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March 1982**

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**TELEPHONE COMMUNICATION
SYSTEM
FOR A DEEP-VEIN METAL MINE**

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Contract J0100093
Terry S. Cory, P.E.

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16. Abstract (Limit: 200 words) This report describes the results of a program to design, procure, install, and evaluate a multi-channel underground telephone system of modern design in the Sunshine Silver Mine near Wallace, Idaho. Although the evaluation portion of the program was deleted, this report contains a cost benefit analysis for such a system using estimates of operational data for the Sunshine Mine. The results show a centrally switched telephone system of conventional design with ruggedized phone enclosures and special environmentally sealed dial pads to be the most economical.			
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FOREWARD

This report was prepared by Terry S. Cory, P.E., Cedar Rapids Iowa under USBM Contract number J0100093. The contract was initiated under the Minerals Health and Safety Program. It was administered under the technical direction of the Pittsburgh Research Center with Mr. James C. Cawley acting as Technical Project Officer. Mr. Doyne W. Teets was the contract administrator for the Bureau of Mines. This report is a summary of the work recently completed as a part of this contract during the period October 1980 to September 1981. This report was submitted by the authors during March, 1982.

References herein to specific brands, equipment, or trade names in this report are made to facilitate understanding and do not imply endorsement by the Bureau of Mines.

No patentable concepts or items of technology have resulted from the work performed under this contract.

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1.0 EXECUTIVE SUMMARY

This report presents the results of a program initially conceived to improve the existing U.S. Bureau of Mines multi-channel test-bed telephone system in the Sunshine mine and to evaluate the performance and utility of the system on a long-term basis. The program work was performed under U.S. Bureau of Mines contract J0100093, "Telephone Communication System for a Deep-Vein Metal Mine" over an approximate 12-month period from October, 1980 through September, 1981. Under the original contract, the work was to have comprised a one-year Phase 1 to plan, procure, and install an improved underground telephone system, with an ensuing 18-month evaluation period. This contract was terminated for the convenience of the Government in the 8th month, short of procurement of upgrading system components, and was supplemented with additional work items toward putting the existing system in good working order and providing planning recommendations to the mine for its future overall telecommunications needs. This report summarizes the work performed prior to termination, and subsequent to the termination under J0100093 Modification 1. Details of the work plans under the original contract are included in an interim report, "Overall Communications Improvement Implementation Plan for the Sunshine Mine," which is included as Appendix A to this report document.

The U.S.B.M. test bed system at Sunshine was the first multi-channel underground telephone system in the Silver Valley. The configuration of this system overlaid the previous single-channel system; again, with the closest phones to the working stopes being located at the shaft stations. The single-channel system remains operational in this mine and is used for backup; a psychological "pillow" for the mine as, overall, the test bed system has proven to be relatively reliable.

The test bed system has achieved acceptance at Sunshine among supply, supervisory and maintenance personnel who normally work in the vicinity of the shaft station staging areas. It is questionable whether or not this system has ever been used or understood by the ordinary miner. The system relieved the congestion during peak communicating periods, according to the testimony of those at Sunshine who use it regularly. Functionally, the system falls short of the communications standard set by Federal regulations in coal mines where loud audible voice paging from a telephone within 800 feet of a working face is required. In coal mines, important messages are almost certain to be heard by a member of a face crew, and the telephone is within easy quick walking distance from any location in the working area.

While a multi-channel system configured functionally like the test bed system is certain to streamline mine supply logistics and operations during shift change periods, it is questionable whether this type

system substantially improves the mine safety or enhances production efficiency. Analyses performed by the Contractor suggest that the provision of communications beyond the shaft stations is necessary to both economically justify the entire underground system and to improve health and safety in deep vein mines.

The Contractor has drawn the following conclusions as a result of work performed under this contract.

1. The "from scratch" procurement and installation investment in a modern multi-channel underground telephone system of any kind having end telephones at the shaft stations cannot be cost justified on a direct operating cost basis (mining cost) for normal day-day operations. Adding indirect G&A costs (corporate cost level), conservative estimates show this investment to be marginally cost justifiable with a projected break even point greater than five years downstream. This is because the estimated savings accrued through the use of the system compared to a single-channel system are those of supply, maintenance, and supervisory personnel labor only and not those directly effecting product throughput/yield.

2. Adding voice paging to a multi-channel telephone system to the shaft stations and extending single-channel wireless communications with paging into the stope areas, the overall system can be cost justified on a recurring basis. This is because the use of the system reduces stope down time; a quantity directly related to product yield in addition to savings of service labor. The projected cost recovery breakeven point at the corporate level is in the second year.

3. The most economic modern telephone system, both from initial procurement and maintenance cost points of view, is a centrally switched "hardwired" system using multi-pair cable. The Contractor has found no multiplex telephone system (more than one channel on a single wire pair) or no specialty mine phone system to be cost competitive with a conventional telephone company (TELCO) type system using ruggedized underground telephones equipped with environmentally suitable dial pads. And, of course, this conventional TELCO type system can be merged with the surface system.

4. Underground telephone system in deep vein mines having the closest phones to the working stopes located at the vertical shaft stations as the sole communication means do not alleviate the most serious health and safety problem of no direct communications o the stope area.. This is because the generation and transmission of carbon monoxide in the mine ventilation system in case of fire will generally reach some working areas of such mines before it is possible to provide warning via methyl captan injection. To improve mine health and safety, communications on at least a single-channel basis should be extended

from the vertical shaft stations on each operating level into the stope areas. Additionally, voice paging should be implemented in both shaft staging and stope working areas.

The following recommendations are applicable, in general, to deep vein mines.

1. Mining companies anticipating the purchase and installation of a multi-channel underground telephone system should:

- a. plan on retaining an outside communication firm to assist in system planning and procurement and establishing a long-term maintenance plan, or
- b. select and train one or more persons within the company to provide these services.

2. The investment in a new underground telephone system should be preceded by an operational time-in-motion study of the logistical supply and product recovery processes to:

- a. determine sources of production disruptions, and
- b. characterize the process of repairing the failures.

This study would best be performed by the mine's industrial engineers rather than by an outside firm.

3. Deep vein mines should extend any telephone or combined telephone/radio communication system beyond the vertical level shaft stations into the working stope areas. The configuration of the telephone or radio link portions of these extensions should be based on the time-in-motion study and the procurement economics for these links.

4. All underground voice communications systems should include voice paging. This is to assure personnel location, notification of a maximum number of personnel of any major operational or health and safety problem, and to provide as much freedom as possible for personnel not located near communication devices.

The following recommendations specifically apply to Sunshine mine.

1. All hardwired portions of the recommended cable plant for the upgraded telephone system should be implemented.

2. The extension of communications toward the stopes beyond the

vertical shaft stations should be wireless, to minimize both initial cost and maintenance. The hardwired telephone system and the wireless portions need not be directly interfaced. It would be best, for Sunshine, if a responsible person at each shaft staging area answered or initiated requests for services or action. The telephone instrument and the fixed wireless instrument should be colocated. It would be well if the two type systems in each staging area employed pages that were audibly distinguishable from one another.

3. The tie trunks between the now separate underground and surface telephone systems should be implemented.

4. Planning should begin as soon as possible toward replacement of the existing underground PBX as its useful remaining lifespan without incurring undue maintenance and down time is expected to be less than two years.

2.0 INTRODUCTION

This report presents the results of a program initially conceived to improve the existing U.S. Bureau of Mines multi-channel test-bed telephone system in the Sunshine mine and to evaluate the performance and utility of the system on a long-term basis. The program work was performed under U.S. Bureau of Mines Contract J0100093, "Telephone Communication System for a Deep-Vein Metal Mine" over an approximate 12-month period from October 1980 through September 1981. Under the original contract the work was to have comprised a one-year Phase-1 to plan, procure, and install an improved underground telephone system; with an ensuing 18-month evaluation period. This contract was terminated for the convenience of the Government in the 8th month, short of procurement of upgrading system components, and was supplemented with additional work items toward putting the existing system in good working order and providing planning recommendations to the mine for its future overall telecommunications needs. This report summarizes the work performed prior to termination, and subsequent to the termination under J0100093 Modification-1. Details of the work plans under the original contract are included in an interrim report, "Overall Communications Improvement Implementation Plan for the Sunshine Mine", which is included as Appendix A to this report document.

2.1 BACKGROUND - STATEMENT OF THE PROBLEM

The majority of U.S. underground mines of moderate-to-large size employ single-channel telephone systems having voice paging with the furthest outby telephone within 700-800 feet from a working face/stope. Deep-vein metal mines in the Silver Valley of the Couer d'Alene District, however, employ a primitive single-channel telephone system having only coded ringing actuated by an AC buzzer or a hand-crank magnetoringer. Phones are located at the vertical shaft stations often being 1000-2000 feet from a stope. The existance of only this type system was suspected to have contributed to the confusion which may have exascerbated the 1972 Sunshine mine disaster.

Subsequent to this particular disaster, in 1975 and at the request of MESA, the U.S. Bureau of Mines entered into a cooperative agreement with the Sunshine Mining Company to establish and evaluate a modern, multi-channel, test-bed telephone system in the Sunshine Mine. Adjunctive to this agreement, the Bureau let an engineering and administrative services contract (S0133035) to Rockwell/Collins to plan, engineer, install, and evaluate such a system. This original test-bed system was installed in 1977 but was never evaluated due to termination of the contract with Rockwell/Collins.

The test-bed system was used by the mine for a period of one year

without outside maintenance support. In late 1978, Terry S. Cory, P.E. was retained by the Bureau under Purchase Orders P0300691 and J0199143 to provide ongoing maintenance support for this system and to assess its viability and utility with recommendations toward continued active Bureau involvement.

Recommendations supportive of continued Bureau sponsored work at Sunshine were made which led to establishment of the current program. A description of the test-bed system and its critique (circa early 1981) is contained in Appendix A. The earlier assessment, (circa late 1979/early 1980) concluded that the system embodied elements which were custom built, were operationally contrary to accepted TELCO practice, were unreliable and difficult to maintain, and which in a disaster scenario provided minimal assurance of added communication capacity compared to the original single-channel system.

The objective of this program has been to upgrade the existing test-bed system, then to conduct the operational performance and utility evaluation which was never performed under the Rockwell/Collins contract.

At the onset of this program, the plans were to replace certain items of equipment underground with more reliable and maintainable ones, to increase the system traffic handling capacity, and to change the system operating control regimen to conform with standard TELCO practice. At that point in time, no particular thought was given to inherent deficiencies in the system topology including the remoteness of the extreme end telephones from the working areas. The test bed system still placed telephones no closer to these areas than did the single-channel system prior to 1977.

2.2 SOLUTION REQUIREMENTS & PROGRAM STRUCTURE

It was recognized in the original Rockwell/Collins program that a new multi-channel phone system, configured and installed to mitigate anticipated health and safety problems, would have to be cost justifiable on the basis of mining operations to achieve acceptance at Sunshine and proliferation to other mines in the area. A secondary requirement realized during the 1978-1979 planning activities was that Sunshine or any other mine in the Silver Valley was unequipped to provide long-term maintenance on its own for a system like the original test-bed. A specific solution requirement for the current program has been to identify a viable system maintenance base external to the mine. Minimizing the required maintenance through system design was also a prime objective.

The program organization was established to ensure meeting the above requirements. A survey of potential maintenance contractors in the

Spokane/Couer d'Alene area was taken during the 1978-1979 planning activity which resulted in the selection of Columbia Tele-Communications, Inc.(CTC), an interconnect company with radio frequency experience, as a subcontractor for this program. Their charge was to provide both continuing on-call and planned maintenance of the phone system as it evolved, to participate in the installation of the upgrading system components, and to provide on-site assistance to the Contractor during the evaluation phase of the program.

A second subcontractor, RAK Associates(RAK) a telephone consulting firm of national reputation run by Richard A. Kuehn, was retained to evaluate the planned improvements to the system and to help configure the system according to standard TELCO practice in order to facilitate provisioning and maintenance.

A third subcontractor, Richard J. Mahany(RJM) was chosen to perform a substantial portion of the system design including the data collection system for long-term evaluation.

Interactions of the project team resulted in the Overall Communications Improvement Plan, given in Appendix A for the improved Sunshine telephone system.

Early termination of the program changed substantially the roles played by the team members. The U.S. Bureau of Mine's intent upon termination, which was made for reasons external to the program itself, was to leave the mine with a usable maintainable system and with recommendations for meeting its future telecommunications needs. The mine could then choose to implement these recommendations as it saw fit.

Since then, CTC has been charged with assisting the mine and the Contractor in putting the existing system into good working order and supporting the preparation of long-term planning recommendations. At the time of the termination and since, the "existing system" has not been static, but has been evolving toward at least partial implementation of the recommended system upgrade as presented in the Overall Communications Improvement Plan. The primary CTC work items, toward program "wrap-up", have been the selection and outfitting of new sealed reliable dial pads in the underground telephones and the connection of a dial-dial tie trunk between surface and underground PBX's.

During the "wrap-up" period, RAK has been charged with preparing the future telecommunications recommendations for Sunshine, including an assessment of system "use" charges and of the economics for future system growth. For the same period, RJM has been charged with assisting the Contractor in the preparation of the final report, including the system cost analysis.

In this final period of the program, the Contractor has had cause to reflect on aspects of the overall underground topology, relative to other mine communication systems, toward providing communications close to the stope areas. This reflection was aided by tests of wireless medium frequency radio transmission in a nearby mine (Con-Sil) under a separate U.S.B.M. contract (J0308012) in which the feasibility of wireless communications in conductor-carrying drifts was proven. The Contractor's conclusion is that the provision of communications beyond the shaft stations is necessary to both economically justify the entire underground system and to improve health and safety in these mines.

2.3 REPORT CONTENTS

Section 1.0, Executive Summary, presents all the important results, conclusions, and recommendations regarding the system in concise form.

Section 2.0, Introduction, traces the history of U.S.B.M. involvement with the Sunshine mine from 1974 through 1981, and details the work performed under this contract.

Section 3.0, Technical Approach, provides a summary description of the system together with the technical reasoning behind the particular system approach chosen; also, a description of the, data collection system as originally conceived for the evaluation program.

Section 4.0, System Cost - Benefit Economics, presents cost estimates culminating in a cost analysis toward justification of the system based on normal recurring mining operations.

Appendix A contains the originally conceived Overall Communications Improvement Implementation Plan for the underground telephone system at Sunshine. Appendix A is used by reference to support Section 3.0.

3.0 TECHNICAL APPROACH

The proposed approach to the telephone system improvement at the program on-set was still based on the distributed switch topology of the original test-bed system. The scope of work called for selecting one of several low capacity EPABXs and working with a manufacturer to make these switches function on the line circuit ports of the Wescom* 503 switch. Also, instead of one circuit per intercom for inter-nodal connection, two circuits were to be used to increase the system call capacity. The entire multiplex concept was a carryover from previous coal mine experiences where there appeared to be an advantage to a single transmission pair in the volatile and often reconfigured topologies of coal mine working sections.

Reviewing the proposed scope of work, Richard Kuehn quickly pointed out the economic and reliability advantages of centralized switching; which, classically for the telephone operating industry, have been:

- 1) centralized switch maintenance
- 2) phones maintained by field replacement with repair of faulty units at a central location
- 3) low unit costs per telephone.

In fact, the subscriber carrier equipment was designed for the intended purpose of permitting the addition of more capacity to existing wireplant (generally in low density/large area rural installations) and was not intended to be cost-competitive with new multi-pair hardwired installations. Detailed economic and functional basis supporting the centralized switching configuration choice for this program is given in Appendix A.

Once the centralized switch/hardwired transmission plant decision was made, the prime design factor of the system upgrade involved wireplant definition and design toward ease of installation and maintenance. Additionally, redesign of the telephone instrument package was contemplated to provide improved reliability of the DTMF dial pads. As of this writing, an evaluation is proceeding using two types of pads: the new CEECO* pad; and the new Allen Tel* TP85(G) pad.

*Reference to specific brands, equipment, or trade names in this report is made to facilitate understanding and does not imply endorsement by the Bureau of Mines.

