level of the audio signal generator until the tenth cycle displayed on the oscilloscope is smeared or blurred for 6/10 of one cycle period as displayed on the oscilloscope. This is shown in Figure 12.

When this signal is fed into the mine phone, a loud tone should be heard from the loudspeaker. The output signal level of the function generator may now be reduced until such a point that the sound output from the loudspeaker either suddenly ceases or becomes noisy with a hissing sound. Remember, there is a 1000X attenuator in series with the trolleyphone; thus, if a 1 volt signal is measured on the oscilloscope,



the trolleyphone is only receiving a 1 millivolt signal. The voltage level at which hiss can be heard is an indication of the sensitivity of the receiver, whereas the voltage level at which the tone suddenly stops is indicative of the squelch setting of the receiver. In some units, the squelch level is adjustable and in other units the sensitivity level is adjustable.

Since signal levels and noise levels in mines are quite different, one to another by nature of the different type of equipment in use, it is not possible to define absolute or ideal values for squelch or sensitivity setting. However, such settings may be determined for the particular mine and class of equipment. If a unit, known to give good performance in all areas of the mine is subject to this test, and the voltage levels recorded, then all other units passing this test satisfactorily and performing as well as the first unit may also be expected to work properly in that mine.

Power Consumption (Figure 13)

The power consumption is most easily measured when the unit is open on the bench for repair and/or calibration purposes. The battery lead may then be disconnected and the test meter placed in series with the battery lead and the battery. With the unit in the standby mode, neither transmitting nor receiving, then a small current drain should be measured from the battery. The standby power consumption should therefore be measured when the transceiver is neither transmitting a signal nor receiving a signal.

The unit should then be set up as for the receiver sensitivity test. When the function generator is supplying a modulated signal to the transceiver and giving tone from the loudspeaker, this is a good standard condition for measuring the receiving signal power consumption. Thus, it may be convenient to measure the receiving signal power consumption during receiver sensitivity measurements.

Similarly, the test to measure the RF transmitter power is also a suitable time to measure the battery current drawn when the unit is transmitting, that is, with the microphone key depressed. A list of figures for typical power consumption for the different manufacturers units is shown in Table 2.

Audio Distortion and Microphone Efficiency

The overall audio distortion of the system is a function of the microphone efficiency, the modulator linearity, the demodulator linearity and the audio output stage of the transceiver.

TABLE 2

TROLLEYPHONE POWER CONSUMPTION

	<u>Standby</u> <u>(amps)</u>	<u>Receive</u> <u>(amps)</u>	<u>Transmit</u> <u>(amps)</u>
Femco	0.03	0.2 - 1.0	3.8
MSA	0.08	0.75 - 1.25	3 - 3.5
Pyott Boone	0.050	1.0	3.6

□

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Audio distortion of the frequency discriminator in the audio output stages can be observed during the receiver sensitivity test. If the oscilloscope is disconnected from the function generator and then connected across the loudspeaker terminals of the trolleyphone units, a sine wave should be observed when the tone is being heard from the loudspeaker. There should be no tendency for clipping of the sine wave peaks nor significant asymmetry of negative and positive excursions of the sine wave.

Also indicative of the quality of the sound capability of the receiver is a test in which the frequency modulation from the audio signal generator is increased from 400 cycles through to 3000 cycles. The amplitude of the voltage across the loudspeaker should be more or less constant up to 800 cycles and then start to decrease until only a small value is observed at 3000 cycles. This small value will be approximately 1/3 to 1/10 of the amplitude at 400 cycles.

There are a number of techniques of measuring microphone efficiency and distortion but unfortunately these generally require an elaborately controlled environment. Therefore, for testing the efficiency and effectiveness of a microphone in the mine, it is suggested that the repairman has, as part of his test equipment, a microphone known to have a good performance. If difficulty is experienced with a unit such that it is producing a high degree of audio distortion, then the receiver section can be checked out as indicated before in this part. The transmitter sending messages may then be checked with the good microphone and its own microphone and a comparison test made. If the good microphone gives good transmission and the original microphone gives poor transmission then the original microphone should be replaced. Note that sometimes a slightly defective microphone will improve performance when shaken. If, however, transmission is equally bad with both microphones, then the modulator should be suspected of being faulty.

Battery Charger Testing

Battery charger testing is the most hazardous test of the trolleyphone. All the previous tests can be carried out while the unit is being powered from its own internal battery. During battery charger testing it is necessary for the unit to be connected to the trolley line. The trolley line has a high and hazardous voltage and great care should be exercised during testing when the unit is connected to the trolleyline.

While all previous tests with the unit operating from its own internal battery can be carried out with the unit open, it is suggested that battery charger tests normally be conducted with the unit closed. This, of course, means that access to the circuit is limited, but two tests are possible.



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The first is that in the Pyott Boone and the MSA unit, large resistors are used to limit the charging current to the battery. These resistors generate a lot of heat and thus the resistor boxes should feel hot to the touch if current is flowing through the resistors. If the resistor boxes are cold, it indicates that no current is flowing through the resistors and the battery charger is faulty.

The second test is to remove the battery fuse from the unit and then restore the connection normally completed by the fuse through the multimeter set to measure amperes. With the trolley disconnected, the meter should show a very slight discharge of the battery due to the standby current, but when the circuit to the trolley wire is completed, a battery-charging current should be seen to flow through the multimeter. Since the value of the current will depend upon the state of charge of the battery, again, no recommended value for this current can be given. Even if the battery is low, however, this current should not exceed one ampere, and, if the unit is in good condition and the battery is fully charged, only a very small current should be flowing.

VERIFYING THAT THE TROLLEY WIRE/RAIL PROVIDES A USEFUL TRANSMISSION PATH

The prime function of the carrier phone system is to provide communication between the dispatcher and motormen on vehicles in the mine. A second function is to provide communication between the motormen.

The first function can only be met if the dispatcher's transmitted carrier signal can reach with adequate signal level to all important parts of the mine and correspondingly if the motormen's transmitted signals can reach the dispatcher from all important places.

The most straightforward method of testing whether the above conditions exist is to determine if the dispatcher's transmitted signal reaches all the important parts of the mine. If it is found that the dispatcher's transmitted signal provides adequate coverage then in most instances, adequate communication from a transmitter at corresponding places in the mine can be expected, but not assured.

The preferred way of testing a trolley wire as a transmission path is to measure the strength of the dispatcher's signal at all important places in the mine. For this purpose a jeep should be outfitted with a battery-operated tuned voltmeter, such as the Sierra ⁹ Model 127C (or, alternatively, a simplified tuned voltmeter such as discussed in the guideline treating special measurement equipment). The low side of the input to this meter should be connected to the frame of the jeep and the high side connected through a 5 ampere fuse and a 0.1 microfarad or larger 1500-volt capacitor to the DC voltage from the trolley pole and connected in such a fashion that the hot side of the capacitor is not exposed to accidental contact by personnel. Assurance should be made that the tuned voltmeter is tuned to the dispatcher's frequency. The jeep should then move throughout the mine, making stops at intervals of 1,000 to 2,000 feet along the haulageways. The measurements of the value of received dispatcher's signal should be entered

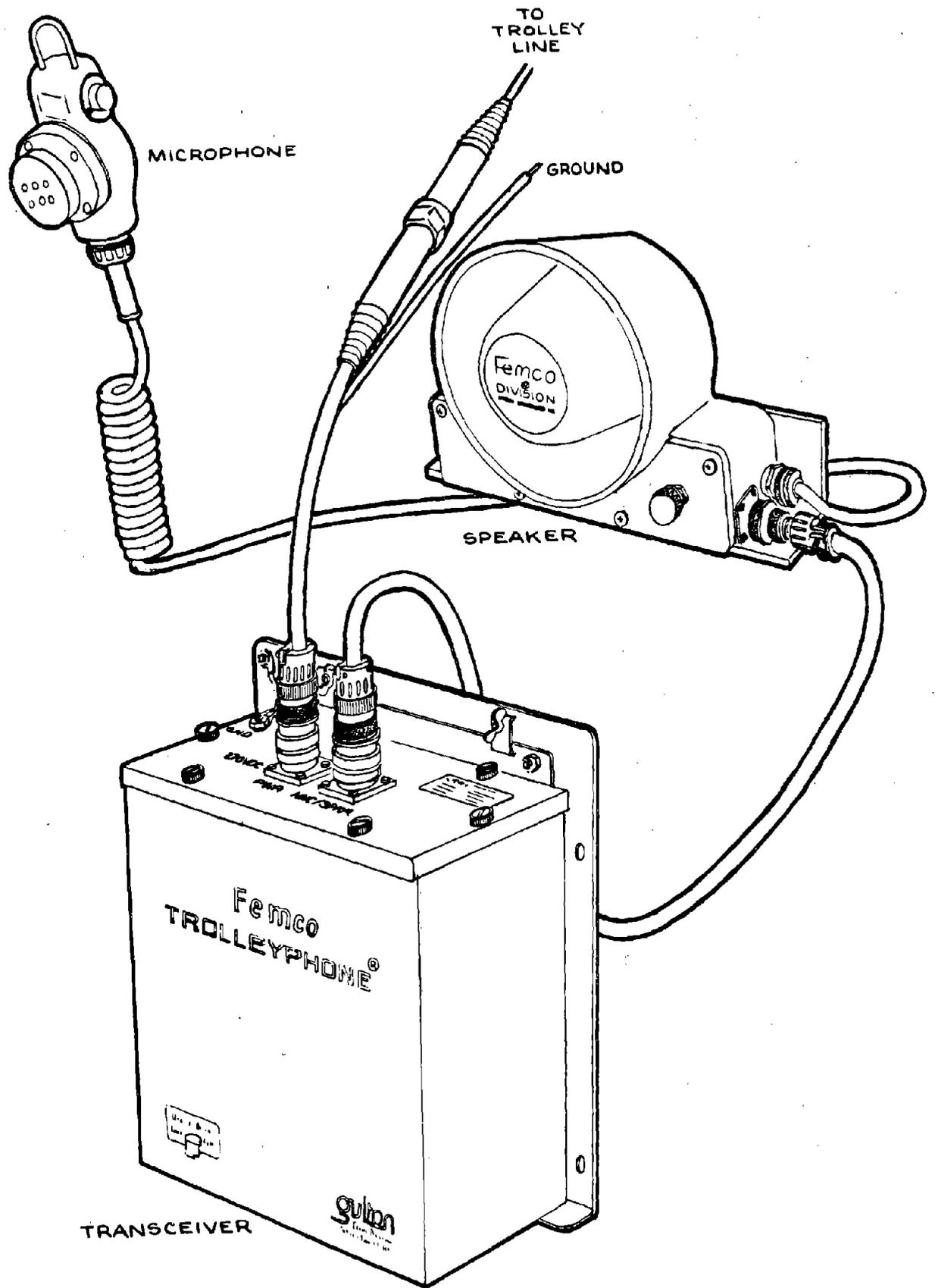


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on a mine map at the places corresponding to the measurement points. This notation will provide a permanent map of signal strength throughout the mine. It is also desirable to enter the level of background noise on this map for the same positions with the same equipment. The resulting signal strength and noise level map can be a powerful tool for later diagnostics concerning changing or deteriorating carrier phone communications. This method of mapping the mine is far more powerful than the simple go-no-go indications that could be obtained by using only the performance of the jeep's carrier phone in determining communication capability. The map will show regions where noise represents the major problem as well as regions where weak signals are the problem. The map also provides a bench mark to compare redistributions of signals that occur as mining advances or deterioration of communication capability that sometimes occurs.