3.1 SUMMARY SYSTEM DESCRIPTION

The evolution of the Sunshine underground test bed telephone system is illustrated in three figures to follow. The system embodying the original hardware configuration, but with modifications as of February 1981, is shown in Figure 1. The proposed system upgrade under eventual full implementation of both #10 and #12 shafts is shown in Figure 2. The recent system status per September 1981 is shown in Figure 3.

The proposed implementation of the Con-Sil redundant route will not be implemented by the mine on its own initiative. The original multiplex system leg serving the #10 shaft has been replaced with multi-pair cable. This comprises 50-pair from the 3700 level PBX(RBM) room to the 4600 level and 12-pair below 4600 to the 5600 level. The original private line mine phones in the #10 shaft staging area and on the surface have been replaced with standard TELCO instruments. The Jewell shaft multiplex leg is still in operation. The 3100 haulage level has been wired with 50-pair cable 1500 feet in by the #10 shaft hoistroom. A surface PBX line runs to the #10 shaft staging area with three extension phones. As yet, no dial-dial trunk linkage has been established between surface and underground PBX's.

With the advent of the 6000 feet of 50-pair cable being supplied by the Bureau, the remainder of the 3100 level plus the 3700 level to the #12 shaft will be wired. Eventually, the Jewell shaft will have to be wired.

New environmentally sealed dial pads have been installed in all underground phones. The existing wiring in the Jewell shaft is suitable for connection of one dial-dial tie trunk.

A key feature of the private line hardwired system is that the dialing procedure for all underground phones is uniform and is the same as that normally experienced in any surface system except for the number of digits. The original multiplex system employed tandem dialling for all phones not on the local "party" line. A recent assessment of the system usage following installation of the #10 shaft phones on a private line basis showed the usage had increased about 300% for persons working in the #10 shaft staging area. Details on operational features of the hardwired system are given in Appendix A.

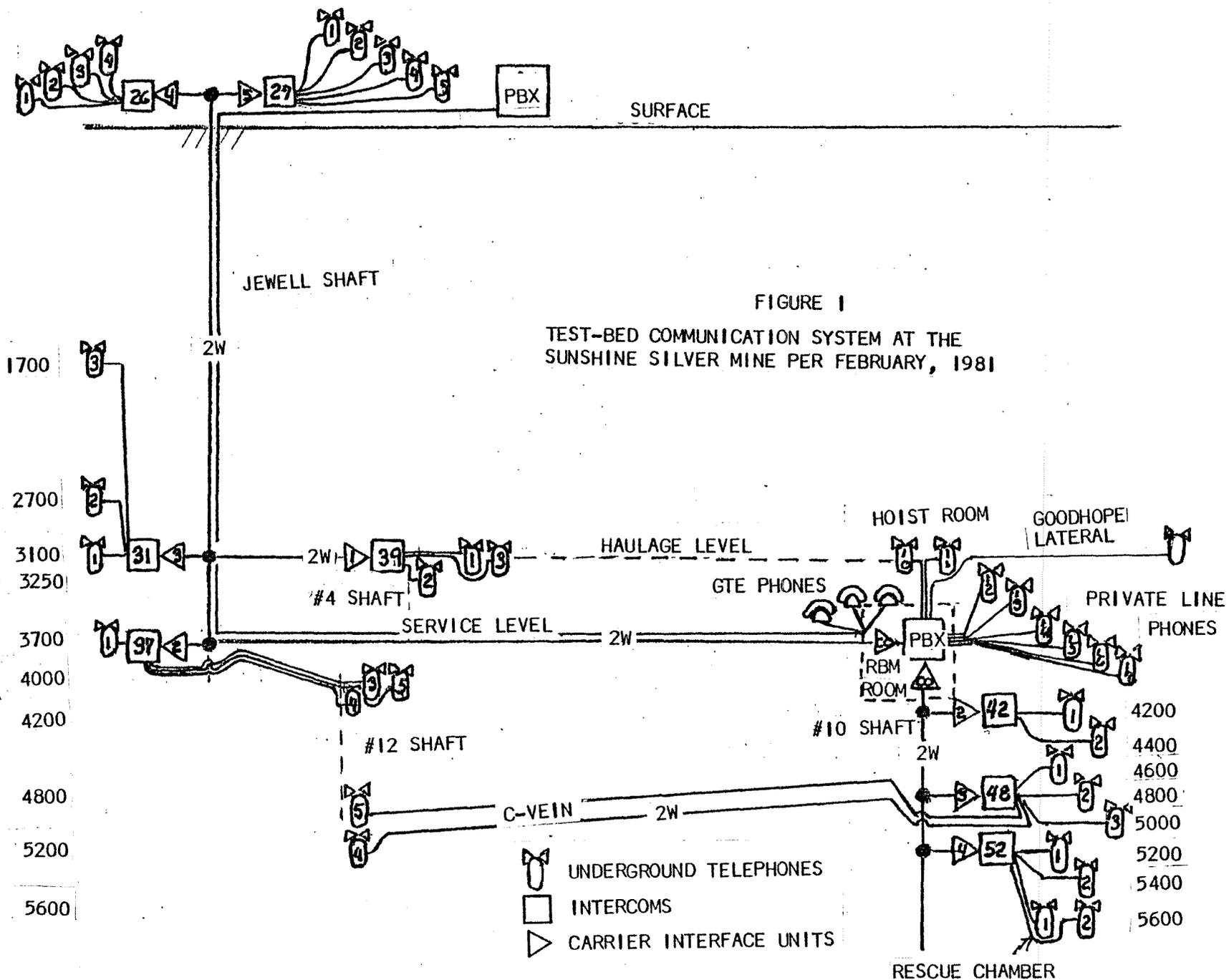


FIGURE 1
 TEST-BED COMMUNICATION SYSTEM AT THE
 SUNSHINE SILVER MINE PER FEBRUARY, 1981

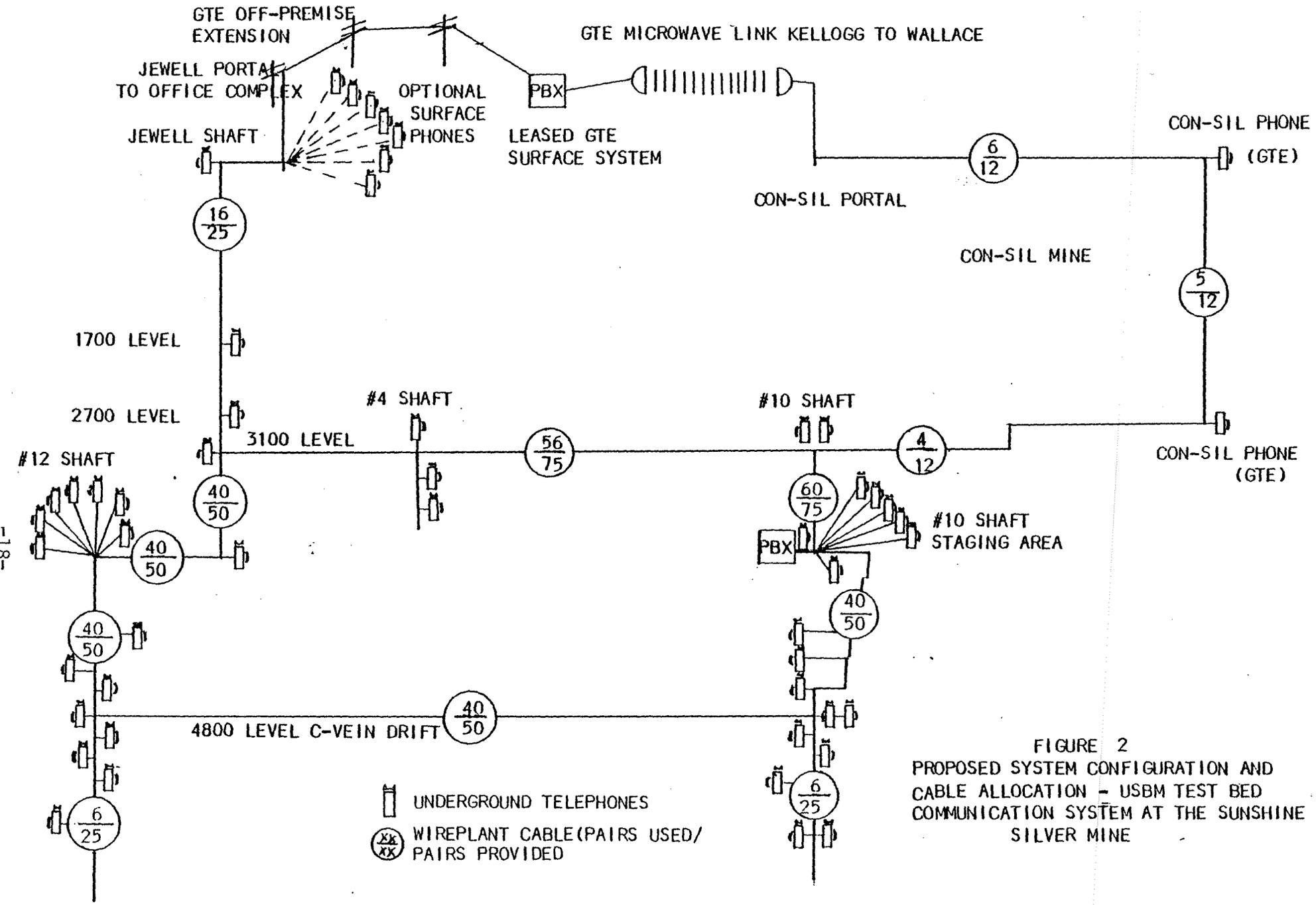


FIGURE 2
 PROPOSED SYSTEM CONFIGURATION AND
 CABLE ALLOCATION - USBM TEST BED
 COMMUNICATION SYSTEM AT THE SUNSHINE
 SILVER MINE

-18-

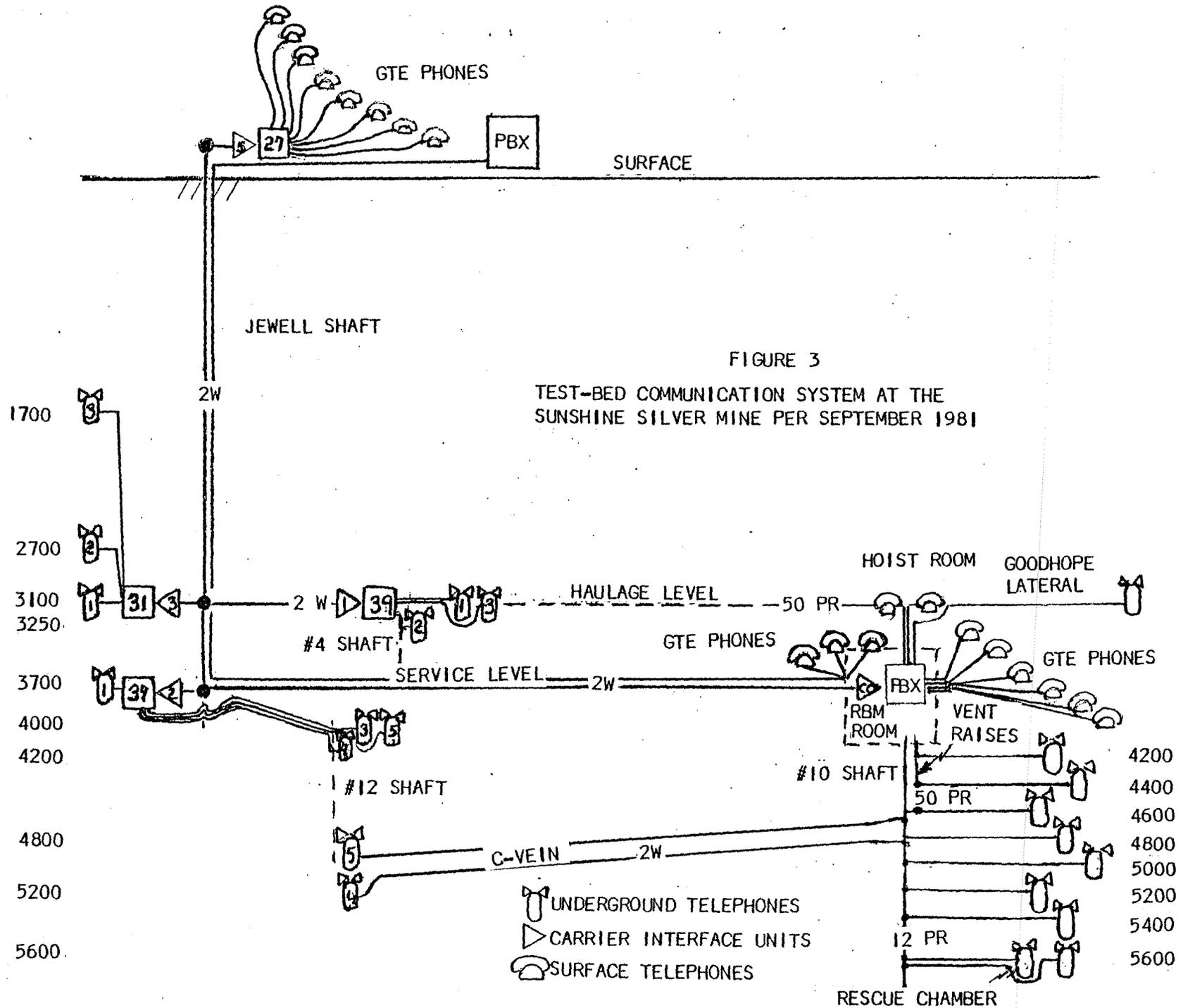


FIGURE 3
 TEST-BED COMMUNICATION SYSTEM AT THE
 SUNSHINE SILVER MINE PER SEPTEMBER 1981

3.1 DEFINITION OF UPGRADING SYSTEM COMPONENTS

Prior to modification of the contract, the list of specific materials and components required for the telephone system transmission plant was defined and submitted to the Bureau for procurement. The list including estimated costs is given in Table 1. Subsequent to the preparation of this list, a program decision was made to substitute armor braided cable for the steel-covered borehole armored cable because of the substantially lower cost.

3.2 DATA COLLECTION SYSTEM

The system evaluation phase of the program was to include a running history of phone system usage from which operational cost benefit measures could be derived. These measures were to be related to efficiency of product yield and to labor savings accrued through the use of the system. In lieu of this running history, conservative estimates of cost benefits on a recurring basis have been made and are given in Section 4.2. The evaluation would have provided documentation of phone system utilization during unusual operating periods. Including these periods along with normal day to day operation was expected to show more leverage on the product yield for communication time benefits derived than would characterize the day to day operations alone.

The data collection system was to have provided the long-term running history of telephone system utilization by call detail recording on a per line/per trunk basis. (The following description of the data collection system design is given in the present and future tenses to facilitate understanding.) The system configurational concept is shown in Figure 4. Data is quasi-continuously gathered and concentrated in the mine, with the data being periodically dumped to a remote computer terminal in Cedar Rapids for arithmetic analysis and storage. The on-site data terminal is polled by the master remote terminal in Cedar Rapids at intervals of approximately once per day. Initially, the data is to gathered at shorter intervals in Cedar Rapids until the data gathering process stabilizes.

The proposed data scanner is a Tekno Industries* Model CMS-240A equipped with DTMF tip and ring inputs for eight lines and E&M lead inputs for 12 trunks. This unit employs 3 DTMF receivers to accomodate three simultaneous dialling intervals. The CMS-240A* may

*Reference to specific brands, equipment, or trade names in this report is made to facilitate understanding and does not imply endorsement by the Bureau of Mines.