With a signal strength map prepared in this fashion, one has a verification of the capability of reaching the various parts of the mine. One also has an indication of places where marginal performance due either to excess noise or weak signal can be expected. The means of treating these problems are covered in another guideline and are not considered here. Should problems of excess noise or weak signal be found during the verification tests that guideline should be consulted.

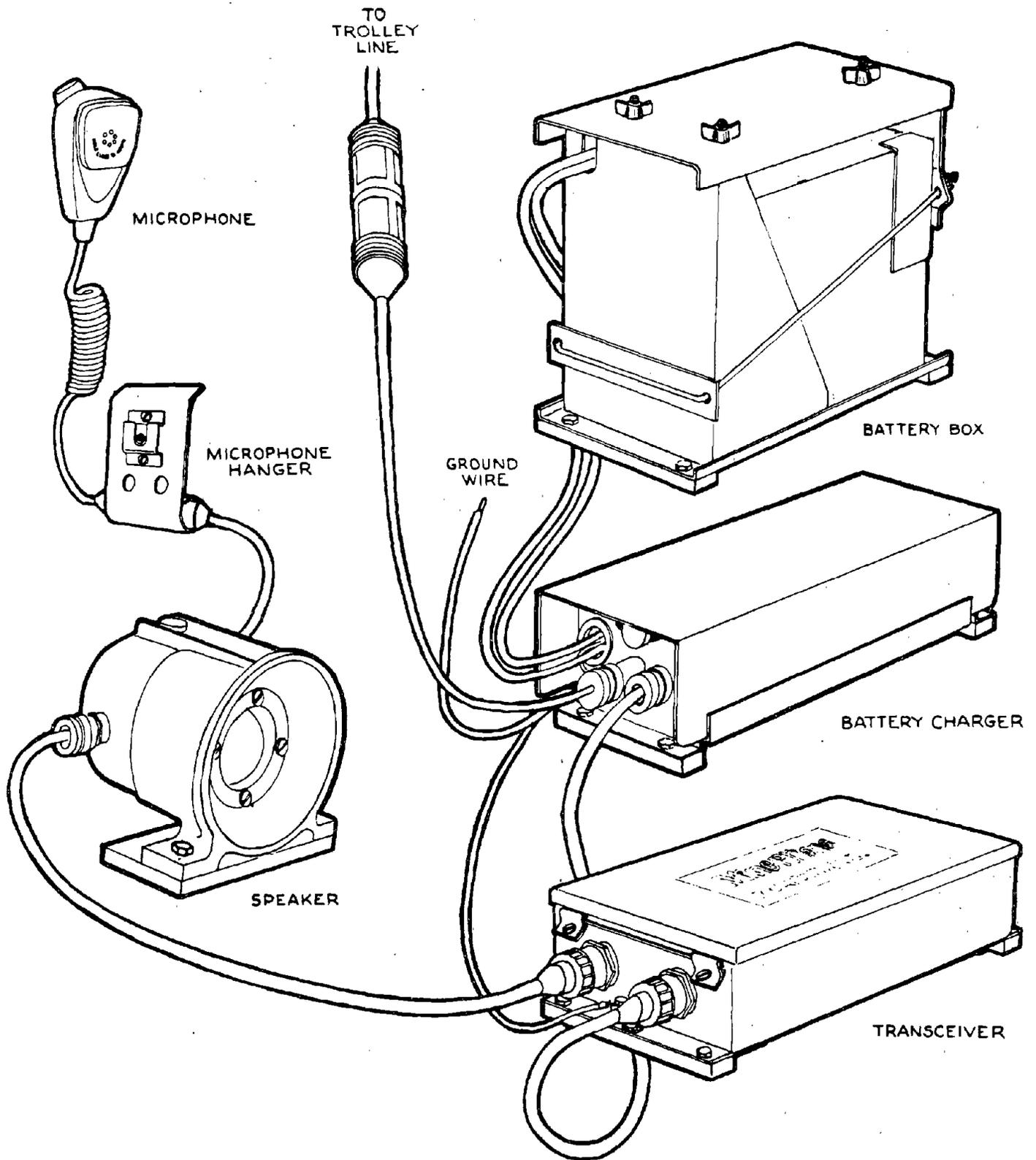




FEMCO TROLLEY PHONE MODEL 73-1901
CARRIER PHONE

FIGURE 1

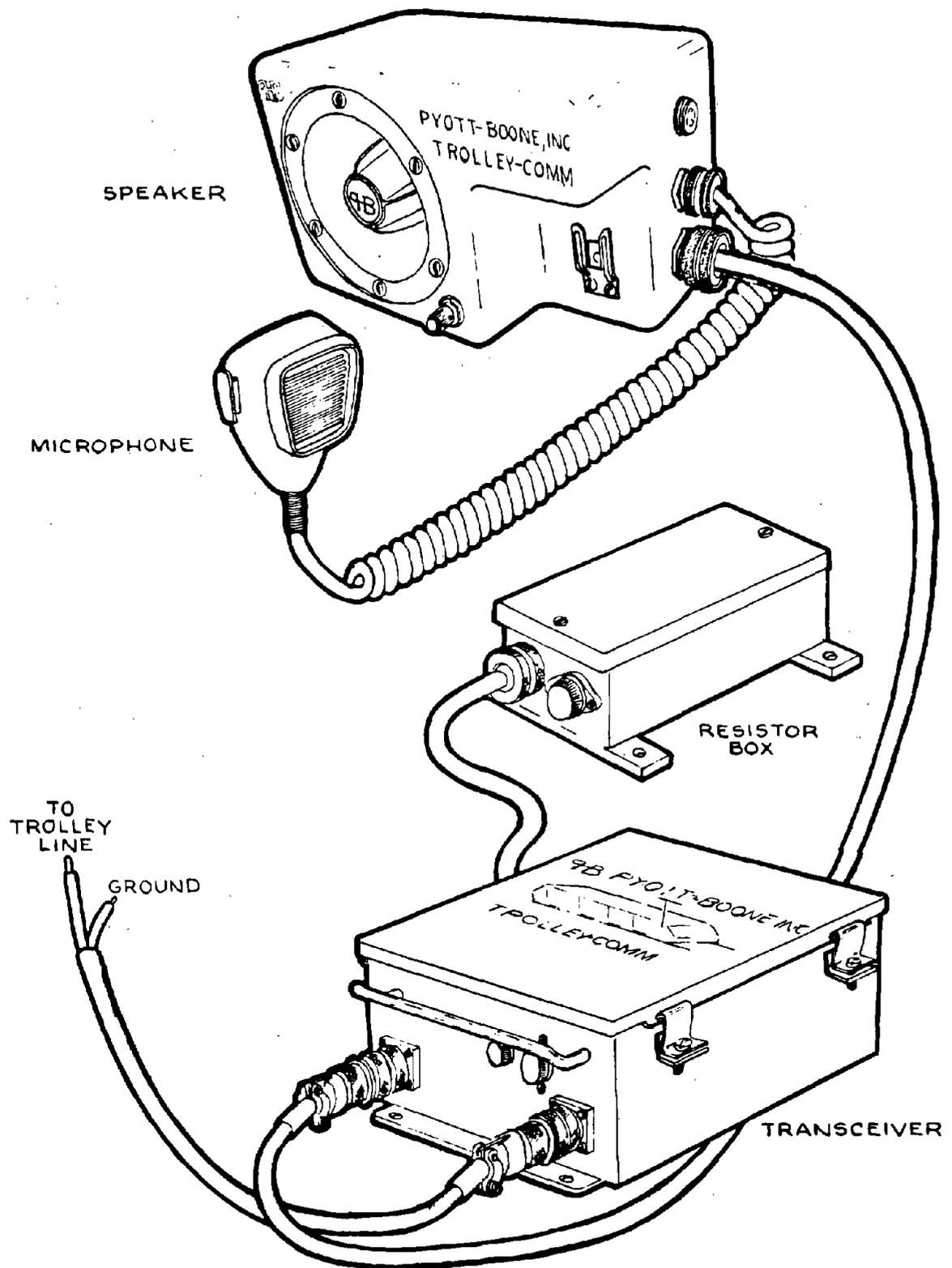
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MSA MINE PHONE MODEL 1601
CARRIER PHONE

FIGURE 2

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PYOTT-BOONE TROLLEY-COMM MODEL 219
CARRIER PHONE

FIGURE 3

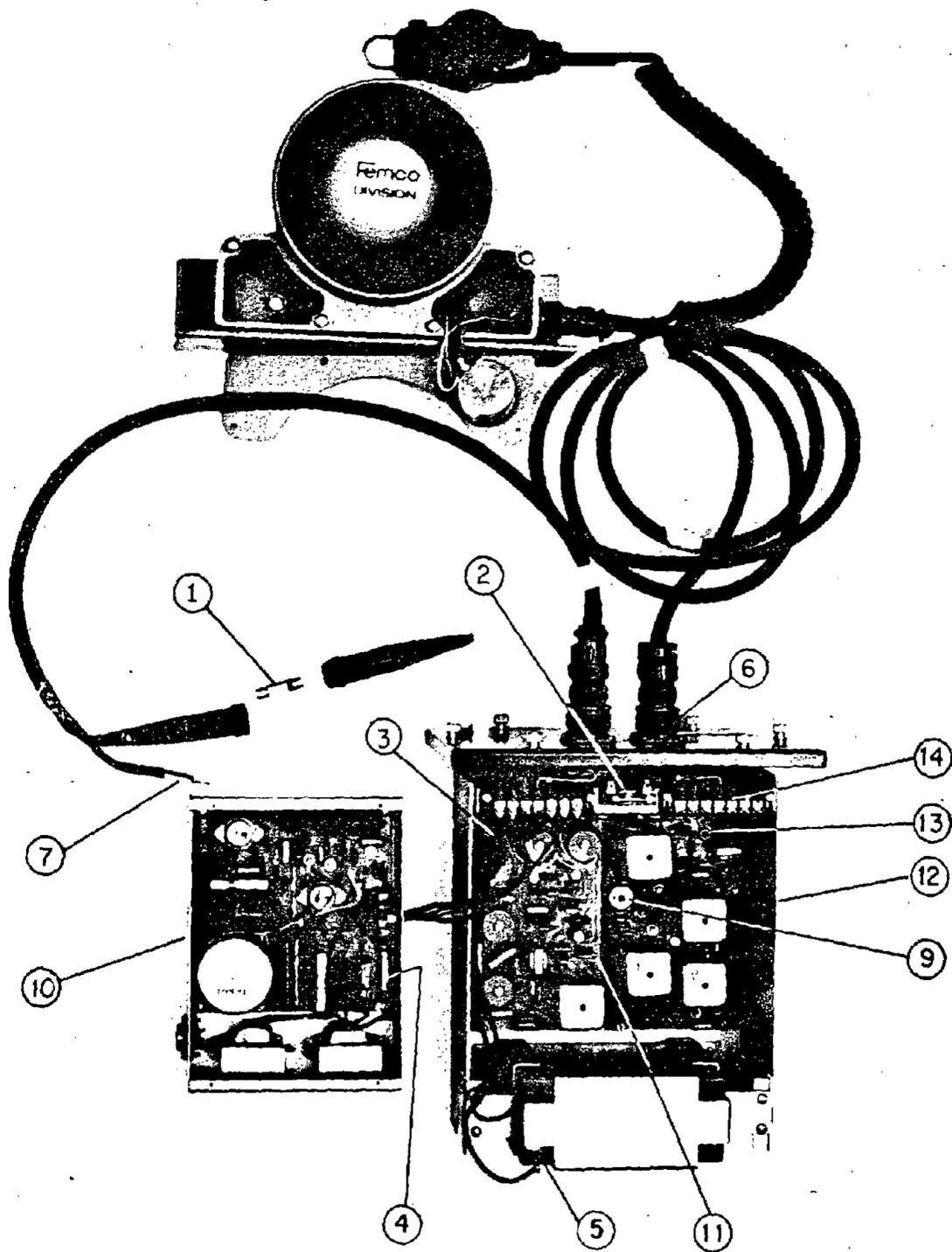


FIGURE 4. COMPLETE FEMCO UNIT OPENED UP FOR SERVICE.