TABLE 1

EQUIPMENT PROCUREMENT LIST FOR SUNSHINE TELEPHONE SYSTEM UPGRADE

CATEGORY	ITEM	QTY	COST
I	TRANSMISSION PLANT		
A.	Wire Plant		
1.	non-armored cable (PE-39)		
	3 PR	2,000	E-\$500
	12 "	12,300	E-\$6,200
	25 "	250	E-\$250
	50 "	7,650	E-\$11,000
	75 "	5,350	E-\$11,000
2a.	armored cable (steel covered)		
	12 PR	3,300	Q-\$14,731
	25 "	7,400	Q-\$35,786
	50 "	3,000	Q-\$17,154
	75 "	1,000	Q-\$9,103
2b.	armored braided cable		
	12 PR	3,300	Q-\$3,135
	25 "	7,400	Q-\$7,992
	50 "	3,000	Q-\$4,020
	75 "	1,000	Q-\$1,646
3.	hanging hardware		E-\$3,000
	split socks		
	bonitas		
	cable clamps		
	J-hooks		
	lag bolts		
B.	TERMINATION HARDWARE		E-\$3,000
1.	junction boxes (Carlton CJ16147)*	50	
	cable glands		
	back plates (Carlton JP1614)*		
	fanning strips		

*Reference to specific brands, equipment, or trade names in this report is made to facilitate understanding and does not imply endorsement by the Bureau of Mines

TABLE 1 (Continued)

EQUIPMENT PROCUREMENT LIST FOR SUNSHINE TELEPHONE SYSTEM UPGRADE

CATEGORY	ITEM	QTY	COST
2.	splicing equipment		E-\$3,000
	splicing connectors (Scotchlock Brand ULG)*		
	connector tools (Scotchlock Brand E-9GB)*		
	cable and wire cleaning kits (Scotchlock 4414 & 4415)*		
	splicing enclosures (encapsulated) (Scotchcast 8985-U7)*		
	re-enterable encapsulent (Scotchcast 4441 or 4401)*		
	shield connectors (Scotchlock 4603SB)*		
C. LINE CONDITIONING EQUIPMENT			Indeterminate
	load coils		
TOTAL			E-\$52,680

II. SUBSCRIBER PLANT

A. TELEPHONE EQUIPMENT

1.	weatherized phone (Graybar 25955(02)*	15	E-\$1,800
2.	dial pads (retrofit) (Stromberg-Carlson 35A11* or Graybar TP85(G))*	35	E-\$1,050
3.	klaxon or ringer (Wheelock)*	50	E-\$5,000
4.	mounting hardware		E-\$1,000
5.	heaters		

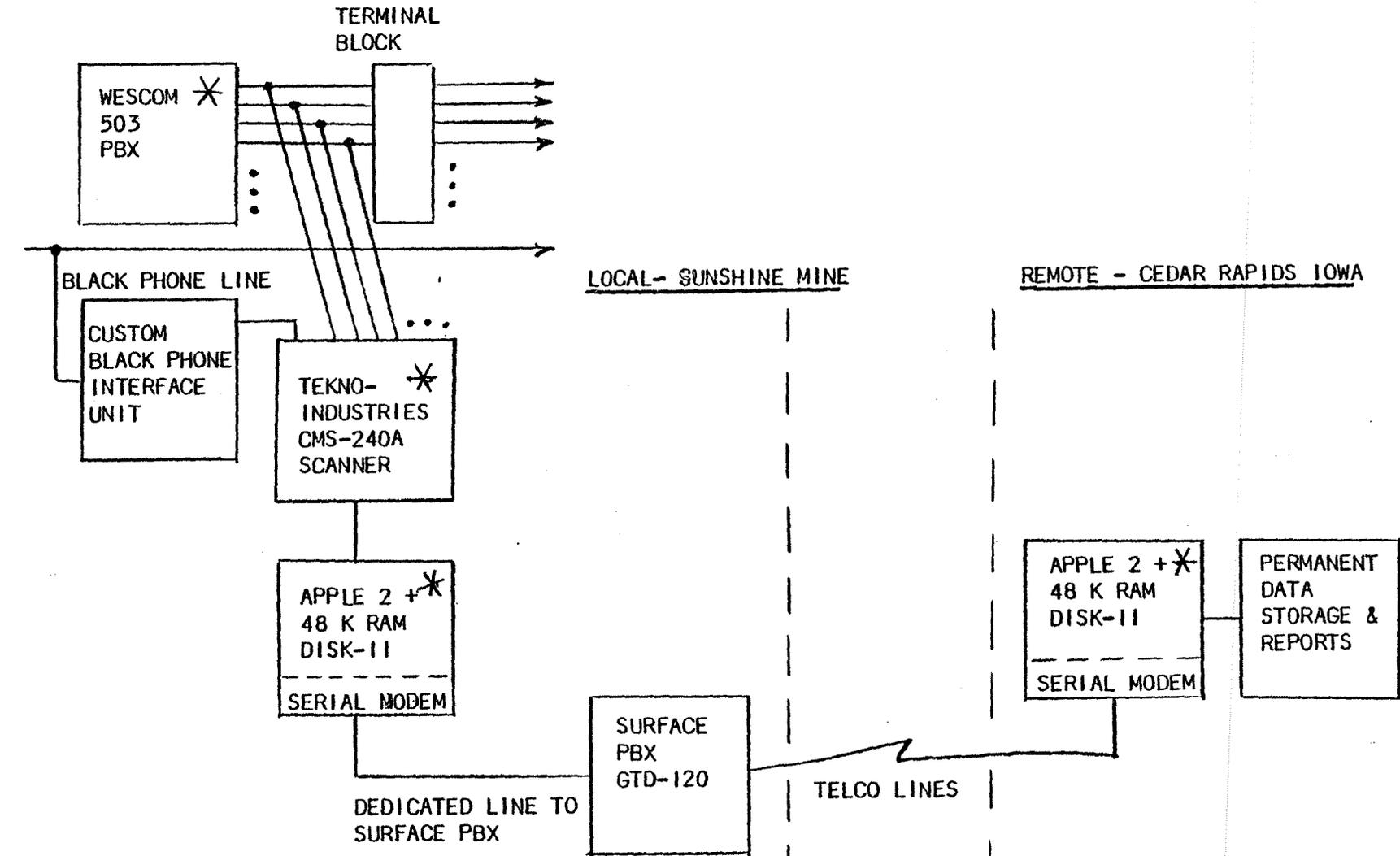
*Reference to specific brands, equipment, or trade names in this report is made to facilitate understanding and does not imply endorsement by the Bureau of Mines

TABLE 1 (Continued)

EQUIPMENT PROCUREMENT LIST FOR SUNSHINE TELEPHONE SYSTEM UPGRADE

CATEGORY	ITEM	QTY	COST
B.	LOUDSPEAKERS		E-\$7,500
	1. speakers (Atlas Sound SPB-3C)*		
	2. mounting hardware		
		Total	E-\$15,550
III. COMMON EQUIPMENT			
A.	LOOPBACK HARDWARE		E-\$2,000
	disconnect/test panels		
B.	PAGING HARDWARE		E-\$4,000
	1. central distribution amplifiers		
	2. interface audio hardware (transformers)		
C.	PBX COMPONENTS		Q-\$6,200
	1. line cards		
	2. trunk conditioning components		
	PCCs: trunk signalling		
	signalling appliques		
	trunk common		
	trunk incoming		
	trunk outgoing		
D.	ATTENDANT/DISPLAY EQUIPMENT		
	attendant console		

*Reference to specific brands, equipment, or trade names in this report is made to facilitate understanding and does not imply endorsement by the Bureau of Mines



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FIGURE 4

DATA COLLECTION SYSTEM CONFIGURATIONAL CONCEPT

be polled via a built-in serial modem having an EIA RS-232C (20 mA loop) interface at 100, 300 or 1200 baud rates from any processor using 8-level, 10-bit ASCII. In the configuration for this program, it will dump data from the preceding one hour reporting interval.

Both on-site and remote processors are Apple II Plus* computers with 48K of RAM and dual 5-inch floppy disk drives. The local and remote polling is controlled via real time clocks in both units. The data time stamp records are supplied from a real time clock in the CMS-240A*. Each computer employs one disk for stored program control and one disk for data storage with "scratchpad" operations performed in RAM. The remote polling of the on-site "slave" computer by the remote "master" computer occurs via long distance telephone modem communications.

The on-site Apple polls the CMS-240A and concentrates the data with the concentrated data being stored in binary form in a section of RAM (ready for remote polling) and on the storage disk for backup. The remote Apple polls the on-site Apple and stores the data on a working disk identical to that in the on-site Apple. The program disk in the remote Apple contains programs to scan the working disk, dump data into RAM on a data file basis, format reports and use internal algorithms for directly preparing cost benefit measures from the data summarized over selected intervals.

All on-site system elements are powered from uninterruptable power sources employing rechargeable batteries.

The functional flow of the data is illustrated in Figure 5. The CMS-240A is programmed to prepare a general call-by-call report (one of the standard reports available on this unit). This report contains standard ICUP usage data for lines and trunks supplemented with real time "called numbers". The report is ordered in chronological form with the call start times. This data, in ASCII form, is then concentrated to a "digitized" form in 1-minute intervals for each line and trunk giving the status of that interval. Additionally, at the interval representing initiation of a call, the address of the called number within the underground exchange is given; or, if a call is to the surface, the trunk address and/or the address of the number in the local surface exchange at the mine (underground calls are designated with a "no-trunk" address). Note: the black phone system is also to be monitored as a "line" within the underground PBX with a special interface, but with no additional to/from information.

*Reference to specific brands, equipment, or trade names in this report is made to facilitate understanding and does not imply endorsement by the Bureau of Mines.

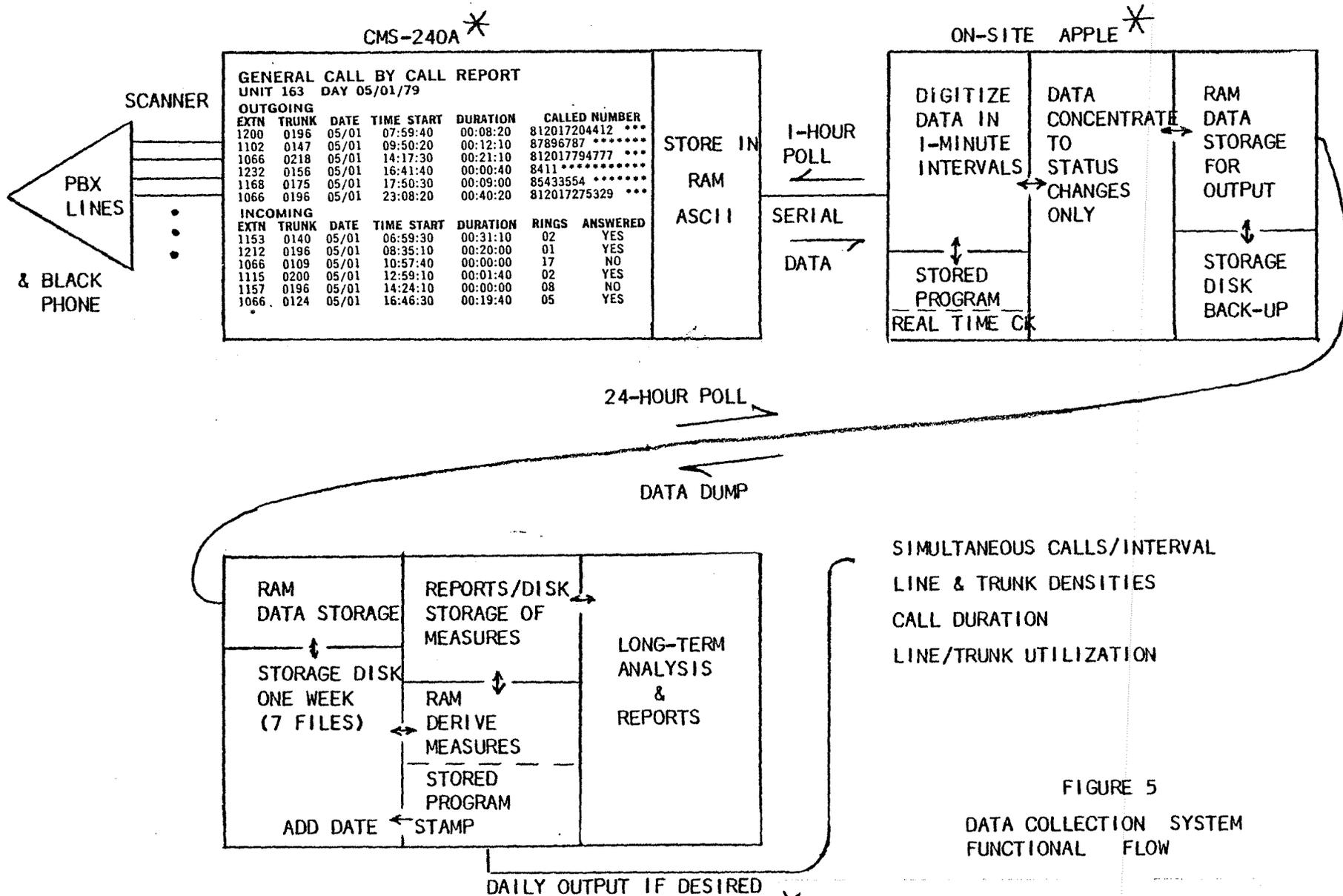


FIGURE 5
DATA COLLECTION SYSTEM
FUNCTIONAL FLOW

*Reference to specific brands, equipment, or trade names in this report is made to facilitate understanding and does not imply endorsement by the Bureau of Mines

The data stored at each 1-minute interval is only that data for active ("busy") lines or trunks. Thus, addresses for "idle" lines or trunks never appear in the listing for a particular interval. If the entire system is quiescent during a given interval, no address data is given and only the time stamp is stored.

The binary word format for the stored interval data per line or trunk is illustrated in Figure 6. The 8-bit (one data byte) data word includes a 6-bit address of the particular line or trunk, a bit to indicate a busy or unanswered call trial during the previous 1-minute period, and a "set" bit to indicate that the next byte is a "called address" byte or the next status word for new line, trunk or time stamp words. The called address word contains two trunk designator bits (for three active trunks or no trunk at all) and six bits for selected address codings from the surface PBX. At the beginning of each 1-minute interval, a time stamp is sent. If the first five address bits in sequence of a presumed new status word are all logic "1" then this word and the following 8-bit word are taken to be the time stamp. The remaining 11 bits between the two time stamp words are used to code the 1440 minute intervals in a particular day (24-hour period).

The stored data is arranged in "files" with each file corresponding to a 24-hour period. The date stamp for each file is provided by the real time clock in the remote processor.

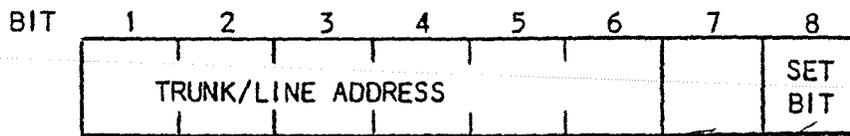
If all lines/trunks were active (assumed to number 50 for purposes of traffic estimation), then the data capacity required for storage would be:

For each 1-minute interval ("scan")	
time stamp overhead	2 bytes
status data	50 bytes
call address bytes	X bytes

The system design accomodates an approximate 10% duty cycle for storage (assuming an average of five status bytes per interval). Call address bytes assuming 3-minute call duration are 1/3 of the status bytes. Thus, the estimated average required storage per interval is:

For each 1-minute interval ("scan")	
time stamp overhead	2 bytes
status data	5 bytes
call address	5/3 bytes
a total of	<u>8 2/3 bytes/interval</u>

-STATION LINE/TRUNK STATUS WORD-



LOGIC"0" NO "BUSY" OR UNANSWERED CALL

LOGIC"1" A "BUSY" WAS ENCOUNTERED

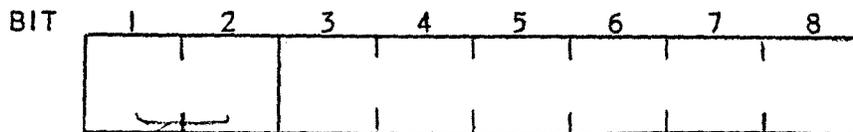
-OR-

A PLACED CALL WAS UNANSWERED

LOGIC"0" NEXT WORD IS NEW STATUS WORD

LOGIC"1" NEXT WORD IS CALLED ADDRESS BYTE

-CALLED ADDRESS WORD-



LOGIC"0,0" NO TRUNK - CALLED ADDRESS IS IN UNDERGROUND PBX

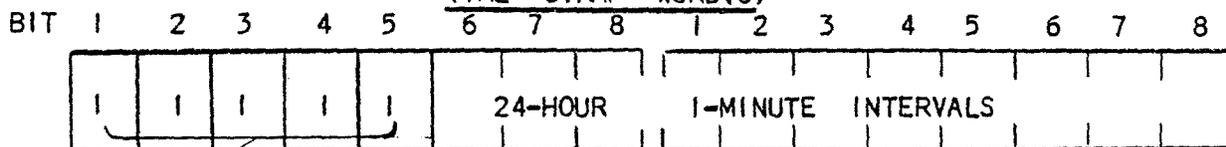
LOGIC"0,1" #1 TRUNK OF 3

LOGIC"1,0" #2 TRUNK OF 3

LOGIC"1,1" #3 TRUNK OF 3

CALLED ADDRESS IS IN SURFACE EXCHANGE NUMBER ASSIGNED ACCORDING TO CODE LIST

- TIME STAMP WORD(S)-



TIME STAMP DESIGNATOR

FIGURE 6

DATA COLLECTION SYSTEM BINARY WORD FORMAT

With 1440 (minute) intervals per day, data storage of approximately 12.5K bytes per day is required. With a maximum daily file storage capacity of 15K bytes, one week of data will require 105K bytes of storage, which, conservatively, is the capacity of one 5-inch floppy diskette.

Data from one day's file is easily analyzed in RAM. The statistics to be derived from the data includes:

- 1) The number of simultaneous calls per interval, which is equal to half the sum of busy lines + busy trunks

Note that this is easily derivable from the data on a "per interval" basis

- 2) Line and trunk usage densities, which is equal to the number of busy lines or trunks divided by the number available

Also derivable on a per-interval basis; can be used to predict the probability of blocked calls

- 3) Call duration, derivable from the number of successive intervals that a line/trunk was busy
- 4) Line/Trunk utilization, obtained over a time period of interest by adding the total busy times and dividing by the time available.

Additionally, the to/from data is available to identify all traffic on particular call linkages.

When the program was terminated, the Contractor was about to begin the software development to implement the above described system.

It is noteworthy that the selection of the Tekno Industries CMS-240A scanner was made because other potential suppliers would not supply data required to permit their scanners to be polled by an arbitrary

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processor. There were two problems with using standard commercial traffic management/analysis systems. These were:

- 1) The cost of the complete systems were about twice that of the chosen system; the remote portion of which was leased by the Contractor early in the program partially to accomodate this requirement
- 2) There was no standard software available that was already suited to the evaluation without further development.

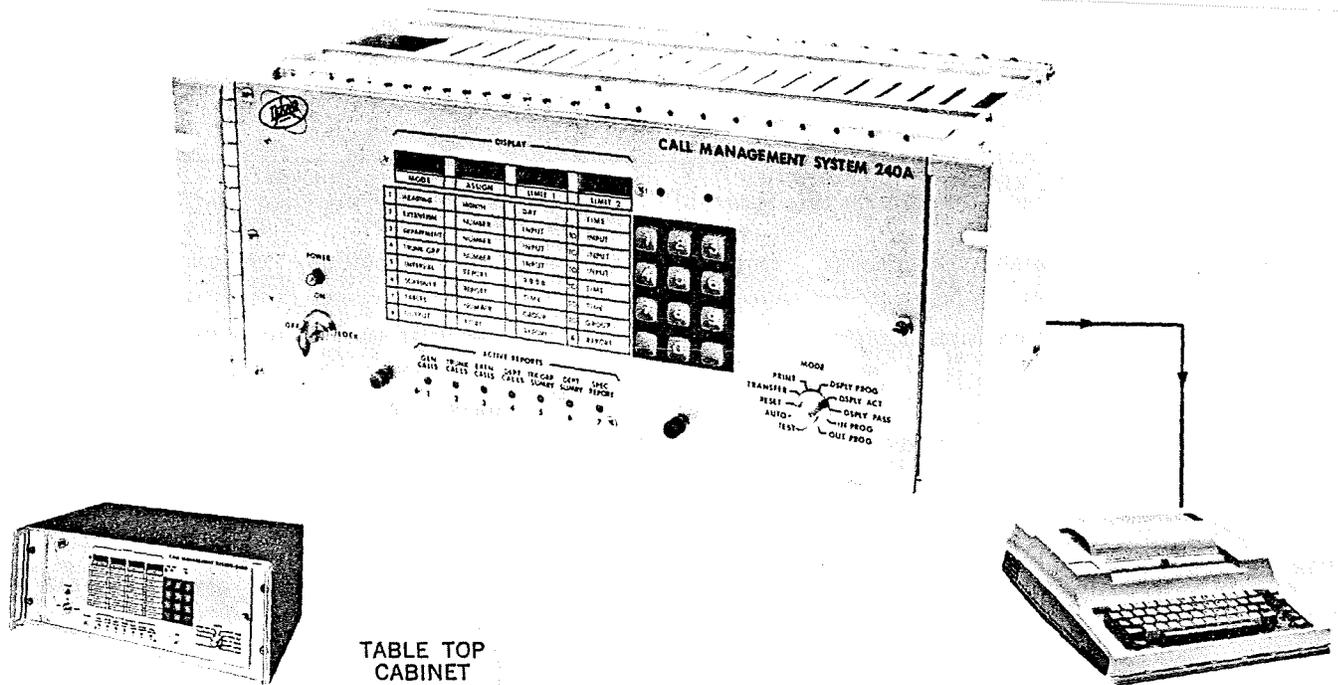
Data for the CMS-240A* is given in Figure 7.

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MODEL CMS-240A

CALL MANAGEMENT SYSTEM FOR P.B.X. & C.O. CALL ANALYSIS

FIGURE 7



SPECIAL FEATURES:

- * Call data on up to 240 P.B.X. trunks or extensions
- * Records date & time, dialed number, duration & cost
- * Stores up to 5500 outgoing & incoming call records
- * Sorts calls by extension, trunk, time or area code
- * Periodically summarizes dept. & trunk group activity
- * Supplies answering time & required circuits by group
- * Prints reports on TTY or poll over telephone network
- * Expandable to 2400 inputs & 65,000 call storage
- * Battery back-up for external power failures
- * Ideal for usage sensitive or verifying billing
- * Mounts in 19" rack or attractive desk top cabinet

The CMS-240A is a low-cost, micro-processor based recorder designed to collect detailed P.B.X. call data and automatically generate extension, department and trunk reports for analyzing telephone usage patterns. This system is completely self-diagnostic and requires no programming experience to operate. Using the front panel keypad simply key-in eight steps such as: time and date, parameters of the P.B.X. to be studied and type of reports desired. The CMS is now ready to go! Once this information is in the CMS it may be retrieved onto cassette tape for automatic loading in the future.

A CMS may be equipped with 24 to 240 Dial Pulse or 120 Touch-Tone inputs for connecting to tip and ring and/or E and M of electromechanical or electronic P.B.X. circuits. On outgoing calls, it records the extension and/or trunk number, dialed digits, account code plus date and time. While the call is in process, it scans the inputs to accumulate call duration and determine the Maximum Busy and Maximum Busy Time conditions for each group. On incoming calls, it records the extension and/or trunk number, number of rings, whether answered or not, call duration plus date and time. The CMS is capable of looking at all 240 inputs simultaneously without losing a call and storing up to 5500 call records in solid-state memory. Periodically this call data may be automatically sorted into Trunk Calls, Extension Calls, or Department Calls and printed locally on a TTY or polled over the telephone network to a remote data center. Similarly, this data may be processed into Trunk and Department Summaries to determine total calls, duration, cost, answer time and circuit requirements by group. Special account code, excessive cost and area code reports are also available upon request.

At any time the inserted program may be viewed on the front panel display and edited as desired. System operations and programming may also be conducted remotely via a teletype keyboard. The CMS system may be easily expanded to 2400 inputs and 65,000 call storage by multilining baskets in increments of 240 inputs. All electronic

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TEKNO INDUSTRIES, INC.

795 EAGLE DRIVE

BENSENVILLE, ILLINOIS 60106

4.0 SYSTEM COST - BENEFIT ECONOMICS

4.1 COST ESTIMATE FOR SUNSHINE MINE UNDERGROUND TELEPHONE SYSTEM

Since the U.S. Bureau of Mine's decision to terminate the program short of installing and evaluating an upgraded underground telephone system at Sunshine, the mine has elected on its own to partially implement the Contractor's recommendations as expressed in the Overall Communication Improvement Implementation Plan. The mine's plans call for:

- Hardwiring the #10 shaft with 50-pair cable from the 3100-level hoistroom to the 4600-level and with 12-pair cable to lower levels
- Hardwiring the 3100-level to the Jewell shaft and topside and on the 3700-level to the #12 shaft with 50-pair cable
- Eventually hardwiring the Jewell shaft with 50-pair cable
- Pulling out all carrier multiplex equipment
- Replacing the #10 shaft staging area and surface "red phones" with standard GTE instruments thus freeing-up these phones for refurbishment and reruse
- Postponing any activities to provide redundant routing or additional cabling at this time for C-vein or #12-shaft expansion.

The current status of the mines's system upgrade is discussed in Section 2.3 and is shown in Figure 3.

This section provides cost estimates for implementing the current mine-planned system configuration. Assumptions include both the implementation of the system from scratch, and the mine completing their plans for upgrading the existing system using additional Government furnished materials plus their own. The transmission plant will be transparent to the future PBX location. PBX location options available include retention of the existing underground PBX, and eventual operation from a larger combined surface/underground switch located in the mine's new office building. The original redundant transmission plant cost of the Overall Communication Improvement Implementation Plan, given in Appendix A, will not be estimated because this cost is not representative of what known deep-vein mines

would install on their own initiative. This is based on cost benefit data estimates for Sunshine, and the supposition that mines will not make the required investment without proven cost benefits. This is to say that without a long-term evaluation of such a system, as was originally to be provided during this program, there is no apparent way to cost justify the generic system of the Appendix A plan. Cost benefits have been estimated for normal recurring operation in the next Section 4.2. These recurring estimates can be substantiated. The occurrence of unusual events over long periods of time that could show accrual of cost benefits cannot be estimated short of an empirical evaluation.

The next several subsections provide cost estimates for the underground telephone system assuming its procurement and installation from scratch.

4.1.1 TRANSMISSION PLANT COST ESTIMATE

Cable Costs-

The Sunshine-initiated plan involves in excess of 5 miles of cable plant, a substantial portion of which is already in place. The cost of cable experiences a seasonal variation due to manufacturer and distributor backlogs (hence, lower prices) during the winter as opposed to the heavy construction summer season. The prices given in Table 2 to follow represent the summer 1981 values which, in addition to seasonal variations, have shown an approximate 7% escalation over the winter-spring 1980-1981 period. Assuming all necessary cable is provided from scratch, Table 2 gives costs assuming 19 gauge wire in all cases and copper wire mesh for all armored cable. The total estimated cable cost is \$34,377.

Wireplant Installation Cost (including J-boxes)-

Wireplant installation rates were derived as part of the study preceding the preparation of the Overall Communications Implementation Plan. These rates are given in Section 4.1 of Appendix A and are used as the basis for the costs for particular run categories at Sunshine. The rates and cost are given in Table 3, reflecting the same cable run categories given in Table 2. The average wireplant installation cost is \$1.18 per running foot. The total estimated wireplant installation cost is \$31,994.

J-Box Procurement & Outfitting

A total of 25 J-boxes are required to accommodate splicing between cable reels and to provide connections at wireplant network junctions. The unit price for the boxes plus fittings is estimated to be \$60.

Outfitting the boxes in preparation for installation is estimated to require one hour per box at a cost of \$25 in labor. This assumed that this preparation is performed by an outside maintenance contractor. The total estimated cost of procuring and outfitting the J-boxes is \$2125.

The total cost of the transmission plant, in-place, is estimated to be \$68496.

4.1.2 SWITCHING EQUIPMENT COST ESTIMATE

Generic PBX costs have been analyzed with the results presented in Section 4.2 of Appendix A. The installed cost of a 50-line underequipped switch including spares and phones is estimated to be \$42,000. Including an additional \$8,100 for special dial pads (and spares inventory), and \$2,500 for battery back-up, the total estimated cost of this switch is \$52,600.

The installed cost of a 150-line surface switch on the same basis as the 50-line switch is \$85,500. Allocating 50 lines of this larger switch to underground service, The estimated cost for the underground portion is \$28,500.

4.1.3 VOICE PAGING EQUIPMENT COST ESTIMATE

Voice paging equipment comprises a central amplifier system for use with the hardwired telephone system, plus wireless paging equipment for communications extension into the stope areas. The central amplifier system consists of a central amplifier and an actuating register to connect to the PBX voice page output terminals, and loudspeakers to be colocated with each underground phone. The loudspeakers are assumed to be inexpensive units which are expendable upon failure. Provisions have been made within the cable plant for transmission of the page signals.

The wireless equipment is presumed to consist of a mixture of fixed wall-mounted units for colocation with shaft station phones, fixed units for placement in the stope areas, and portable units. The fixed units may be of the conventional trolley carrier phone transceiver variety, or may be of the new medium frequency base station or vehicular transceiver variety being developed by several manufacturers. The portables may be page receivers only which have been available for some time for use with trolley carrier phones, or they may be new medium frequency transceiver units being developed as companions for the new fixed units.

The estimated costs for the voice paging equipment are given in Table 4. Costs for the wireless equipment will be subject to some variation

according to the type procured, any custom packaging by mine personnel necessary, and due to firm pricing not being available on some of the new medium frequency radios. The total estimated cost for the voice paging equipment is \$38,360.

4.1.4 MAINTENANCE COST ESTIMATE

Maintenance costs for the telephone system have been estimated considering a percentage of a mine employee's time plus time for either the telephone company (TELCO) or an outside contractor to service the phones. Continued use of an underground PBX will require an outside contractor's help to perform the maintenance on a long-term basis. With a surface PBX only, the service to maintain the phones could be performed either by TELCO or outside contractor personnel. A Spokane-based interconnect company has offered to maintain the underground system for about \$1000/month; the estimated cost for the TELCO to service the phones would be about \$800/month. This presumes an arrangement could be worked out with the TELCO to service these underground phones at the rate at which they charge for servicing TELCO-owned surface phones, but with the mine carrying the necessary parts and spares inventories. The maintenance costs for the wireless equipment are expected to run about 10% of the purchase cost, which is equivalent to carrying 10% spares on an annual expendable basis. The maintenance cost estimate is given in Table 5. Separate costs are given for the phone system serviced by an underground PBX, serviced by a surface PBX, and for servicing the wireless paging equipment. These estimated totals are \$23,160 using the underground PBX, \$10,480 using the surface PBX, and \$3,600 for the wireless equipment.

4.1.5 SUMMARY OF ESTIMATED COSTS

A summary of the estimated costs for both the from-scratch system and the incremental add-on costs to the existing Sunshine system are given in Table 6. These include options of surface or underground PBX and paging.

The incremental costs for Sunshine to complete the system as an add-on to the system status as of 9-81 is given in Table 7. These costs assume that Government furnished materials and labor pledged to complete the contract commitment are at no cost to the mine.

The above cost estimates will be used in conjunction with the estimated cost benefits to be given in the next Section 4.2. This next section will provide the basis for an overall economic analysis of the underground communication system at Sunshine, which is given in Section 4.3.