Figure 4 Legend

- ① 3A 250V (270V DC model) fuse
2A 600V (600V DC model)
- ② 5A 125V fuse
- ③ 2A 250V fuse
- ④ $\frac{1}{2}$ A 250V fuse
- ⑤ 'Gel/Cell' battery terminals
- ⑥ Measure battery voltage on this MIC/SPKR connector on transceiver between sockets B(-) and G(+)
- ⑦ Leads to ground and trolley wire
- ⑧ Terminals to measure signal across loudspeaker for distortion
- ⑨ Sensitivity/squelch control
- ⑩ Power conditioning unit/battery charger
- ⑪ Transmitter board
- ⑫ Receiver board
- ⑬ Talk-back control jumper
- ⑭ Audio (loudspeaker drive) output on terminals #5 and #6 (#5 is common)

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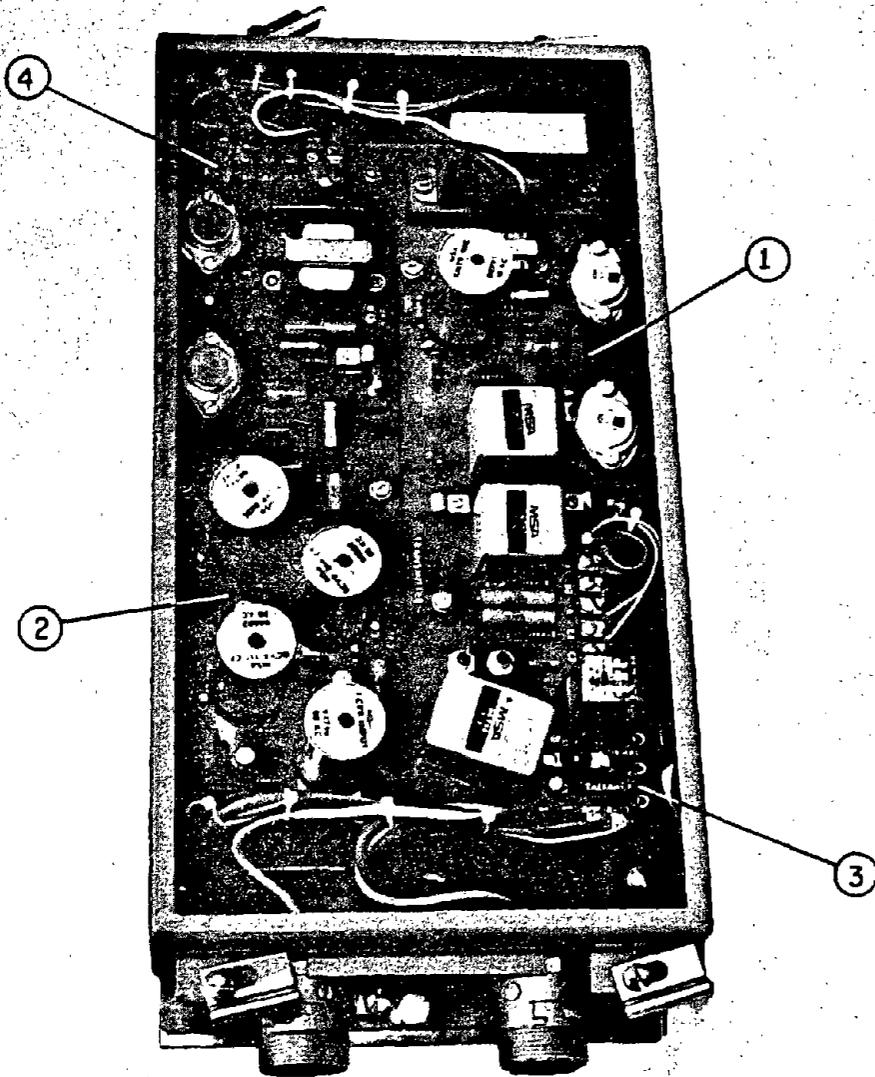


FIGURE 5. MSA TRANSCEIVER UNIT OPENED FOR SERVICE.

Figure 5 Legend

- ① Transmitter board
- ② Receiver board
- ③ Sensitivity/squelch and talk-back jumper
- ④ Line drive impedance jumper

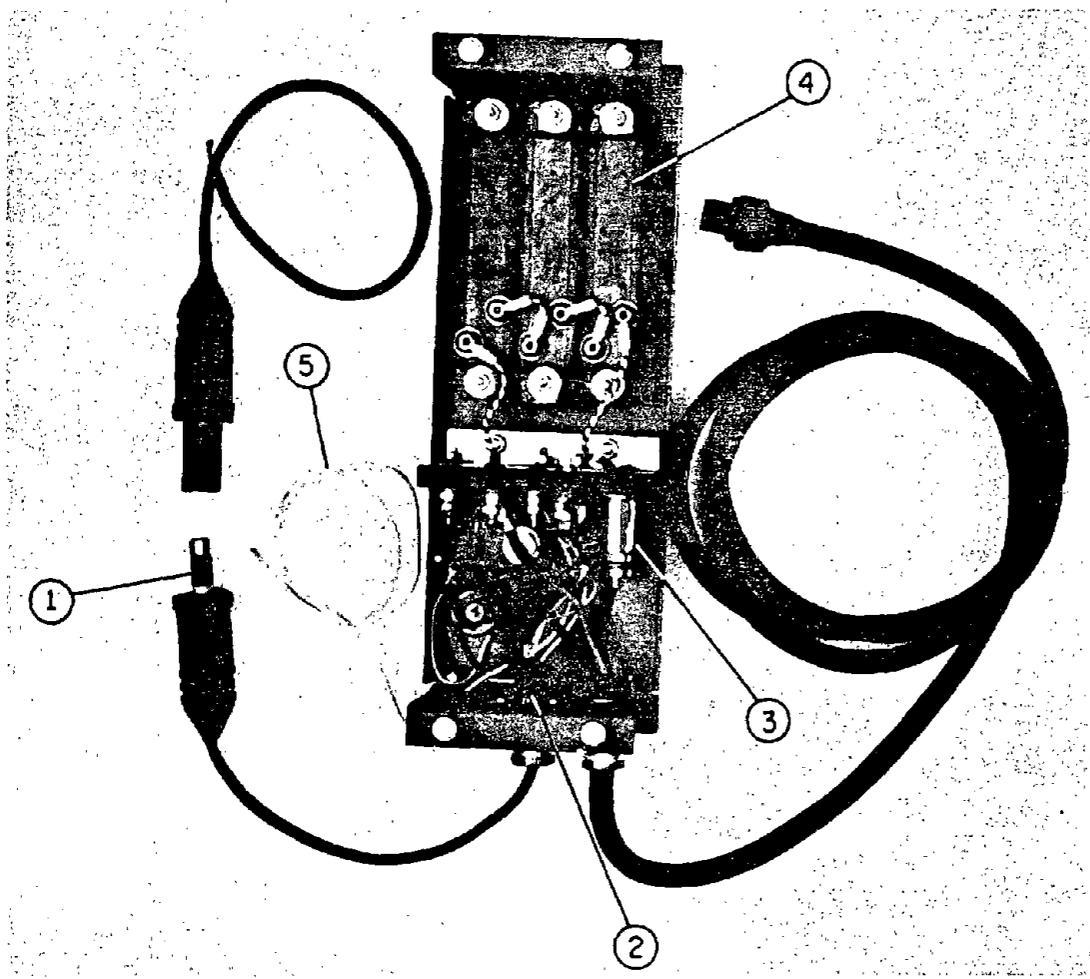


FIGURE 6. MSA BATTERY CHARGER UNIT
OPENED FOR SERVICE.

Figure 6 Legend

- ① 3A 600V fuse
- ② 6A 250V fuse
- ③ Battery connection posts
- ④ Current-limiting resistors for battery charging, 120V, 150 watts
- ⑤ Ground wire

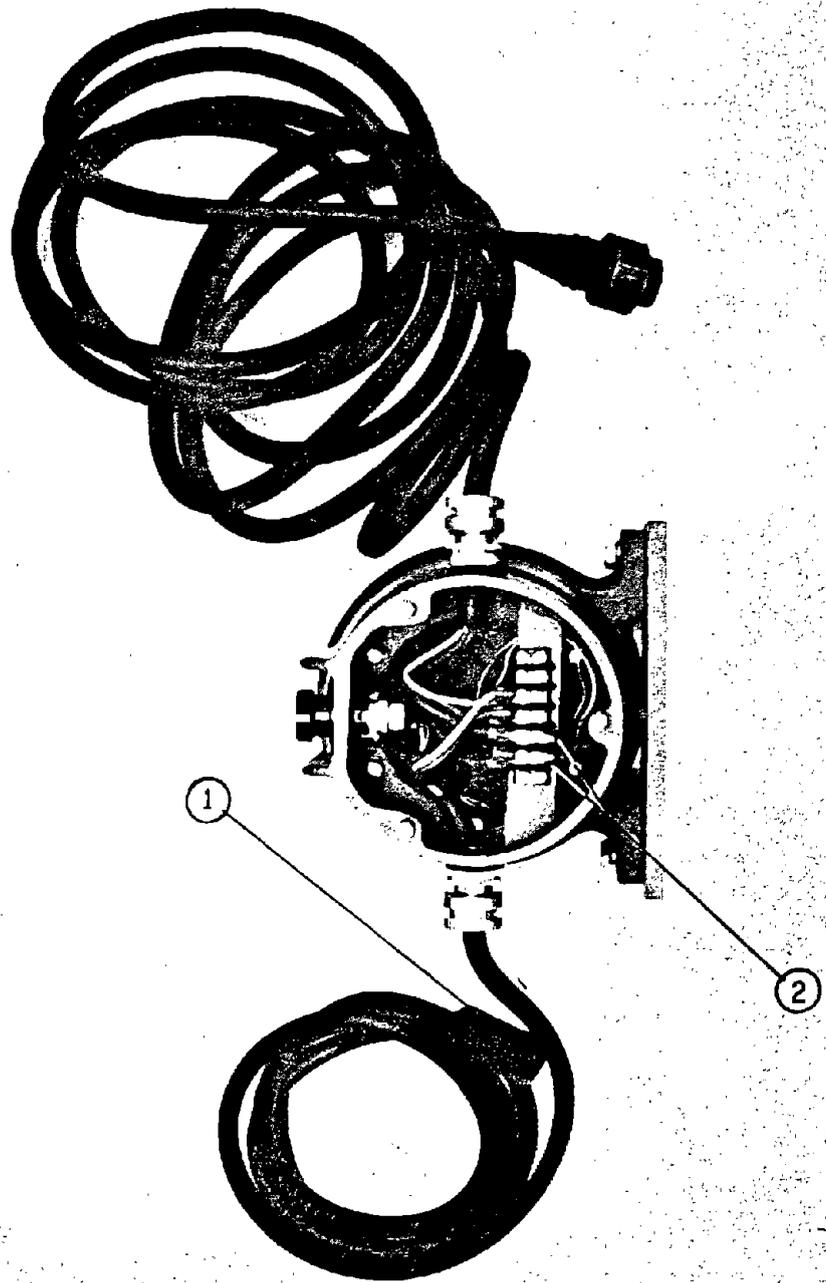


FIGURE 7. M S A SPEAKER BOX OPENED FOR SERVICE.

Figure 7 Legend

- ① Microphone connector
- ② Loudspeaker terminals (#1 and #2)

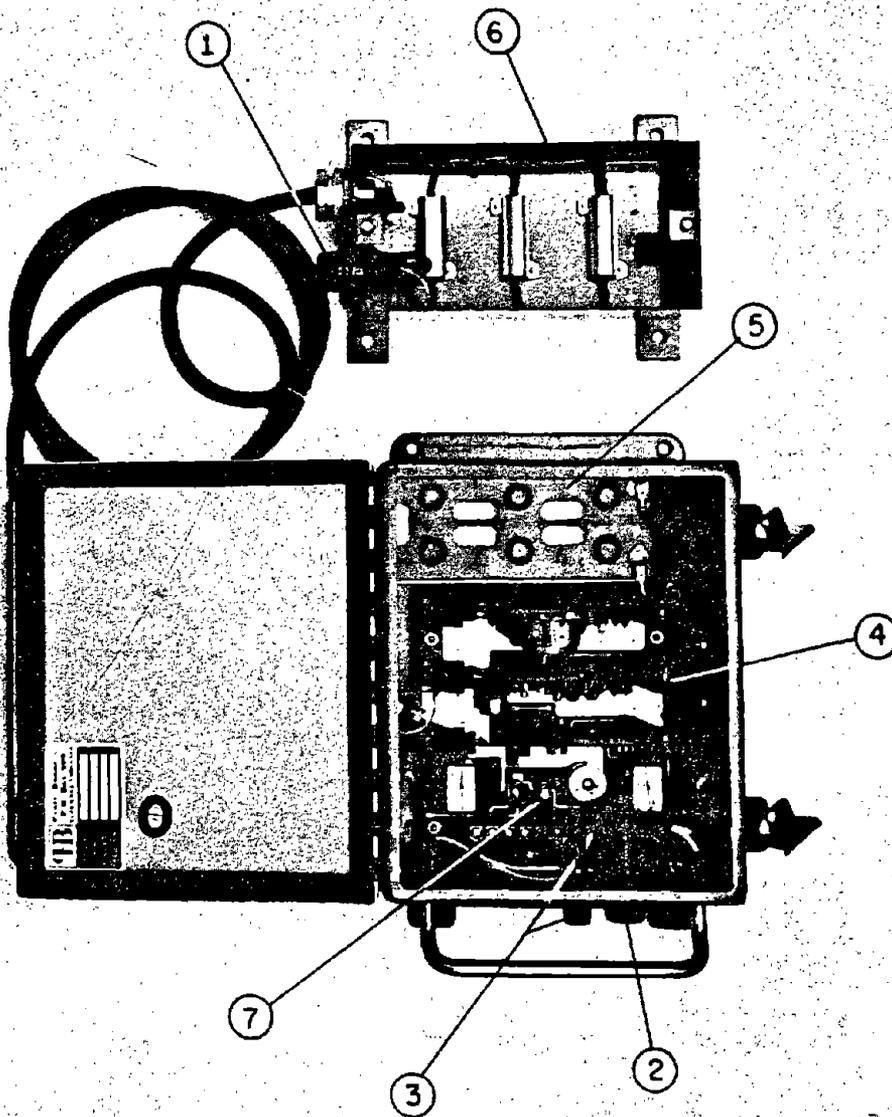


FIGURE 8. PYOTT-BOONE TRANSCEIVER AND BATTERY CHARGER BOX OPENED FOR SERVICE.

Figure 8 Legend

- ① , ② 3 amp, 600V fuse
- ③ 5 amp, 250V fuse
- ④ Printed circuit cards
- ⑤ 'Gel/cell' battery
- ⑥ Resistor box for battery charger (contains
3 x 330 Ω 50 watt resistors)
- ⑦ Emergency operating switch to allow the
unit to run from battery power only

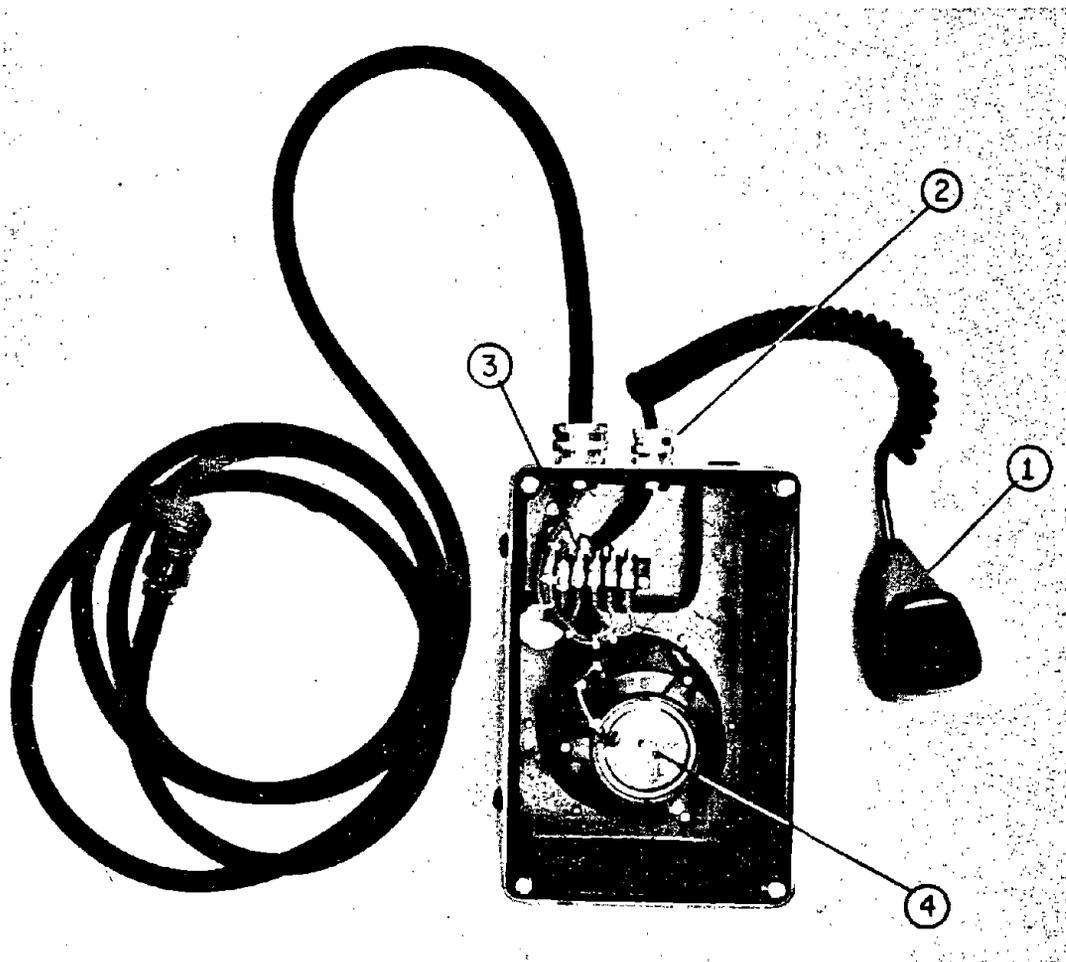


FIGURE 9. PYOTT-BOONE LOUDSPEAKER AND MICROPHONE ASSEMBLY.

Figure 9 Legend

- ① Microphone
- ② Microphone bushing - must be uncoupled to allow microphone to be changed
- ③ Microphone terminals
- ④ Loudspeaker terminals