TABLE 2

WIREPLANT COSTS FOR SUNSHINE MINE TELEPHONE SYSTEM
 ASSUMED TO BE PROVIDED FROM SCRATCH

1) 3.65 K feet 50-pr non-armored cable, #10 shaft 3100-4600 levels in vent raises at \$1424/ K feet	\$ 5198
2) 2.10 K feet 12-pr armored mesh cable, 4600-5600 levels of #10 shaft, in-haft at \$1300/K feet	\$ 2730
3) 4.90 K feet 50-pr non-armored cable, #10 shaft 3100-level hoistroom to Jewell shaft at \$1424/K feet	\$ 6978
4) 5.05 K feet 50-pr armored mesh cable, Jewell shaft to topside at \$3254/K feet	\$16433
5) 1.20 K feet 50-pr non-armored cable, 3700-level Jewell to #12 shaft at \$1424/K feet	\$ 1709
6) 5.20 K feet 1-pr non-armored cable, for individual phone connection at \$129/K feet	\$ 671
7) 5.10 K feet 1-pr non-armored cable, for C-vein drift run at \$129/K feet	\$ 658
SUBTOTAL ESTIMATED CABLE COST	<u>\$34377</u>

TABLE 3

ESTIMATED WIREPLANT INSTALLATION COSTS FOR SUNSHINE
TELEPHONE SYSTEM ASSUMED TO BE PROVIDED FROM SCRATCH

1) vent raises, 3.65 K feet at \$1.56/foot	\$ 5694
2) shaft, 2.10 K feet at \$2.40/foot	\$ 5040
3) straight drift, 4.90 K feet at \$0.52/foot	\$ 2548
4) shaft, 5.05 K feet at \$2.40/foot	\$1210
5) flat drift, 1.20 K feet at \$1.03/foot	\$ 1236
6) hook-up, 5.20 K feet at 0.52/foot	\$ 2704
7) straight drift, 5.10 K feet at \$0.52/foot	\$ 2652

SUBTOTAL WIREPLANT INSTALLATION COST \$31994
average of \$1.18/foot

TABLE 4

ESTIMATED COST OF VOICE PAGING EQUIPMENT FOR SUNSHINE MINE

phone. system central amplifier	\$ 1200
loudspeakers(100% spares)	\$ 1160
100 speakers at \$8.00 each	
2 days labor at \$180/day	
SUBTOTAL PHONE SYSTEM PAGING	\$ <u>2360</u>
wireless paging to stopes	\$36000
60 units at \$600 each	
40 units for stopes	
10 units for shaft station areas	
10 units, portables	
TOTAL VOICE PAGING EQUIPMENT-----	\$38360

TABLE 5

ESTIMATED MAINTENANCE COSTS FOR SUNSHINE TELEPHONE SYSTEM

1) phone system with underground PBX	
\$800/month outside labor	\$9600/year
1/2 time for 1 man at \$11/hr	\$10560/year
materials at 10% of phones an PBX cards	\$ 3000/year
	<u>\$23160/year</u>
2) phone system with surface PBX	
outside labor allocated as 50 out of 150 total lines or 1/3 of capacity	\$ 3200/year
1/4 time for 1 man at \$11/hr	\$ 5280/year
material as 10% of phones 50 phones at \$400 each	\$ 2000/year
	<u>\$10480/year</u>
3) wireless paging equipment	
10% of cost	\$ 3600/year

TABLE 6

SUMMARY OF ESTIMATED COSTS FOR DEEP-VEIN METAL MINE TELEPHONE SYSTEM BASED ON THE SUNSHINE CONFIGURATION WITH AND WITHOUT ADDED WIRELESS PAGING

- Wireplant Costs	
Wireplant Procurement	\$ 34,400
Wireplant Installation	\$ 32,000
J-Boxes	\$ 2,100
SUBTOTAL WIREPLANT	\$ 68,500
- Switching Costs	
50-Line Underground PBX w/Phones (incl. installation & spares)	\$ 42,000
Special Dial Pads	\$ 8,100
Battery Backup	\$ 2,500
SUBTOTAL UG PBX	\$ 52,600
50 Lines of 150-line Surface PBX (incl. phones, installation, & spares)	\$ 28,500
Special Dial Pads	\$ 8,100
Battery Backup	\$ 2,500
SUBTOTAL SURFACE PBX	\$ 39,100
- Paging Equipment Costs	
Hardwired Phone System Voice Paging	\$ 2,400
Wireless Paging Equipment	\$ 36,000
TOTAL UNDERGROUND PBX SYSTEM W/O WIRELESS PAGING	\$123,500
TOTAL SURFACE PBX SYSTEM W/O WIRELESS PAGING	\$110,000
TOTAL UNDERGROUND PBX SYSTEM WITH WIRELESS PAGING	\$159,500
TOTAL SURFACE PBX SYSTEM WITH WIRELESS PAGING	\$146,000

TABLE 7

INCREMENTAL COSTS FOR SUNSHINE TO IMPLEMENT THE IMPROVED
TELEPHONE SYSTEM BY MODIFYING THE EXISTING SYSTEM BEYOND
THE 9-81 STATUS

- Wireplant Costs	
Procuring 50-pair Cable with Armor Braided Cable	\$ 16,400
Installing Jewell Shaft Cable at \$2.40/Foot	\$ 12,100
Installing Government-furnished 50-pair Cable at \$0.52/Foot	\$ 3,100
SUBTOTAL WIREPLANT	\$ 31,600
- Switching Costs	
Procuring 11 Additional Underground Phones Plus 5 Spares to Bring Total Complement to 50	\$ 7,600
- Paging Equipment Costs	
Hardwired Phone System Voice Paging	\$ 2,400
Wireless Paging Equipment	\$ 36,000
TOTAL UNDERGROUND PBX SYSTEM W/O WIRELESS PAGING	\$ 41,600
TOTAL UNDERGROUND PBX SYSTEM WITH WIRELESS PAGING	\$ 77,600

4.2 ESTIMATED COST BENEFIT FOR SUNSHINE FROM IMPROVED COMMUNICATIONS

The cost benefits of communications in deep-vein metal mines are of three types:

- Those which save stope mining crew time; and, therefore are related to the time value of muck (product) produced .
- Those which save labor only, predominantly of maintenance crews and of supervisory personnel
- Those aiding mine health and safety; thereby saving time, lives, and dollars during emergency periods.

This section will estimate the savings expected on a recurring normal operation basis comprised of the first two types. Estimates of the savings due to the third type are difficult and subjective; although no one will argue that the long-term repercussions of the 1972 mine disaster have cost the mine money, and that improved communications during that period had it been available may have reduced the severity of the disaster.

All estimates of Sunshine Mining Company operations given to follow were obtained from data in the Sunshine Mining Company 1980 Annual Report.

Examination and analysis of Sunshine mine operations from 1977 to-date suggests that the average mine daily output has run 737 tons clean (no waste) with an average of about 23 oz of silver/ton and with Sunshine's share running about 56.5%. Additionally, the mining costs/oz of silver have increased from about \$3.90 in 1978 to \$5.80 in 1979 to \$15 in 1980 (unusual due to strike) with an estimated current cost of about \$8.50/oz. Recently, Sunshine has consolidated and acquired other interests in the mine which will be reflected in the future operations. For purposes of the cost benefit estimates, a prorated 56.5% share will be assumed. The estimates will consider mining costs only; and, thus, are independent of other overhead and G&A burdens from overall operations.

The cost benefit estimates assume that 40 active stopes are in operation with 2-man crews working 6 hours/shift on-station for a total of 480 manhours/production shift. They further assume 2 production shifts per day. Assuming a nominal \$10/oz of silver, the estimated time value of product is then \$41640/shift or \$86.75/minute over all stopes. Correspondingly, the value of product per production crew manhour is also \$86.75.

Assuming mining costs of \$8.50/oz, the cost/shift is estimated to be \$35394; the gross margin(profit)/shift is estimated to be \$6246.

Several generalizations based on this analysis are apparent. These are:

- 1% variance in product output is worth 6 3/4% in margin
- a loss of one production(mining) manhour
-or-
one minute in product-time-value is worth 1.4% of gross margin/shift
- each stope is worth \$1000/shift or 16% of gross margin/shift
- each minute of production(mining) crew time is worth at least \$1000/year.

The current telephone systems(both "black" and "red") provide communications only at the shaft stations, with no communications being available in the stope areas. The most significant recurring and production related cost benefit would involve extending paging communication from these shaft stations into the stope areas, as is the rule in mining operations elsewhere in the U.S.. If this were accomplished, the potential cost benefits may be illustrated via the following scenarios. These scenarios will, hopefully, provide a basis for concurrence on the benefits of communication extension into the stopes.

- 1) Assume out of 40 stopes, a failure of essential services for mining(electrical,water,air,sand) occurs in one stope once/shift necessitating a man to walk an average of 1000 feet to the shaft station area and back to report the failure and to solicit help

Just the "reporting time" for this compared to using communications is estimated to require 15 minutes.

- 2) Assume that once per day, just the location of a roving maintenance man, presumed to be already underground, to solve a problem which has shut down a stope takes 30 minutes without paging(compared to a shorter time with paging)

Estimate this time comparison to be 15 minutes/shift

- 3) Assume this maintenance man, on station, diagnoses the problem & needs parts from an underground shop on that level; his time to walk back and request or get them compared to using communications, again for only one occurrence/day, is estimated to be 15 minutes

This would be equivalent to 7 1/2 minutes/shift

- 4) Assume that once a week, one stope out of 40 is shut down for half a shift waiting for parts available from the surface and that including diagnosis, two hours could be saved by communicating rather than just "walking out"

This would be 120 minutes over 10 shifts, or 12 minutes/shift of production time.

- 5) Assume that in getting a maintenance man to and from a shut-down stope requires 2 cage rides, and that notifying cager in advance of getting there using communications could save 10 minutes/ride(up & down) or 20 minutes/day

This would be equivalent to 10 minutes/shift of production time.

In terms of production time, these assumptions save 1 hour for 1 stope (2 hours total for the 2-man crew) or 0.42% of the total production manhours/shift. On an annual basis this would save an estimated \$83,000. Of this savings, the breakdown allocation to the paging and to the phone system proper is as follows:

\$51,000 paging benefit alone

\$32,000 having phone system proper available to work in conjunction with the wireless paging

The original premise on which the multi-channel phone system economics was based was that the labor time saved in moving men and materials in and out of the mine would cost justify the system acquisition. The operational problem involved in this premise has been viewed as having two parts:

- A communications "bottleneck" occurs when only a single channel "black" phone is available. During shift change periods, groups of maintenance or supply people often "wait" to define their shift's work.

This information and coordination exchange ties up these groups until the single channel is available and the call(s) has been placed.

- The average waiting time during normal operation to place a short call from any or all active shaft station levels is significant when statistically considered over an entire shift time period.

An analysis of this problem has been prepared using fundamental traffic theory plus a few operational assumptions. The average call length using the "coded" "black" phone system has been assumed to be 3 minutes. The expected delay in getting a call through on a per-call basis vs the number of persons simultaneously trying to make a call is given in Figure 8 for the single-channel and for a two-channel system. An offered traffic level of 0.05 Erlangs (number of calls times the average time/call divided by elapsed time) is assumed in the figure. From Figure 8, it is noteworthy that for the anticipated amount of phone usage, the availability of two channels compared to one reduces any call delays to negligible values. Figure 9 gives the probability of call delay vs offered traffic level for several combinations of available channels and number of callers.

Considering the possibility of a communications bottleneck during shift change periods, several scenarios were tried giving nearly identical results; the following is typical:

- Assume
- 1) 20 calls are made during "peak" activity during shift changes over an approximate one-hour period
 - 2) There is one short peak interval when 10 people are trying to make calls simultaneously, with 6 calls being completed
 - 3) There is a longer interval when 6 people are trying to make calls simultaneously, with 4 calls being completed
 - 4) For the remainder of the period an average of three people are trying to make calls simultaneously with 10 calls being completed
 - 5) For each of the call situations of 2) - 4) above, there are three people waiting, including the caller

These assumptions give 66 minutes of labor expended waiting compared

with 3-6 minutes if more than a single channel were available; or, on an annual basis assuming 2 shifts/day, 240 days/year, and \$11/hour direct labor, an amount of \$5280. This is the savings of a multi-channel system over a single-channel system of 1 hour/shift.

In conjunction with this shift change period, assume one person physically goes topside(or underground) per day to conduct business with a round trip time of 60 minutes(30 minutes/shift) or an amount of \$2640 annually. Thus the total estimated recurring "peak" period savings of a multi-channel system is \$7920/year.

Considering the average waiting period to make a short call during the remainder of a shift, assume there are:

- 1) 10 active shaft station levels, each having one call/hour of 3 minutes; for a total of 80 calls(240 minutes) per shift, or 50% utilization of a single-channel system
- 2) 2 persons simultaneously trying to place calls (or one call in progress with one call trying to be placed)
- 3) there are two people waiting, including the caller for each call(say, a 2-man crew where one man waits while the other calls)

This assumption gives 21 1/2 minutes/shift of waiting time, corresponding to \$1877 annually.

Thus, as a result of labor-only savings due to the telephone system, the estimated total annual savings is \$9797 or approximately \$10000.

The productivity related savings(taken to be lower bound estimates) plus the labor-only savings(taken to be nominal average estimates) result in an estimated composite savings of \$93,000 annually, with \$51,000 of this savings accruing to the use of wireless paging into the stope areas. Note that the productivity related savings of \$83,000 annually for a 0.42% savings of production manhours based on product yield is roughly equivalent to a \$200,000 annual savings for a 1% increase in productivity.

The authors expect a 1% productivity increase to be near average for communication systems in typical deep-vein mines; but, in absence of hard empirical data, the microscopically derived conservative estimates of this section are the only ones which can be made with reasonable confidence. It is interesting to note that, nationally, larger mines which recognize they have a communications problem are

FIGURE 8

COMPARISON OF SINGLE-CHANNEL AND DUAL-CHANNEL
SYSTEM CALL DELAY TIMES VS THE NUMBER OF
SIMULTANEOUS CALLERS FOR AN OFFERED TRAFFIC
PER STATION OF 0.05 ERLANGS

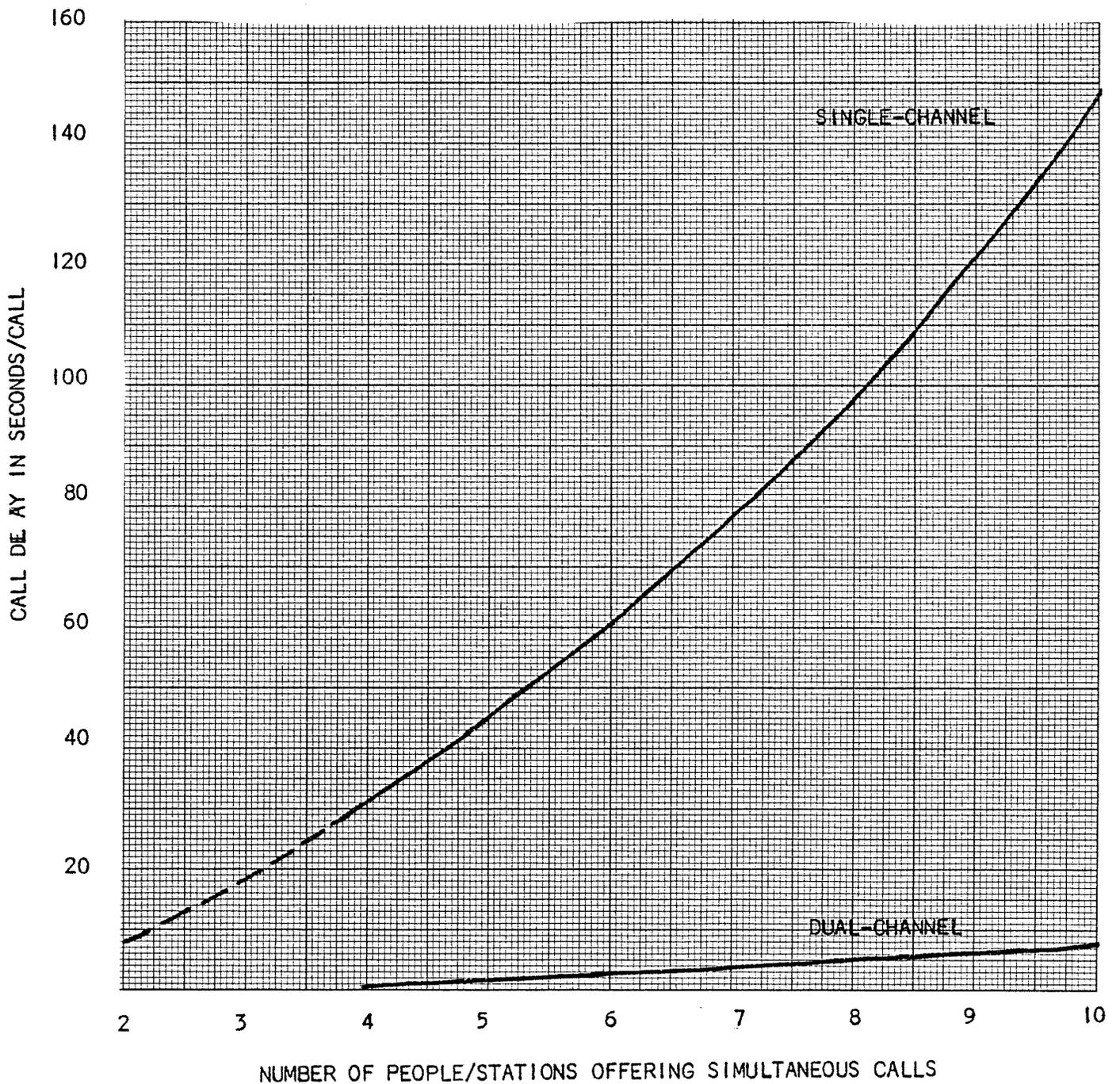
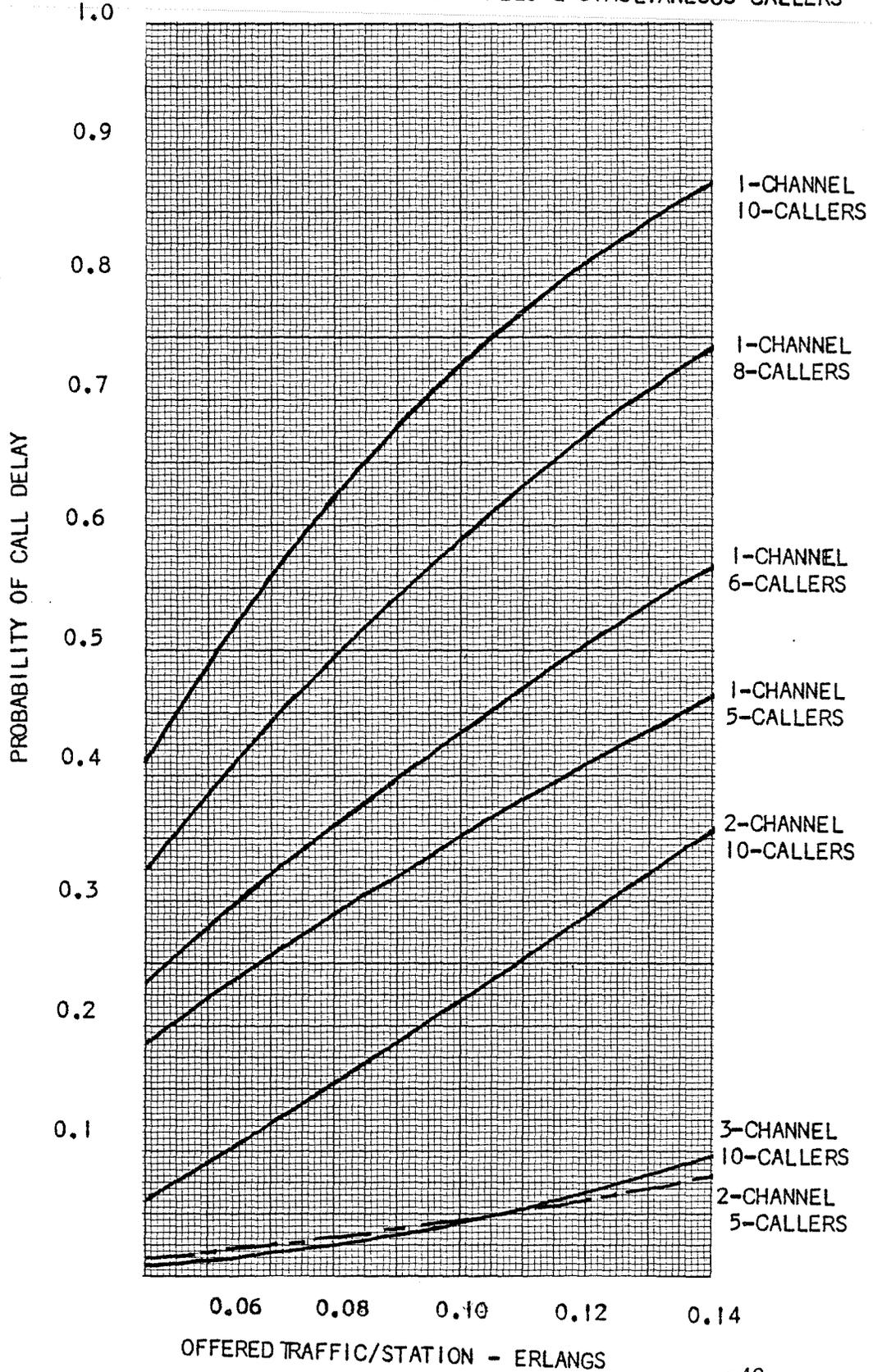


FIGURE 9

PROBABILITY OF CALL DELAY VS OFFERED TRAFFIC IN ERLANGS
PER STATION FOR NUMBER OF CHANNELS & SIMULTANEOUS CALLERS



willing to spend up to \$100,000 for an installed system and expect to spend another \$100,000 in the following two years on maintenance and provisioning; also, they expect system payout to be within 1-2 years. If the economics of Sunshine are typical, and the savings is really about 1% of productivity annually, the payout occurs by the end of the first year.

These estimates of Sunshine mine operations were derived from the Sunshine Mining Company 1980 Annual Report and were correlated with selected data from the Hecla Mining Company Second Quarterly Report, Six Months Ending June 30, 1981. These derived data on which the estimates are based are given in Table 8.

4.3 OPERATIONAL COST ANALYSIS FOR UNDERGROUND TELECOMMUNICATIONS AT THE SUNSHINE MINE

This section combines estimates of telecommunications system cost and expected cost benefits to be derived from system usage at Sunshine. The factors considered include initial installed system cost, recurring maintenance on an annual basis, and projected cost savings on an annual basis toward system cost recovery. Subjective potential cost savings due to system usage during unusual operational events, including health and safety aspects, are not included. Also excluded are aspects of convenience which may result in the savings of valuable management personnel time. The system configurational and functional variations considered include the system with and without paging, the system with hardwired phone system paging only, the system including wireless paging into the stope areas, and the system using a dedicated underground PBX compared to shared usage with and operation from a surface PBX. Also considered is the impact of system cost if the system were procured from scratch compared with costs to Sunshine of completing its planned hardwired system upgrading beyond that provided from the benefits derived from participation in this Government sponsored program.

Case 1-

Procuring and installing the underground system from scratch without paging and using a dedicated underground PBX, the pertinent costs are:

Initial installed cost	\$123,460
Annual maintenance cost	\$ 23,160.

Without paging and on a normal operational recurring basis, the authors can find no direct correlation between phone system usage and product yield. The net savings by virtue of having the multi-channel phone

paging assuming use of a single surface PBX, the pertinent costs are:

Initial installed cost	\$146,000
Annual maintenance cost	\$ 26,760

With paging, both phone system voice and wireless, savings accrue both to the phone system proper and to the wireless portion of the investment, estimated to be:

A) Gross savings over entire system

Estimated annual savings	\$ 93,000 minimum
Net annual savings (gross minus maintenance cost)	\$ 66,240 minimum

System cost recovery in 2.2 years

B) Phone system(\$110K) portion of entire system

Estimated annual savings	\$ 42,000
Net annual savings	\$ 18,840

Phone system portion cost recovery in 5.8 years

C) Wireless system(\$36K) portion of entire system

Estimated annual savings	\$ 51,000
Net annual savings	\$ 47,400

Wireless system portion cost recovery in 0.8 years

Case 4-

Completing installation of mine-initiated hardwiring of phone system without paging and keeping the existing underground PBX, the pertinent costs are:

Initial installed cost	\$ 39,273
Annual maintenance cost	\$ 23,160

with the expected annual savings the same as for Case 1:

Estimated annual savings \$ 10,000

with the conclusions being the same as for Case 1.

Case 5-

Completing installation of mine-initiated hardwiring of phone system with paging and keeping the underground PBX, the pertinent costs are:

Initial installed cost \$ 77,633

Annual maintenance cost \$ 26,760

with savings accruing both to the phone system proper and to the wireless paging portion as in Case 3, with gross savings over the entire system of:

Estimated annual savings \$ 93,000 minimum

Net annual savings (gross minus maintenance cost) \$ 66,240 minimum

System cost recovery in 1.2 years

Case 6-

Completing wiring of 3100-level using 6000 feet of Government furnished 50-pair cable and not buying any more phones, but adding paging, the pertinent costs are:

Initial installed cost \$ 41,480
phone system \$ 5,480
paging \$ 36,000

Annual maintenance cost \$ 26,760

with savings over the entire system of

Estimated annual savings \$ 93,000

Net annual savings \$ 66,240

System cost recovery in 0.6 years

These analyses clearly show the potential advantages of adding paging including wireless paging to the existing or future telephone system. The authors believe the true annual savings to be about 1% of product

yield, which would provide about \$200,000 of savings annually.

Assuming the validity of the analysis premises:

Case 1, 2, and 4 analyses clearly illustrate the inability to cost justify a modern multi-channel telephone system in this type mine without paging communications within the hardwired system and also into the production areas via wireless equipment.

Case 3, 5, and 6 analyses employing paging and, therefore, relating time savings directly to productivity clearly illustrate cost recovery for the system investment in less than two years.

Previous analyses performed under this contract and reported in Appendix A have confirmed the centrally switched system as being the most economic architecture available for this type mine from both initial procurement and recurring maintenance points of view.

The system cases employing paging also provide communication where it is needed when it is needed with respect to minimizing the impact of unusual situations other than normal recurring operations. This obviously further substantiates cost justification; but, more importantly, it also improves mine health and safety. The clearest example of potential health and safety benefit is in providing warning in remote stope areas of the mine in case of fire. Without this warning, there may be cases where carbon monoxide carried in the mine ventilation system will reach remote areas before the stench of methyl captan because of the time delay involved in the injection and diffusion of this chemical.

Several of the above conclusions have become apparent "after the fact", following the investment in the test-bed system. This has occurred largely because of increased understanding of the cost-benefit relationship of communications and mine productivity gained by the Contractor and U.S.B.M. personnel during the course of this program. The importance of characterizing normal and emergency operations "before the fact" is underscored by this situation. Time-in-motion studies performed prior to procurement of a new communication system will identify logistical supply and product recovery processes which, in turn, will enable the procurement economics to be assessed. These studies can probably be most efficiently performed by an outside communications firm in cooperation with the mine. Inherent in the studies and procurement planning is the establishment of a long-term maintenance plan, usually involving training one or more mine maintenance persons.

The Contractor would encourage Sunshine to eventually implement all portions of the recommended cable plant, including the tie trunks to

connect the surface and underground PBX's. The remaining useful life of the underground PBX is expected to be less than two years, so that planning for its replacement or supercession by a new surface PBX should begin soon. Further, the Contractor specifically recommends implementation of both wired and wireless paging at Sunshine as soon as possible because of the potential economic benefits.

TABLE 8

SUMMARY OF ESTIMATED OPERATING DATA FOR SUNSHINE
MINING COMPANY SUPPLEMENTED WITH RECENT DATA FOR
HECLA MINING COMPANY

TOTAL SUNSHINE MINE QUANTITIES				
ITEM	1980	1979	1978	1977
ANNUAL TONNAGE	50,442	171,858	200,884	153,982
OZ SILVER	902,300	3,556,814	4,993,976	3,795,656
OZ SILVER/TON	17.9	20.7	24.9	24.7
TONS/DAY: MAX GROSS	679	866	1,012	775
CLEAN	566	722	844	646
AVERAGE DATA	737 TONS/DAY CLEAN, 23 OZ/TON			
MINING COST: \$/TON	269	121	98	121
\$/OZ	15	5.8	3.9	4.9
ESTIMATED SUNSHINE SHARE OF TOTAL OUTPUT: 56.5%				

HECLA DATA

1ST 6 MONTHS 1980	147,099	TONNAGE,	10.8 OZ/TON
2ND 6 MONTHS 1980	147,329	TONNAGE,	12.5 OZ/TON
COSTS 1980	\$ 6.4/OZ, \$79/TON		
COSTS 1981	\$ 9.7/OZ, \$104/TON		

SUNSHINE OPERATING FORMAT ESTIMATE

40 STOPES, 80 MINERS/SHIFT
70-80 MEN/SHIFT OVERHEAD (MAINTENANCE/SUPPLY/SUPERVISORY)
2 PRODUCTION SHIFTS, 8 HOURS TOTAL/SHIFT
6 HOURS/SHIFT ON-STATION

SOURCE: Sunshine Mining Company 1980 Annual Report
Hecla Mining Company Second Quarterly Report
Six Months Ending June 30, 1981

APPENDIX A

TELEPHONE COMMUNICATION SYSTEM FOR A DEEP VEIN METAL MINE

OVERALL COMMUNICATIONS IMPROVEMENT IMPLEMENTATION PLAN

FOR THE

SUNSHINE SILVER MINE

USBM CONTRACT NO. JO100093

PREPARED FOR:

U. S. Bureau of Mines
Section of Procurement, Washington
Columbia Plaza, 5th Floor
2401 E Street, N. W.
Washington, D. C. 20241

ATTEN:

Doyme W. Teets
Contracting Officer

PREPARED BY:

Terry S. Cory, P. E.
2857 Mount Vernon Rd. S. E.
Cedar Rapids, Iowa 52403

February 1, 1981

ABSTRACT

This paper assesses the application of currently available multi-channel telephone equipment as a means to increase profitability and improve health and safety in deep-vein metal mines. Both functional and long-term cost benefit expectations derived from using this equipment are emphasized, compared with the usual single channel party line magneto phone. The application of both conventional and new specialized mine phone equipments are considered. A comparison of candidate system combinations suggests that a CENTRALIZED PBX CONFIGURATION WITH HARD-WIRED TRANSMISSION PLANT AND INDUSTRIAL GRADE TELEPHONES IS OPTIMUM; WITH SURFACE AND UNDERGROUND SYSTEMS LINKED WITH DIAL TIE TRUNKS. The material is presented in the context of information gathered over the last five years in an ongoing and continuing project at a USBM sponsored test bed in the Sunshine mine near Wallace, Idaho. Current planning for that system combines surface and underground telephone systems into an integral network.

FOREWARD

The described work embraces seven years of USBM involvement in deep-vein mine communications for Sunshine. This experience has defined the communication system needs to best affect productivity and mine health and safety. In this type of mine, most crucial activities are time related in moving men, supplies and product up and down deep vertical shafts. The coordination of these activities is more difficult than it is in largely horizontal mining operations typified by Eastern coal mines of similar lateral extent. Likewise, timely repairs and maintenance functions are more difficult to accomplish. These mines are incrementally developed over long periods of time and, although the mine wireplant is relatively static, it must be reliable. Thus, there is extreme leverage in communication system investment relative to product yield with recurring maintenance costs of any system potentially outstripping the initial cost within one to two years. This cost is much more sensitive to the differences between the time value of product yield versus mining overhead than it is to idle labor cost alone

The current USBM test-bed system at Sunshine was planned in 1973, developed through 1975 and became operational in 1977. The project was initiated largely for health and safety reasons following the 1972 disaster at Sunshine. The purpose of the request was that confusion on an overloaded single channel phone system may have contributed to the severity of the disaster. The USBM expanded this purpose to link the health and safety features of improved communications with operational features directed toward improved productivity. The project goal has been to evaluate the applicability of commercially available telephone equipment, configured to meet the mine's needs, as demonstrated by 1) mine acceptance; 2) maintainability 3) ability to expand/reconfigure the system, and; 4) cost/benefit analysis in addition to providing multiple channels to streamline communications during emergencies.