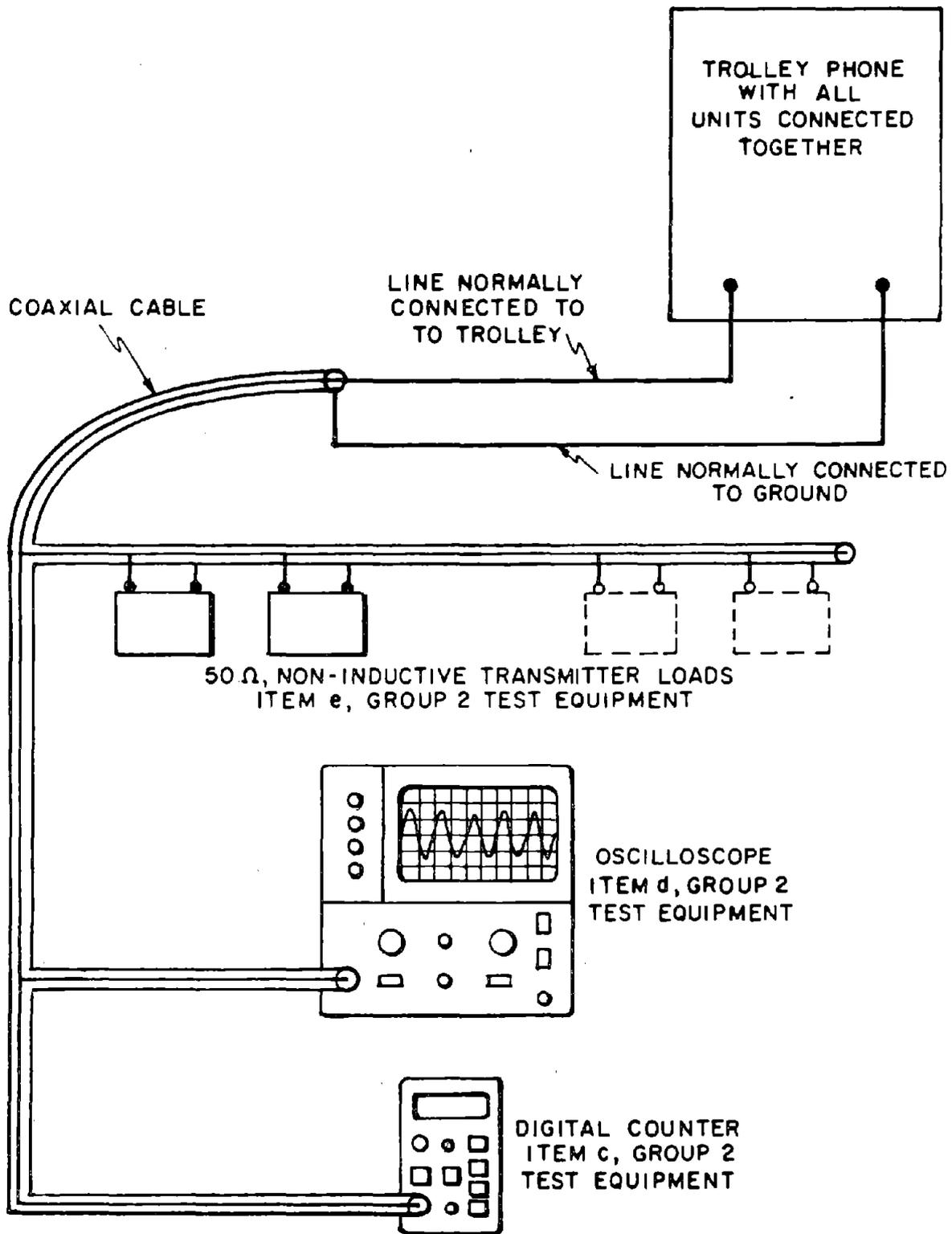


FIGURE 10. RF TRANSMITTER POWER TEST SET-UP.

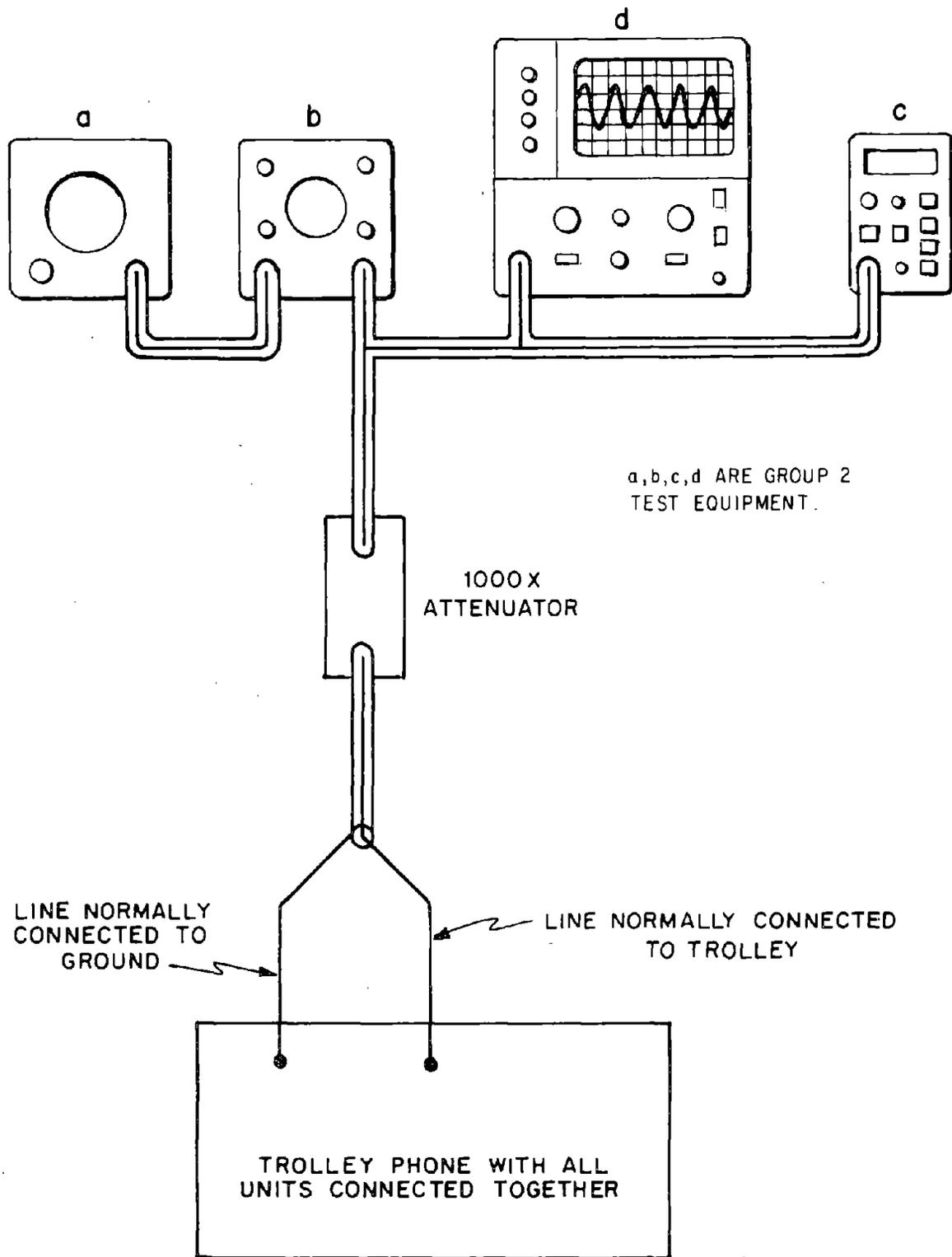


FIGURE 11. RECEIVER SENSITIVITY TEST SET-UP.

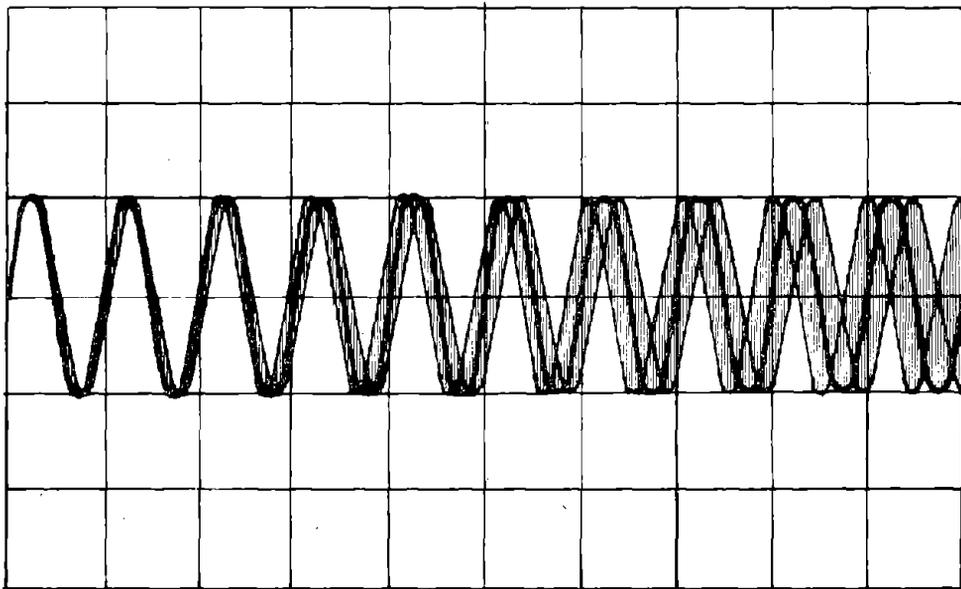


FIGURE 12. SKETCH SHOWING 3% FREQUENCY MODULATION.

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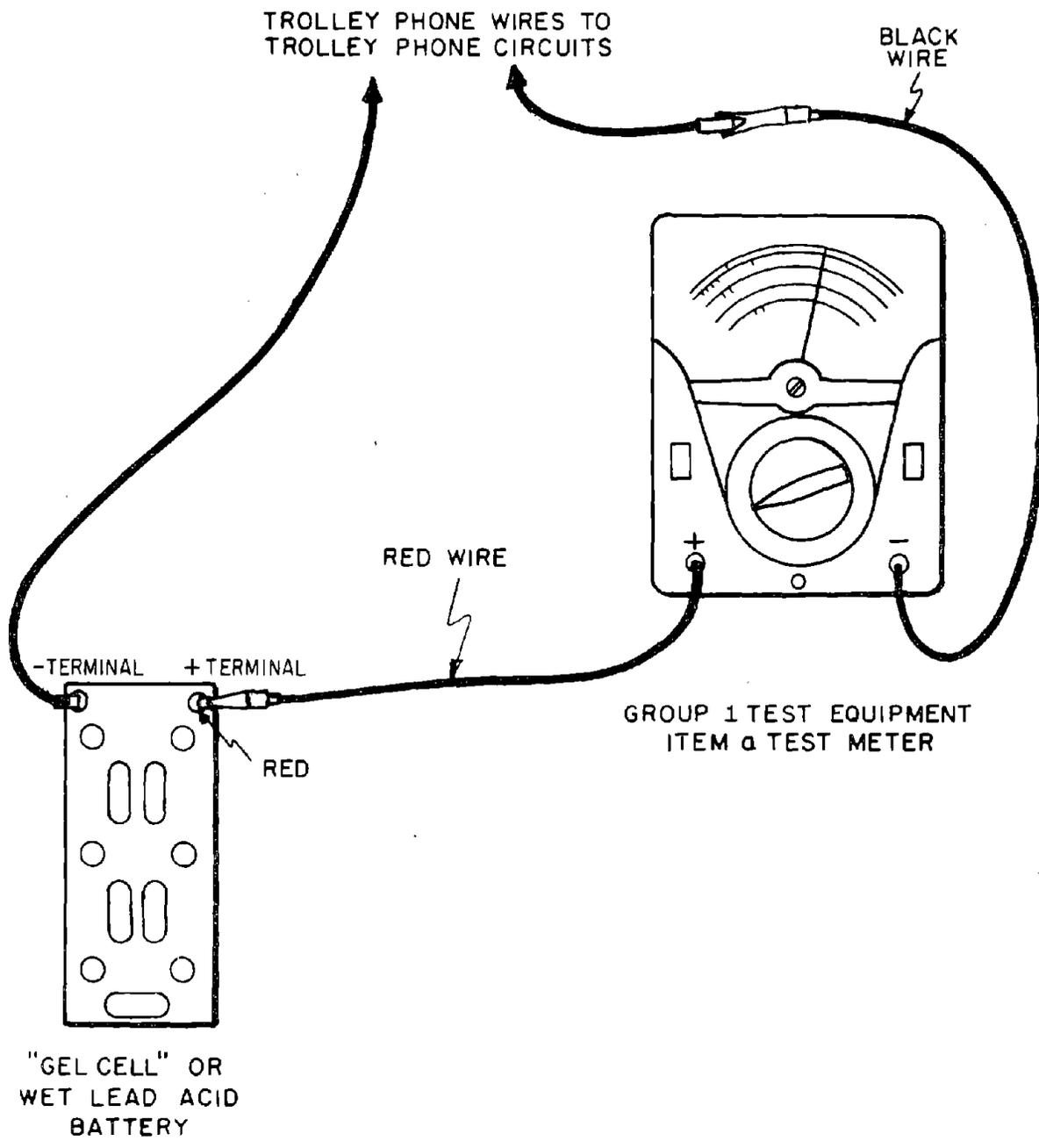


FIGURE 13. POWER CONSUMPTION TEST SETUP.