The original contractor defaulted and the engineering and administrative services necessary to demonstrate objectives 2) and 4) ceased, with the contract being terminated for the convenience of the government. Mine personnel kept the system operational during the next year without outside help. In 1979, interim maintenance and planning services for continuation of the test bed project were provided via two small separate contracts. An outcome of this planning has been a recommendation for upgrading the existing system prior to defining the maintenance base and performing an in-depth evaluation. In 1980 the current contract was awarded to continue these activities at Sunshine. This paper presents the results of the planning for continuation of this project.

The original contractor's design of the test bed system emphasized simplicity in the initial installation with relatively low installed cost. The design was configured to use existing mine wireplant whenever possible by virtue of enabling multi-channel signal transmission over a single wire pair. We now recognize that the most reliable and maintainable design requires multiple pair cable and will require new wireplant in most mines. Furthermore, the wireplant should provide a physically redundant route to the surface to assure communication in the event of an emergency. Since the original test bed was established, the advent of interconnect companies and mine owned/leased surface PBXs offers the possibility of substantial simplification of the phone systems; both economically and for assurance of external maintenance support availability. During this timeframe, the choices of potentially suitable equipment for this application have multiplied. For these reasons, the test bed system is being upgraded beginning with a reassessment of equipment applicability.

The upgraded system is scheduled to become operational in late 1981 with subsequent evaluation to continue into 1983. Once completed, this evaluation will document the system procurability, long-term maintenance requirements and system usage, which will permit an assessment of the specific economic benefit to the mining industry available through use of the system.

1.0 PROJECT STATUS

1.1 TEST BED SYSTEM DESCRIPTION

The existing test bed system is shown functionally in Figure 10 and topologically, as installed in Sunshine, in Figure 11. The system embodies the following elements:

- 1) a sixty line PBX located centrally underground in an air conditioned room used to switch a number of small distributed party line PBXs (intercoms)
- 2) distributed subscriber carrier units used to multiplex the intercom lines (one for each intercom) onto a single twisted pair; two separate systems
- 3) distributed party line PBXs (intercoms) used to switch a number of individual phones on a selectable dial basis
- 4) a single pair transmission system providing a path from working levels to the surface
- 5) a number of private line telephones linked directly to the PBX from areas close to the PBX
- 6) special industrial grade telephones with klaxon ringing and DTMF dialing
- 7) a centralized uninterruptible back-up power source located near the PBX

The intercoms and the telephones were custom units prepared for installation by modifying purchased equipment components.

1.2 EXISTING SYSTEM CRITIQUE

Excluding cost, technical criticisms of the existing test bed system fall into four areas: vulnerability, reliability, maintainability, procurability and ease of operation.

The system is vulnerable by virtue of having only one electrical path from each intercom back to the PBX and to the surface and only one

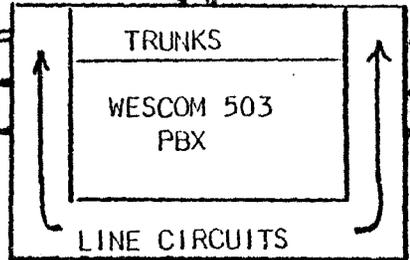
SOON TO BE IMPLEMENTED
DIAL-DIAL TIE TO SURFACE PBX



1 OR 2 E & M
TIE TRUNKS

ANACONDA S6A
MUX CONCENTRATOR
CO END

ANACONDA S6A
MUX CONCENTRATOR
CO END

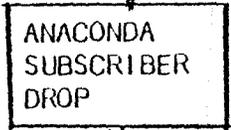
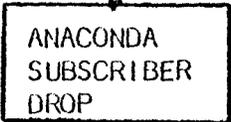


SINGLE TWISTED PAIR

SINGLE TWISTED PAIR

3700 LEVEL
TOWARD #12 SHAFT
& JEWELL SHAFT

DOWN #10 SHAFT



8 LINES

8 LINES

LINE CIRCUITS

RINGDOWN
INTERFACE

RINGDOWN
INTERFACE



5 INTERCOMS

4 INTERCOMS

1 DIGIT DIAL
"DIAL 9" PBX
INTERFACE

1 DIGIT DIAL
"DIAL 9" PBX
INTERFACE

PRIVATE LINE CIRCUITS
2-DIGIT DIAL

4-WIRE

- TIP
- RING
- -24 VDC
- GND

- 5-WIRE
- TIP
- RING
- -24 VDC
- GND
- SW GND

UP TO 8
PARTY LINE PHONES

UP TO 8
PARTY LINE
PHONES

TO BE REPLACED
WITH NEW LOW-CAPACITY
SOLID-STATE SWITCHES

FIGURE 10

FUNCTIONAL BLOCK DIAGRAM OF EXISTING SUNSHINE MINE
DISTRIBUTED SWITCHED TELEPHONE SYSTEM

163

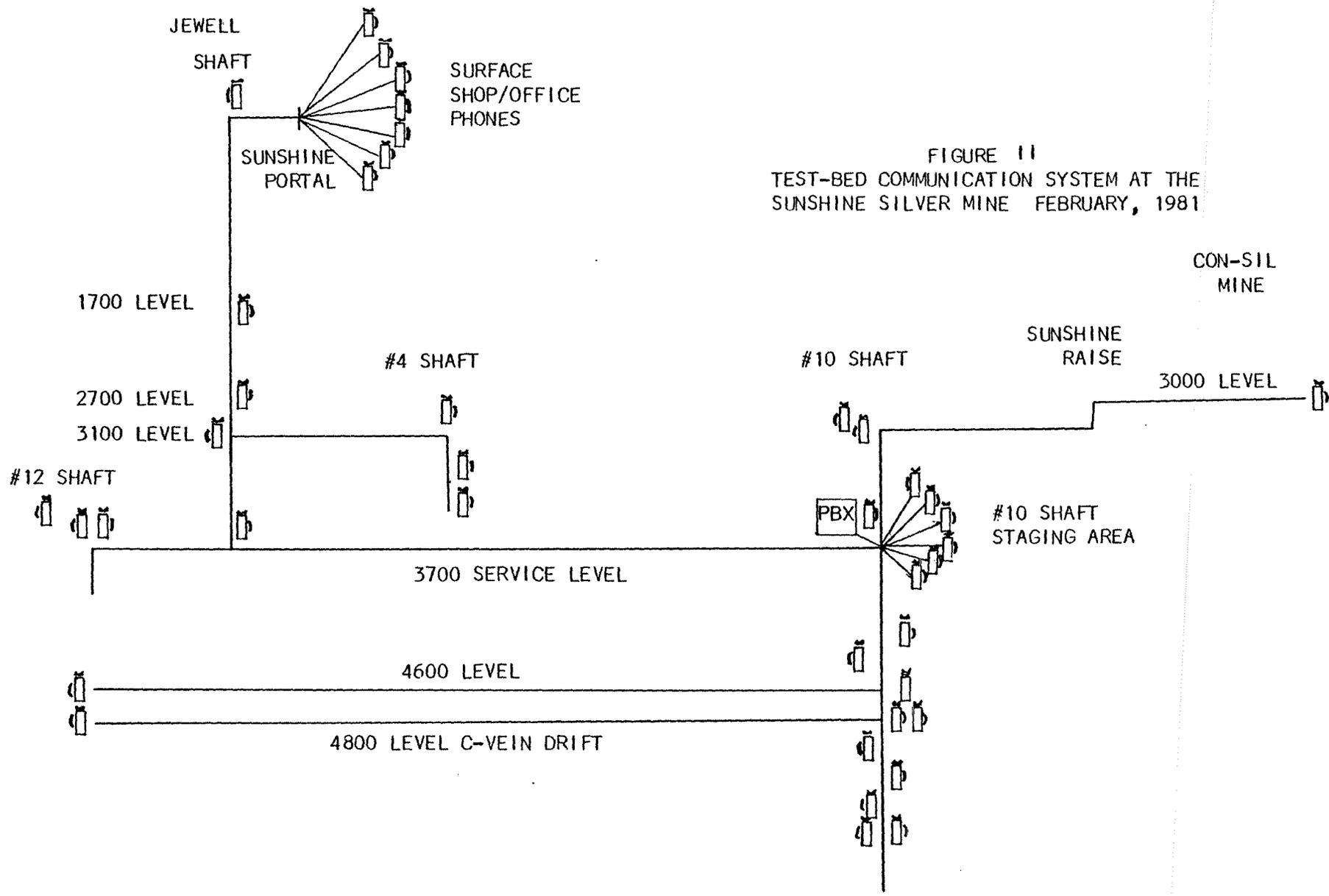


FIGURE 11
 TEST-BED COMMUNICATION SYSTEM AT THE
 SUNSHINE SILVER MINE FEBRUARY, 1981

"channel" from each intercom into the rest of the system. In an emergency, either existing local conversations within the intercom at either end of the desired path, or a physical break in the single wire pair linkage would obviate communications. In this sense, the system is as vulnerable as the single-channel party-line magneto phone. The system has all-call capability in each intercom, but does not have a default mode in case any of the equipment fails.

The system is potentially unreliable because a failure in either the multiplexing portion of the transmission plant or in an intercom can "take out" a portion of the system involving more than one phone. Similarly, maintenance procedures requiring taking one of these type equipments temporarily "off-line" will disrupt service to more than one phone.

The system is difficult to maintain because the rather complex multiplex and intercom equipments are distributed in diverse locations; both within the mine and on the surface. The equipment must be "trouble-shot" on site and several trips from a shop or maintenance area to the site are usually required to affect repair.

The system is not procurable because it includes custom-modified units which cannot be directly purchased and installed. As the system was not designed to established TELCO standards, there are no generic substitutes for these equipment units which can be procured from a variety of vendors. Thus, a systems engineering function is required, not only to configure the system and design the wireplant, but also to "customize" these non-standard equipments

The system is difficult to operate because of the complex tandem dialing procedure involved, whereby either one or two access codes followed by distinct dial tones are encountered in normal operation. Additionally, in any busy period, there is a high probability of blocked calls because there is only one electrical path between any two intercoms.

1.3 UPGRADED SYSTEM REQUIREMENTS

A complete treatment of requirements and functional specifications will be given in the next section. This subsection addresses the overall requirements and the basis for approaching them in the context of mitigating the criticisms of the existing test bed system.

The upgraded system will be made less vulnerable by requiring a physically redundant path from underground to the surface, and physically looped-back paths to and from as many shaft station phones as possible. The loopback will minimize the possibility of a break in the transmission plant obviating communications with these phones.

Additionally, a centralized one-way dial-access/answer paging system will be implemented having a loudspeaker colocated with each phone. This will serve as a redundant electrical path to summons particular persons or groups of persons, and to relay important information. There will also be a separate dedicated line from the surface PBX to the #10 shaft hoist cab for use during emergencies.

The upgraded system will be made more reliable by requiring that the only distributed equipment items, other than the wireplant, that can fail, be the telephone instruments. Thus, a failure in a particular telephone only obviates communication to that phone. A requirement for the system will be that a telephone failure cannot obviate communication to and from any other phone. Additionally, the upgraded system will require that the only failures in the transmission system be in the wireplant, or in the interface circuitry associated with the wireplant (which can be maintained in a central location). A default mode for the underground PBX will be provided, whereby four designated phones will be crossconnected to trunk lines in the event both the primary mine power and the backup power to the PBX fails

The upgraded system maintenance will be simplified by requiring that the only distributed electronic equipment will be the telephone instruments. Additionally, a failure in a telephone will be presumed to be mitigated by replacement of the telephone with a spare, and that the repair can then be affected at a surface location or else that the instrument be expendable.

The upgraded system will be made procurable by requiring all component equipments of the system have generic functional equivalents available from multiple vendor sources. Furthermore, these equivalent equipments should conform to the same standards for interconnecting wiring. This will be accomplished by requiring the component equipments to conform to TELCO standards, with the exception of the centralized paging system and the loop-back monitor panel. Modifications to phone instruments themselves to accomodate the mine environment will be required to be those familiar to the mine (addition of heating elements to retard the corrosive effects of moisture), or those where improved subcomponents (such as dial pads) can be packaged in a generic electro-mechanical equivalent package. Provision of a centralized uninterruptable power source (already in place at Sunshine) will use standard electrical components familiar to mine electricians.

The upgraded system will be easier to operate by requiring that all underground phones be capable of simple selective dialling without requiring any tandem dialling operations. Voice paging will be implemented if a satisfactory loudspeaker can be found; this paging, accessible via a single-digit code, will be easy to use by all mine personnel. Code-call paging will be implemented, after demonstration to

mine supervisory and maintenance personnel, if they feel it will serve their needs. The more complex operation of this feature will not normally be used by ordinary miners.

2.0 DESCRIPTION OF GENERIC SYSTEMS: CONFIGURATION AND DESIGN METHODOLOGY

The deep-vein silver mines in the Silver Valley are understandably similar in topology and mining techniques, so the communication system designed for the Sunshine mine is considered to be generally applicable to the other large mines in the valley. In general, these mines have the following characteristics:

- 1) mining is now conducted between depths of roughly three thousand and six thousand feet; at the three thousand foot level near the production working shafts are staging and support areas for the mining operations
- 2) men, materials and "muck" are transported by hoists between horizontal levels and on electric trains along haulageways between production and entry/portal shafts
- 3) discrete working levels are driven horizontally from the working levels to support the stope and raise with sand backfill mining operations
- 4) raises are maintained between levels to provide ventilation, escapeways and to distribute electrical cables
- 5) mine operational development is planned ahead for the next five to ten years
- 6) the mine environment at the working levels is hot and humid (below four thousand feet the ambient temperature is 90+ degrees F, with condensing humidity, which varies between alkaline and acidic depending on the location)
- 7) the mine has a single channel party line phone system with either magneto-actuated ringing, or an AC buzzer for for belling with audible signalling in these mines consisting of "bell codes" stemming primarily from hoistroom-to-level signalling practices
- 8) mine electrical personnel are familiar with electrical principles and operations (including multi-pair cable, which is used in the rock burst monitoring systems), but not with electronic hardware or interconnections thereof
- 9) alternate escape routes are maintained with adjoining mines

- 10) the surface communication operations are linked via leased leased GTE PBX equipment

To varying degrees, these characteristics are applicable to many non-gassy metal mines. The context of this plan specifically addresses mines in the Coeur D'Alene district; wherever possible, the methodology of this system will consider wider applicability.

The existing communications via party line phones is easy to operate and is reliable. Discussions with Sunshine and Hecla personnel have indicated that the "black" phone system (or equivalent single-channel system) is generally sufficient for mining operation; although, this may be due to limited experience with more capable systems. Electricians at Sunshine said that considerable congestion existed on the "black".phone system before the existing multi-channel "red" phone system was installed. The limitations of the Sunshine "black" phone system in an emergency when many phones were simultaneously in operation was clearly demonstrated in the 1972 disaster. Sunshine personnel have suggested that some of the confusion which compounded the severity of the disaster was attributable to congestion of the telephone system which impaired definition of the problem and detained the direction of corrective actions.

2.1 OVERVIEW OF GROUND RULES FOR NEW MULTI-CHANNEL SYSTEMS

Any improved communication system installed in the mines will probably be implemented in addition to the magneto phone system, rather than as a replacement for it, for two primary reasons. The magneto phone system is widely used and accepted, is of proven reliability, and the hardware and cable plant are in place. New wiring will be required in most mines to implement a multi-channel system while retaining the existing single-channel capability as a back up. The costs of providing hardwired pairs for each phone are less than those for providing the same service using fewer wires and adding subscriber carrier equipment. If carrier equipment were cost-effective, the increased vulnerability and requirements for distributed maintenance in this type mine would not justify its choice. The ground rule is, thus, the provision of all transmission plant on a hardwired basis.