PORTABLE INSTRUMENTATION TO AID IN MAINTENANCE

OF TROLLEY CARRIER PHONE SYSTEMS

INTRODUCTION

The maintenance of trolley carrier phone systems requires not only the maintenance of the equipment involved, but the maintenance of the transmission line used to transmit the dispatcher's signal from his position to the vehicles in the mine. This line also serves as a path from the vehicles to the dispatcher's office. Evidence accumulated over the years indicates that this signal path is subject to many impediments to the propagation of useful signals over the long distances typically encountered in coal mines.

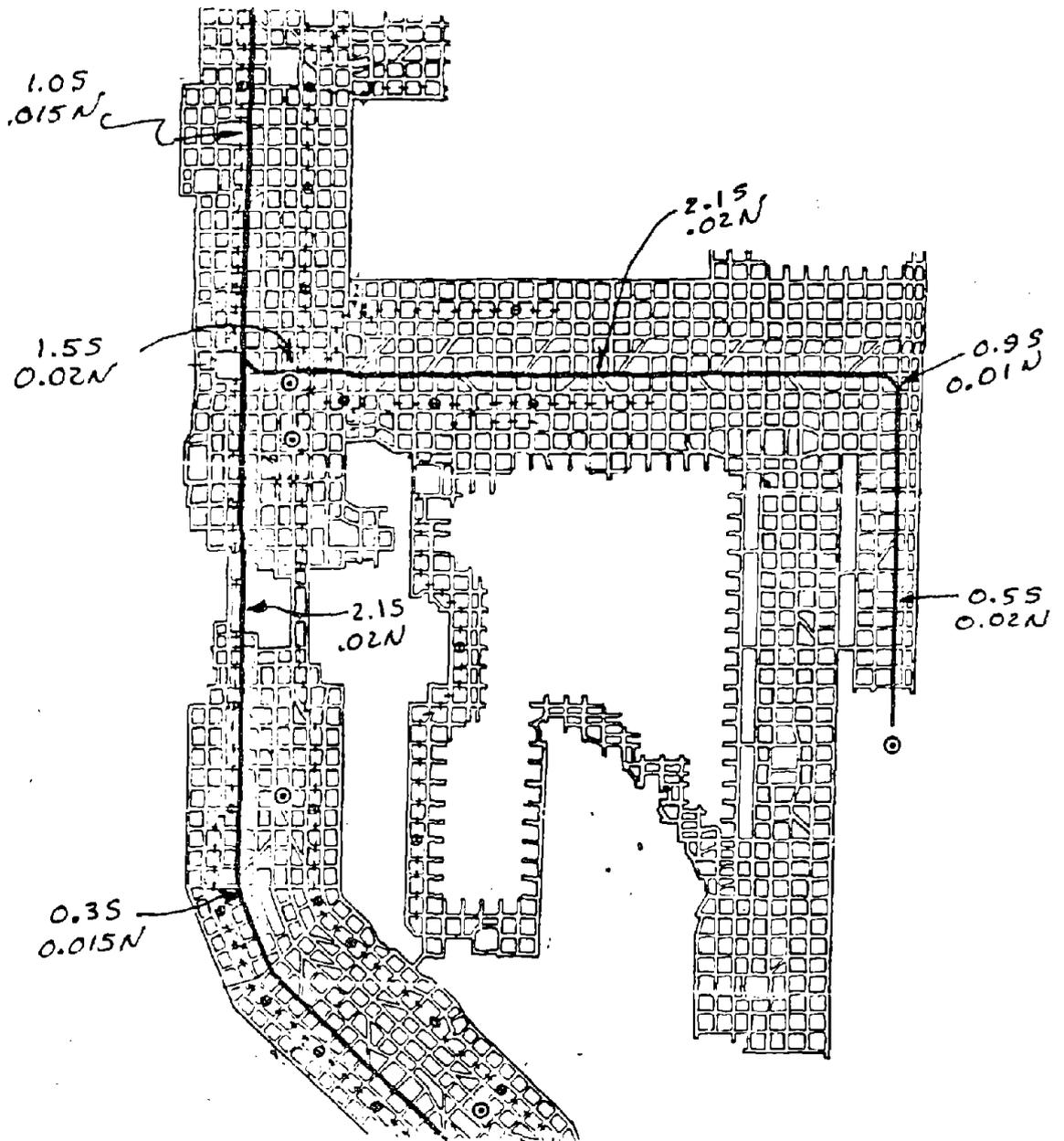
One of the most useful ways of determining the state of the overall system is to map the signal and noise strengths throughout those regions of the mine which are covered by the trolley carrier phone system. Such mapping requires a tuned signal-measuring device, typically not available in most mine maintenance shops. This guideline suggests two commercial instruments which can be used to map the signal strength and noise levels in a rail haulage mine. It also presents a special design of an instrument for such purposes.

The mapping is preferably carried out by measuring the signal strength produced by the dispatcher's transmitter at various points along the rail haulage system where vehicles operate. A satisfactory way of conducting the measurements is to place a suitable tuned voltmeter aboard a mine vehicle (such as a jeep) and progressing throughout all those regions of the mine where dispatcher-to-vehicle communication is desired. At appropriate places along the rail haulage - for example, at 2000 or 3000 foot intervals - the received dispatcher's signal and the background noise are both measured. These values are noted on a mine map for future reference as the mine expands, or as carrier phone problems occur. Except under extremely unusual conditions, the signal strength map produced in this manner will also indicate the level of signal that a vehicle transmitter at the measuring position would produce at the dispatcher's place.

An example of a portion of a mine map annotated with such readings is shown in Figure 1.



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EXAMPLE OF SIGNAL LEVEL MAP

FIGURE 1

EQUIPMENT DESCRIPTIONS

The equipment for making such a signal strength map must be battery-operated, easily portable, and easy to use and read. There are two such units commercially available, the Sierra Model 127C tuned voltmeter* and the Rycom 3115**. These tuned voltmeters are general-purpose, battery-operated instruments appropriate for many tasks other than the mapping of trolley carrier signal levels. For this reason careful attention to the tuning of the instrument to the precise frequency used in the mine must be effected, and careful attention must be paid to the attenuator settings and meter indications. Nevertheless, the units are commercially available and satisfactory for this particular purpose and are illustrated in Figure 2.

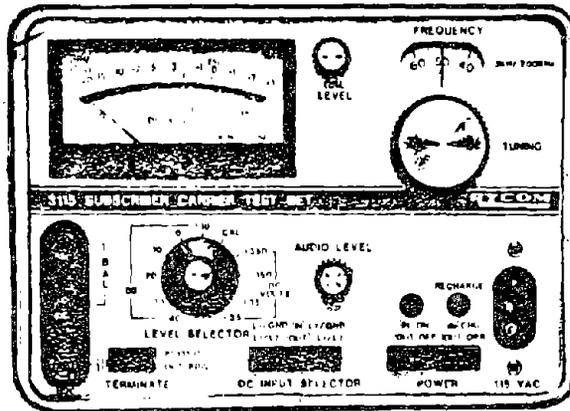
Alternatively, another appropriate instrument is the experimental model of a simplified tuned voltmeter that we have developed. This unit, which is smaller than the other models, is limited to the two main carrier frequencies used in most coal mines: 88 and 100 kHz. Furthermore, its bandwidth has been tuned to be compatible with that of the trolley carrier phone. A photo of the instrument is shown in Figure 3. The key specifications of the instruments are presented in Table I.

* Information is available from: L.S.I./Sierra, 3885 Bohannon Drive, Menlo Park, California 94025, Telephone 415-321-5374.

** Information is available from: Rycom Instruments, 9351 East 59th Street, Raytown, Missouri 64133, Telephone 816-353-2100.



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RYCOM 3115



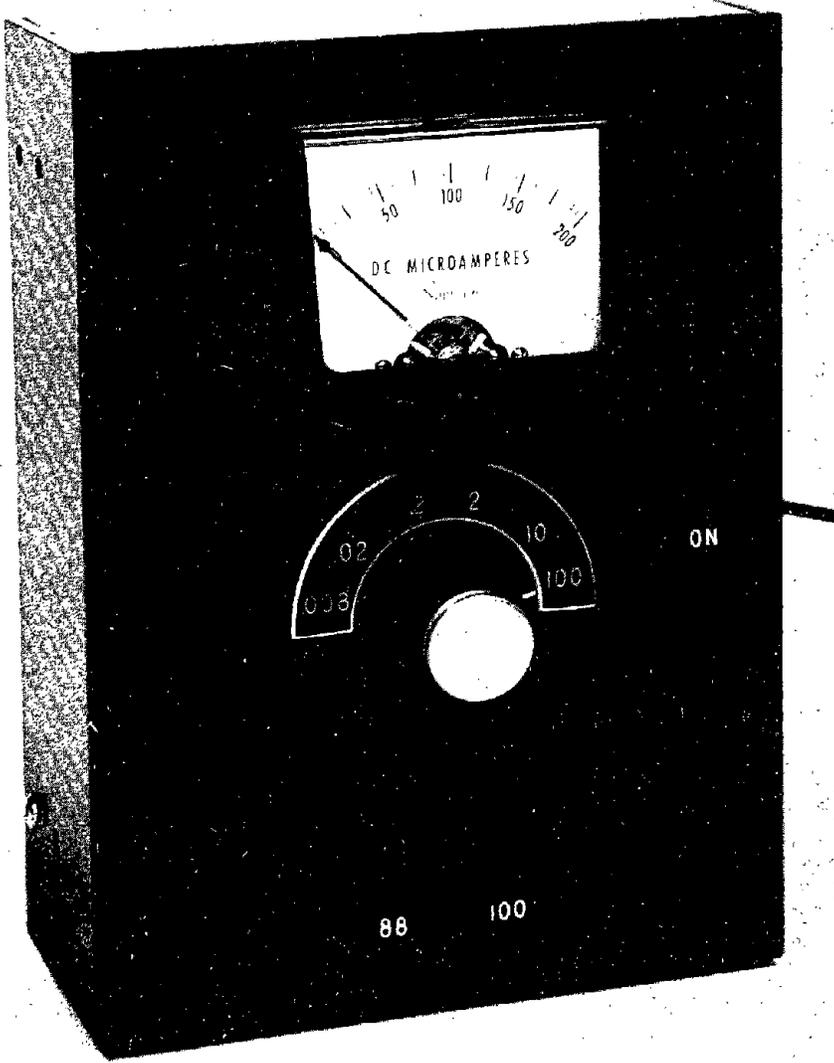
SIERRA 127C

TUNED VOLTMETERS

FIGURE 2

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0 1 2 3 4 5
Centimeter Scale

Figure 3.
Simple Instrument for Measuring
Trolley Carrier Voltage



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TABLE I

KEY SPECIFICATIONS OF TUNED VOLTMETERS

	<u>Sierra 127C</u>	<u>Rycom 3115</u>	<u>ADL Experi- mental Unit</u>
Frequency Range	2 to 350 kHz	3 to 200 kHz	Fixed 88 kHz & 100 kHz
Accuracy			
Frequency	+ 1 kHz	+ 1 kHz	+ 0.1 kHz
Level	+ 1dB	+ 1 dB	+ 1 dB
Selectivity			
Standard (250 Hz)			
3 dB bandwidth	250 Hz	1000 Hz	6 kHz
35 dB bandwidth	600 Hz		
60 dB bandwidth	1000 Hz	4000 Hz	
Ranges (full scale)	1 mV to 10V	-37 dB to +13 dB (3.7 mV to 1.65V) to + 53 dB* (165.V)	10 mV to 100V 6 ranges
Intermediate Frequencies			
1st 1F	1305 kHz		NA
2nd 1F	330 kHz		NA
Power Requirements	6 zinc-carbon or 7 NiCd Re- chargeable "D" size cells	2 GEL cells Globe 610	
Voltage	9V nominal	12V	+ 6.75 V mercury cells
Battery Life (zinc carbon)	100 hours	5 hours continuous	-
Temperature Range	-10° to 50°C	-10° to 55°C	-10° to 50°C
Dimensions			
Width	12 inches	7 1/4 inches	5 1/4 inches
Height	7 1/2 inches	5 1/4 inches	7 1/4 inches
Depth	7 1/2 inches	7 3/4 inches	2 1/2 inches
Weight	15 lb.	6 lb.	2 lb., 6 oz.
Cost	\$1,695	\$895	\$500 (est.)

*With model 3069 40 dB
fixed attenuator

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METHOD OF USING THE TUNED VOLTMETERS FOR CARRIER SIGNAL LEVEL MAPPING

The simple and straightforward procedure of measuring the dispatcher's signal level from a jeep or vehicle moving about the mine can best be accomplished by connecting the trolley wire voltage on board the vehicle to the input of the tuned voltmeter. Because of the hazards associated with the high voltage of the trolley wire, either a nominal 300 or 600 volts dc, either instrument has to be properly isolated so that personnel operating the instruments are not subjected to this voltage through error in operation. Therefore, it is important that a capacitor and a fuse are connected in series with the instrument to ensure that the potentially lethal voltage of the trolley wire does not inadvertently reach an operator. The specially designed instrument has these safety features built into it so that, once the connection is made the operator is protected from inadvertent contact. Thus, the entire set of measurements may be made safely without removing this instrument from its connection to trolley wire voltage. A diagram showing a possible way of connecting the instruments is shown in Figure 4.

METHOD OF TAKING DATA AND TABULATING RESULTS

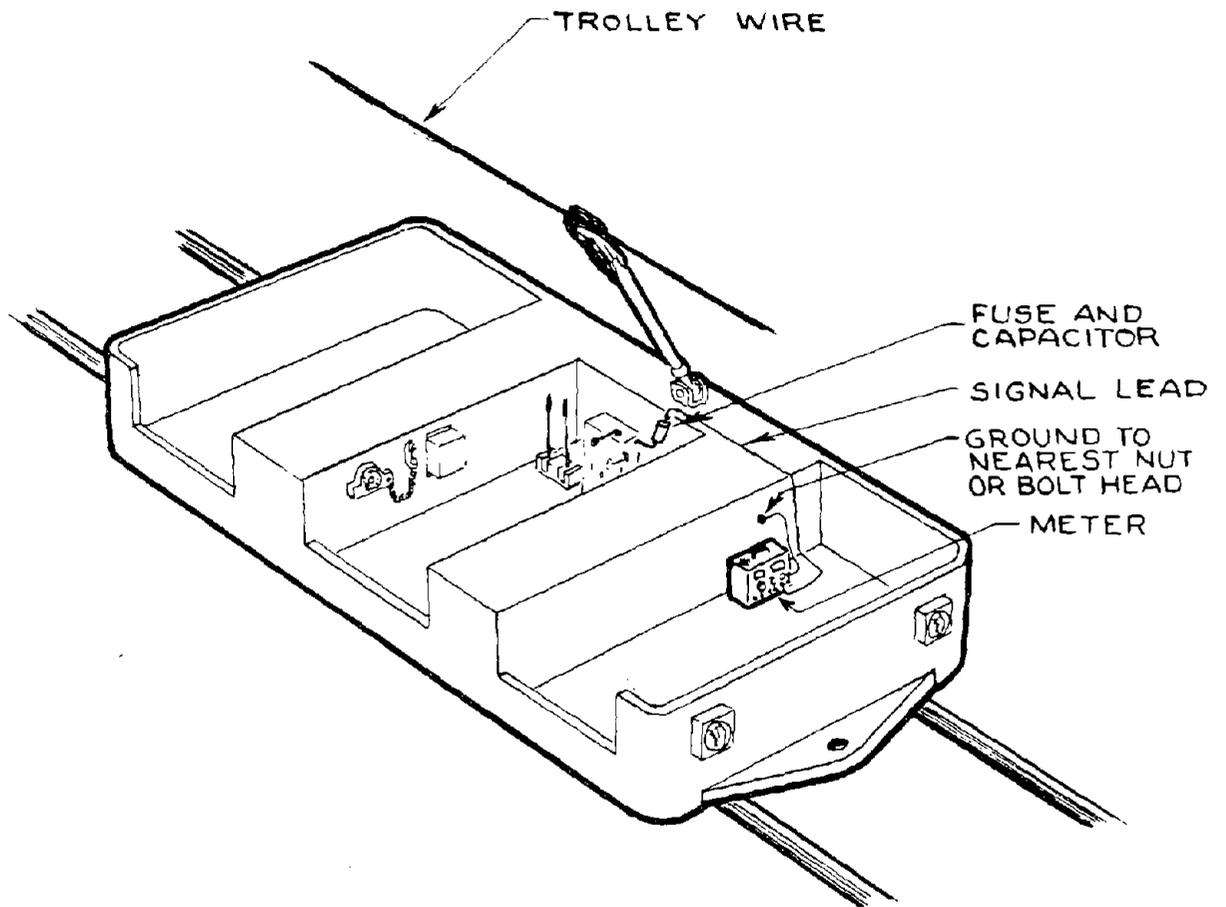
To make a measurement the vehicle is moved from the dispatcher's office to predetermined regions of the mine, where the vehicle is stopped. The operator then asks the dispatcher for a 5-second long transmission of unmodulated carrier. The response on the indicating meter is noted, together with any attenuator setting, so that an absolute value of voltage (in volts rms) can be noted on the corresponding position on the mine map. It may be necessary when starting measurements to switch the range knobs of the instruments to make sure that the instrument's response is on scale rather than high and off the scale. In this event, perhaps two transmissions will be required before on-scale readings are obtained.

Similarly, after the transmission is over the sensitivity of the instrument should be increased and the noise level at the particular position noted again in volts or millivolts rms. When the operator of the vehicle asks the dispatcher for a transmission, a large level of signal is applied to the meters. For this reason, one has to be careful of the range settings, although both instruments are protected against overload.

USE OF INFORMATION FROM THE SIGNAL-LEVEL MAP

The signal-level map will reveal regions of the mine where the dispatcher signals received are weak and thus may cause difficulties in carrier communication. The mine map will also reveal regions where excessive noise is the main cause of poor communications. In this event, it is important to locate the source of the offending noise and to take measures as discussed in the Guideline, entitled "Converting a Rail Haulage Trolley Wire and Feeder System into a Functional Carrier Frequency" transmission line.

The signal-level map will also be extremely useful should carrier communications deteriorate with time, or with the installation of new equipment,



INSTRUMENT CONNECTIONS

FIGURE 4

or with the advancement of the mine that occurs. One can refer back to the original signal levels and determine, to a large degree, the reasons why communications have been degraded.

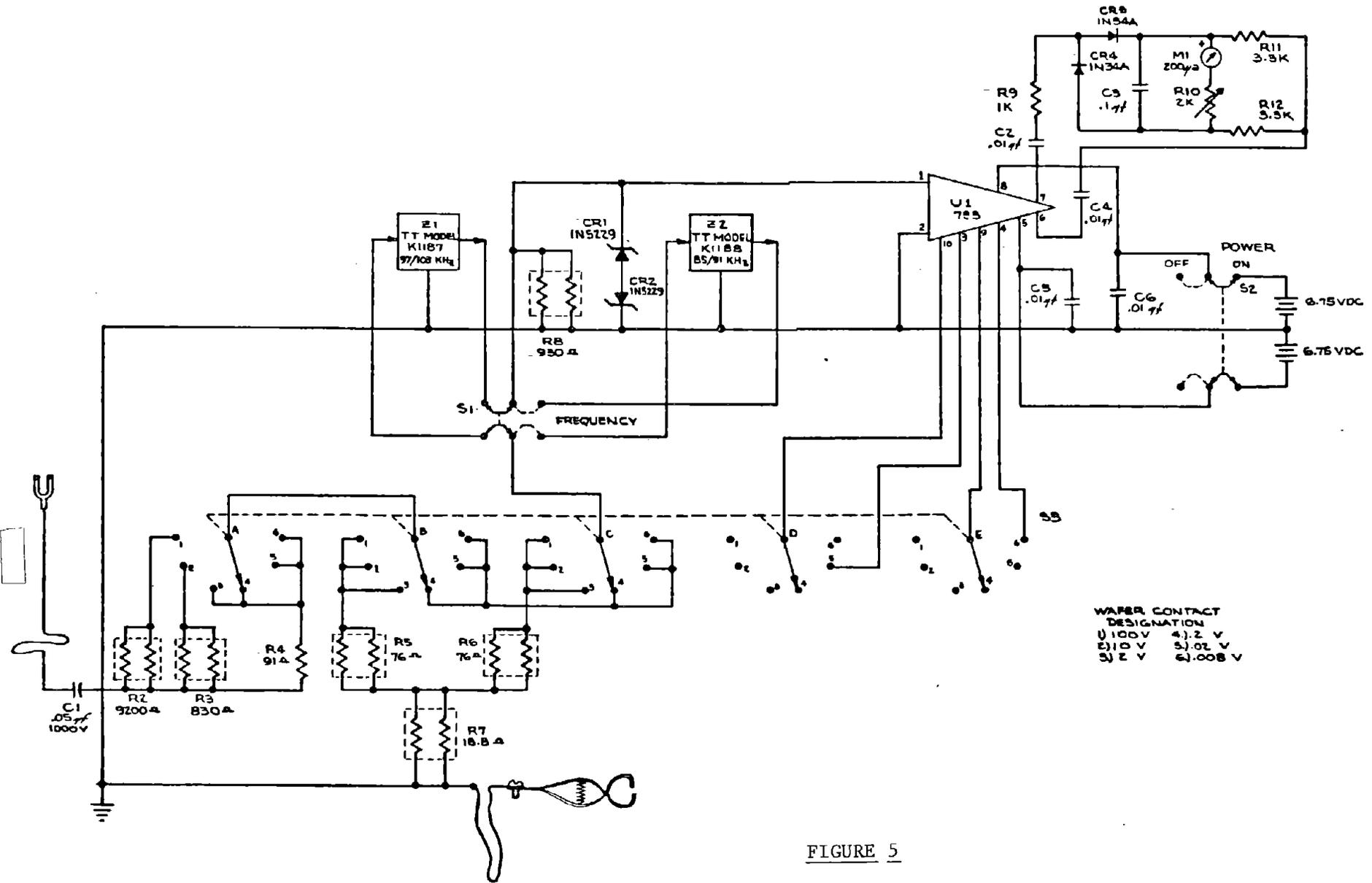
APPENDIX

This appendix presents the descriptions of the breadboard unit constructed for this program and includes a circuit diagram. In the following paragraphs we discuss the principles of operation of this instrument.

The schematic diagram of the portable tuned voltmeter is shown in Figure 5. The DC trolley wire voltage is isolated from the circuit by the .05 microfarad 1000-volt capacitor. The a-c signal enters a switchable attenuator which accommodates full scale voltage ranges from 100 volts to 8 millivolts. The signal that passes through the attenuator is then impressed on either a 100 kHz or an 88 kHz nominal, 6 kHz wide filter comprised of passive elements only. A front panel switch F1 provides for the selection of which frequency is to be used. The signal from the output of the selected filter is limited in amplitude by the back-to-back Zener diodes, CR1 and CR2, so that transient excursions do not saturate the stage of amplification represented by U1, a 733 high-speed operational amplifier with programmable gain. The gain of this amplifier is set in accordance with the D and E wafers of the range selection switch to be appropriate for the particular settings of the instrument. The output signal from the amplifier is rectified by the two IN34A's and thence, is fed to a metering circuit comprising a 200 microampere meter. The power for the system is supplied by a pair 6.75 volt mercury cells in combination with the on-off switch represented as S-2. Basically the circuit is of extreme simplicity; signal attenuation being provided for the most part at the front end where passive components are used so that non-linearity and dynamic range considerations are minimal; passive filters are used as discussed to provide for the selective feature necessary to ascertain the behavior of signals in a noisy environment such as found on the trolley wire. The entire unit as shown in the photograph is in an insulated package to prevent accidental exposure to the high voltage of the trolley wire.

The frequency response of the instrument is shown in Figure 6 and the calibration curve is shown in Figure 7.

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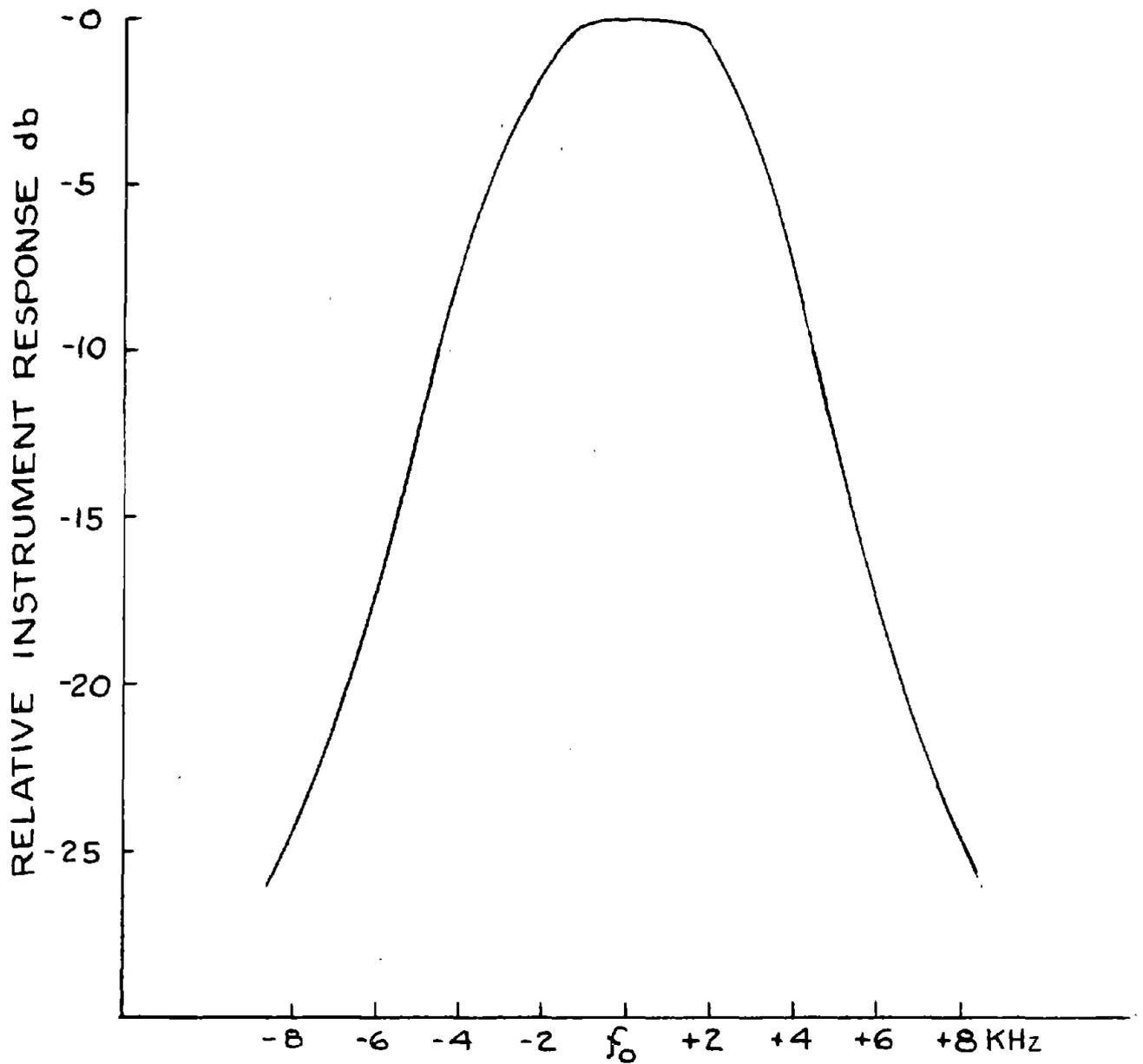


WAFER CONTACT
DESIGNATION
 0 100V 4.32 V
 1 10 V 3.02 V
 2 2 V 6.008 V

FIGURE 5

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Q1 9.7M Quartz El. Q1 AND SELECTED LTR TIME REVISION DESCRIPTION APPROVED DATE		DATE 3/25/76 APPROVED DATE		CASE NUMBER 75629 USED ON		CODE IDENT NUMBER 75629 SIZE C		DRAWING NUMBER 0* SHEET 0*		REV	
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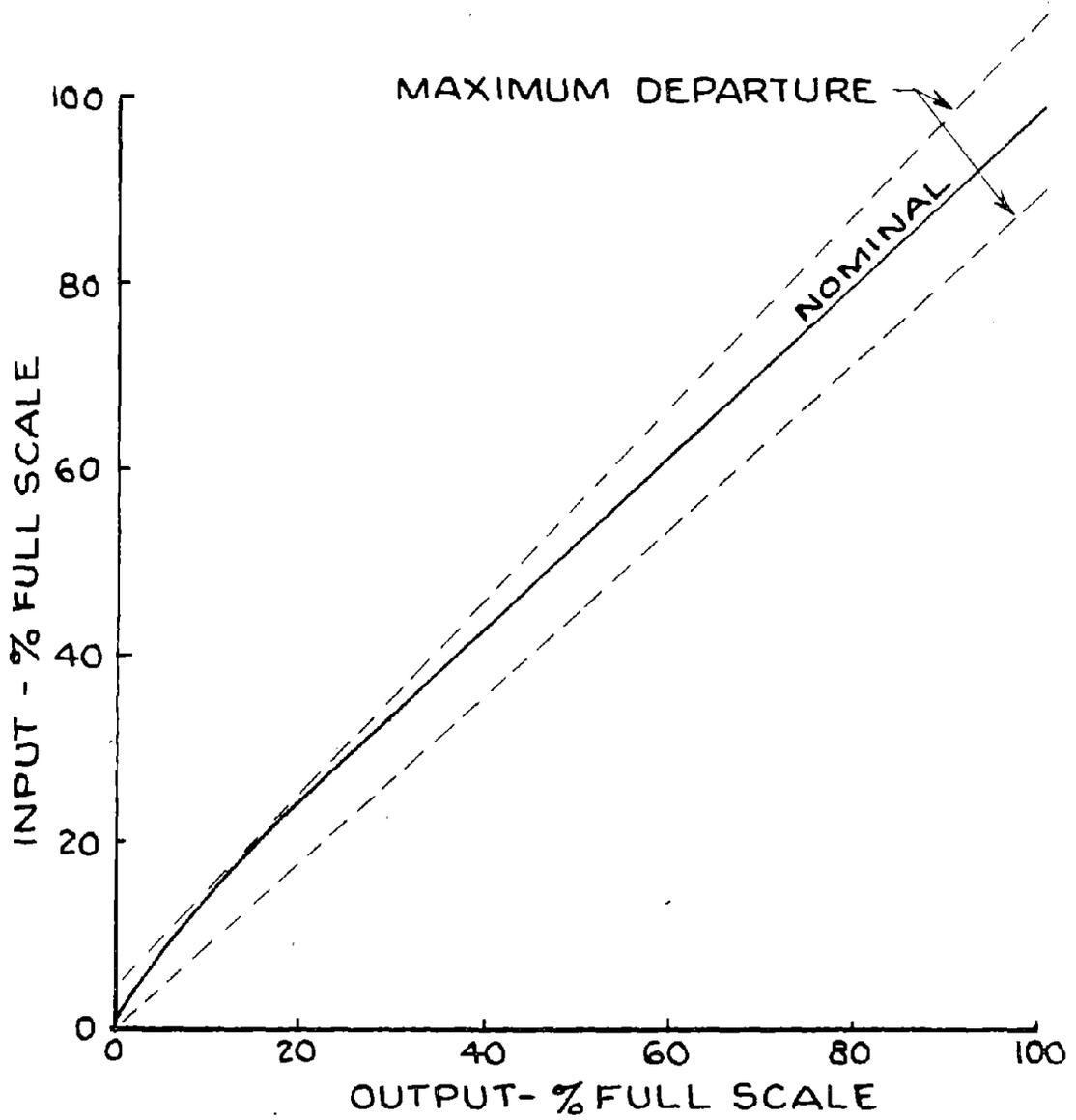


INSTRUMENT FREQUENCY RESPONSE

FIGURE 6



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CALIBRATION OF INSTRUMENT

FIGURE 7