Until recently, PBXs were not available to the mining companies and all surface operations were linked directly into the TELCO central office. Now the major mining companies in the Valley have private PBXs and the generic configuration of new systems considered in this plan assumes that they are available. Considering the capital investment

(or lease status) involved with these PBX's, the ground rule is that these provide the centralized switching bases for this type telephone system.

Any new telephone system for these mines will be of marginal utility unless an adequate maintenance base can be located or developed. This base is presumed to be external to the mining operations, due to the specialized nature of the technical skills required. This attitude has been reinforced by the express desire of the Sunshine mine management that the support of the communication system not require the full-time effort of even one man. Thus, the viability of providing this base in the Valley via one or more private companies is germane to the overall plan. Presently, even the surface telephone systems are serviced by the TELCO. TELCO personnel are prohibited from performing service underground; however, they can service defective equipments brought to the surface for repair as part of an overall maintenance plan. There are requirements for both preventive maintenance and faulty equipment repair. The Sunshine evaluation program will assess the viability of both TELCO and interconnect companies for maintenance. The groundrule is that an external maintenance base will be required.

With the availability of surface PBXs to the mining companies, the surface and underground communications can be linked in an integral system while satisfying some of the existing concerns of the mine in making surface links available to the miners. This will be an important aspect in the Sunshine evaluation program, as the major loss of productivity in normal operations involves the coordination of work items between surface and underground operations and the shaft transportation is the predominant logistical situation where efficiency can be gained through improved communications. Corollary to this is, of course, providing fault isolation of the communications system at a central location of the surface. Linking surface and underground systems is a ground rule for this program. Attendant considerations include physically redundant cable routing for health and safety reasons, which is also a groundrule for the system

2.2 GENERIC SYSTEM CONFIGURATION CONSIDERATIONS

Given a new centralized switched system with hardwired transmission plant operating on a private line basis in conjunction with an existing single channel magneto phone or AC buzzer system, specific configurational considerations include:

- 1) providing the means of connection of underground phones to an assumed locally owned or leased surface PBX over an adequate number of lines

- 2) providing physically redundant "loopback" routing from each phone to the surface switch, as far as is practical
- 3) providing sufficient capability for growth and/or periodic mine initiated reconfiguration of the system

Simplified sketches of two basic configuration alternatives are shown in Figures 12 and 13 . These figures differ by showing:

- 1) use of a surface PBX only in Figure 12
- 2) use of both an underground PBX and a surface PBX that are linked by dial-dial four wire tie trunks in Figure 13

Topologically, these figures have in common:

- 1) major working shafts with requirements for
 - a) groupings of up to ten to twelve phones in relatively close proximity describing a staging, maintenance and inventory area at the top of the working shaft

NOTE: these shafts extend downward from about the 3000 level to the 6000 level with horizontal haulage and service drift development every 200 feet or so

 - b) distribution of up to ten to twelve phones per working shaft at each of the incremental 200 level shaft stations; plus, perhaps, a separate phone for one or more rescue chambers at the lower shaft levels
- 2) one or more entry shafts from the surface to the nominal 3000 level; presumably with up to three phones distributed between the hoistroom and several intermediate level shaft stations which are useful for maintenance, etc.
- 3) horizontal drifts interconnecting the entry shaft(s) and the working shafts (which may not require phones); in some instances, separate haulage and service drifts

Ideally, the central local PBX is located on the surface (as in Figure

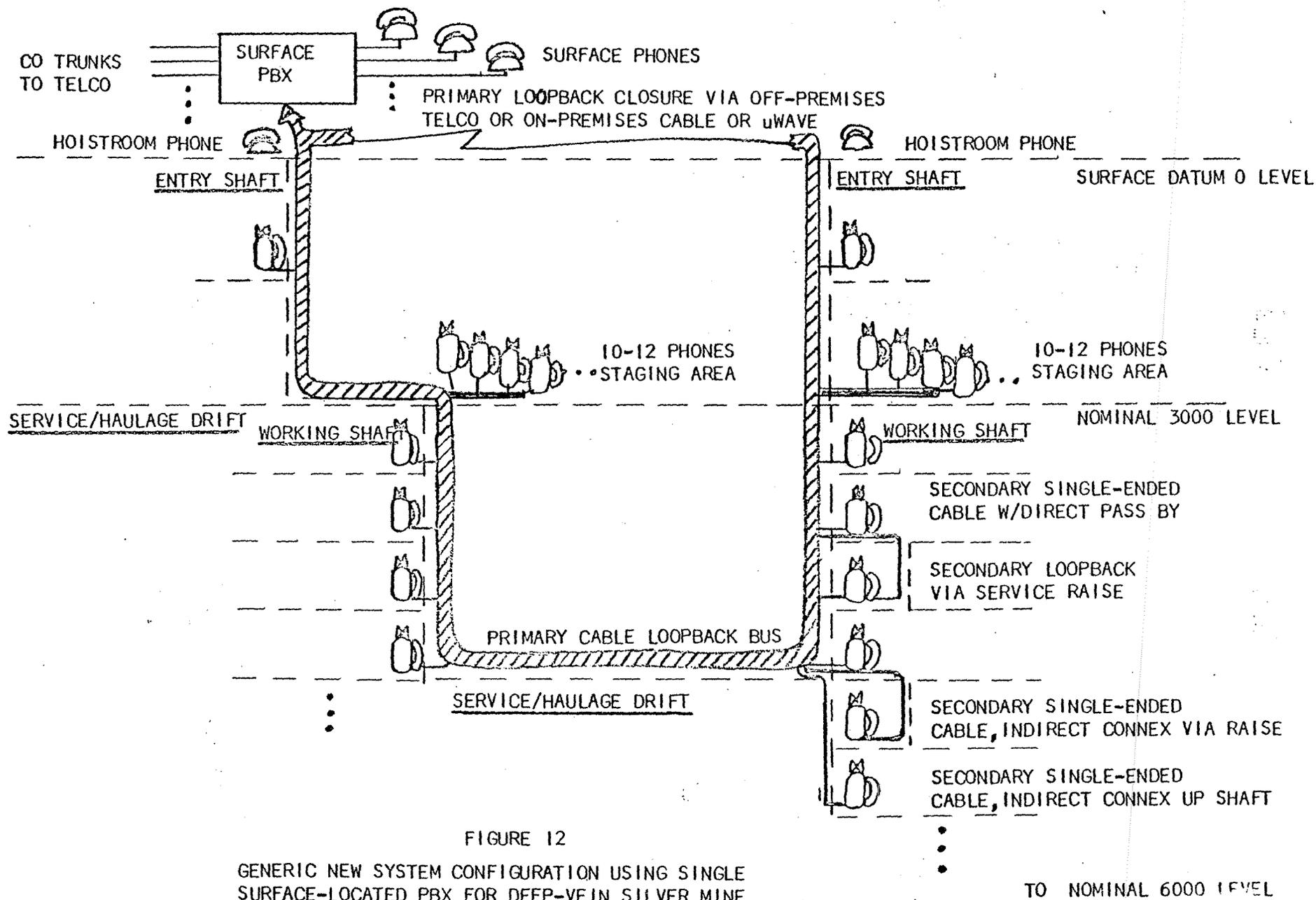


FIGURE 12

GENERIC NEW SYSTEM CONFIGURATION USING SINGLE SURFACE-LOCATED PBX FOR DEEP-VEIN SILVER MINE

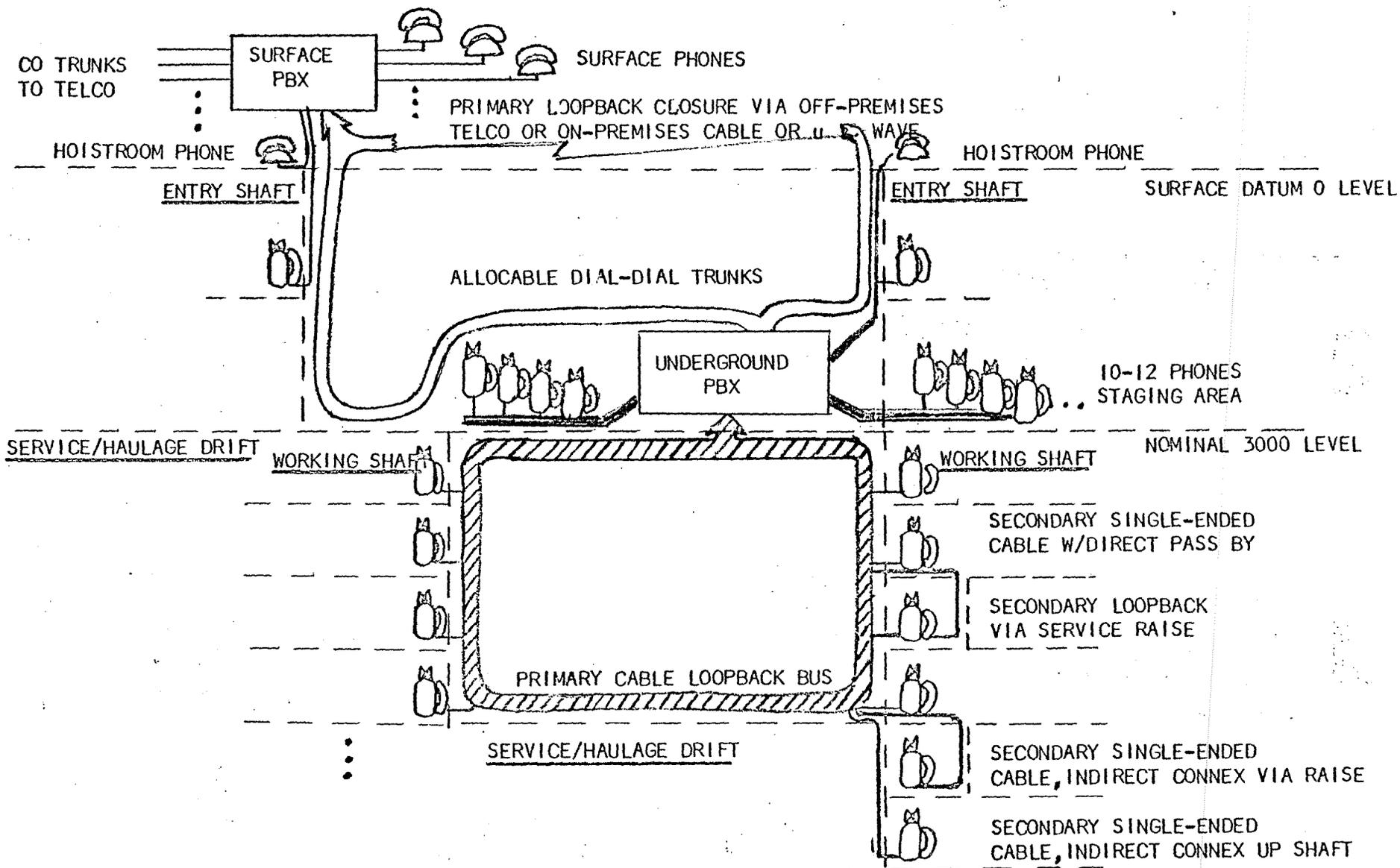


FIGURE 13

GENERIC NEW SYSTEM CONFIGURATION USING SURFACE AND UNDERGROUND PBX'S WITH TRUNKED INTERCONNECT FOR DEEP-VEIN SILVER MINE

TO NOMINAL 6000 LEVEL

12) with an uninterruptable power source, with adequate line capacity to handle all surface and underground phones. If the surface PBX is assumed to pre-exist the decision to establish an underground multi-channel phone system, the individual underground phone plus line card equipment costs will be inexpensive; i.e., approximately \$560/phone. With an assumed eight miles of wireplant, a fifty phone system on this basis could be provided with an initial cost of approximately \$1,700 to \$2,100 per phone, depending on the size of the multi-pair cable used.

Ideally, also, would be the presence of two entry shafts on-premises to provide physically redundant routing for the underground to surface interconnect cables. Thus, for a single surface PBX, all phones could have their dedicated lines from the PBX without incurring costs for off-premises line charges.

NOTE: GTE in the Silver Valley has comparable charges for both trunks and off-premises subscriber lines from Sunshine to Con-Sil at the rate of:

\$62/month/pair recurring
\$60/pair one time installation

Assuming an off-premises redundant routing situation at \$60/line, a fifty phone system would accrue \$3,000/month of line charges or \$36,000/year (approximately one third of the total installed cost of the system).

To curb off-premises line charge and, in some instances, to minimize wireplant, the configuration of Figure 13 showing an additional small underground PBX (as closely configured for optimum line size as possible) is presented. The surface and underground PBXs are linked with the dial-dial tie trunks. For instances where this type system is economically optimum, the tie trunk arrangement offers:

1) line allocation

which permits fewer lines to be used to handle a given volume of traffic for a given degree of reliability (higher utilization)

NOTE: trunking is the only means of line allocation available within standard TELCO methodology

2) simplified redundant routing and loopback

as there can be no "parallel circuit" level or interface problems, and as lines are allocated across both physical paths during normal operation

It is estimated that no more than three trunks for each to the two routes (six allocable trunks during normal service) will accommodate a fifty phone system. Considering the GTE tariffing as being typical, the off-premises charges would be reduced to \$30 per month on a recurring basis. Of course, functionally it is not clear a priori whether or not this number of trunks will be sufficient to handle traffic during abnormal periods or emergencies, or whether six trunks is too many. The evaluation program is expected to resolve this issue (although only four trunks will be provided at Sunshine due to specific circumstances at the mine).

Considering the intra-mine wiring topology, the distinction is made between "primary" and "secondary" cable routes. The primary routes form a "bus" for providing loopback and direct connection to the PBX. The secondary cable routes are either:

1) those from the primary "bus" to phones in a staging area where some local grouping is possible (even on a party line basis)

or

2) those from the primary "bus" to working level shaft station phones, where all such phones are distributed (the bus may not pass directly by each shaft station)

Theoretically, 100% physical loopback is possible and if implemented the primary and secondary routes would entail two levels of loops (this would save wireplant in that all primary "bus" pairs passing a given location would not have to be looped back). The secondary loopback would be accomplished by routing the loop up/down through a service raise to an adjacent level, then tying back into the primary "bus". In practice, it is doubtful whether the mine management will opt for the additional wireplant cost of implementing secondary loopback, so the working shaft station secondary cable routes are expected to be single-ended. Secondary loopback is not as important as primary loopback, providing that the primary "bus" passes each shaft station, as the phones are located there, rather than on the horizontal drifts near the stopes.

Either of the configurational alternatives of Figure 12 and 13 may be used and "building block" mixture of the several primary and secondary routing situations shown may be encountered in system design for these mines.

2.3 TRANSMISSION WIREPLANT DESIGN CONSIDERATIONS

The wireplant will consist of the multi-pair cables selected for particular runs, junction boxes for terminating sections of cable (splices between reels and primary/secondary taps) and items of line conditioning equipment which may be required.

Consider the impact of direct parallel connection of loopback lines without fault detection and transfer relays. DC-wise, this connection operates the same as if it were single-ended, except for the split of the signalling current. A possible concern is that of induced noise circulating currents (primarily expected between low-resistance cable shields). The wireplant design must provide for such current limiting in these shield loops to mitigate noise; also, the shield should not be tied directly to the "master" mine ground bus. On single ended lines (called loops) audio level potential problems are normally controlled by using spaced inductive loading to inhibit impedance "nulls" from occurring. The standard TELCO practice in this regard will be followed as required. The direct parallel-connected loopback actually aids the normal single-ended standing wave impedance situation. However, for long runs, multipath can produce signal nulling and/or distortion. Though not probable, phasing circuitry may be required for some individual loop links. The necessity for this will be determined on an individual installation basis.

For any looped-back path, a convenient means is required to check the integrity of the lines in each leg of the path at least on a periodic maintenance basis. This is true whether a direct parallel connection of the legs or a switched connection is used. Consistent with the concept of procurability, an electrical box with standard electrical switches which can be configured by mine electricians is proposed.

Regarding the standard TELCO rules for laying out single-ended loops, the design guidelines are summarized below in Table 2.

TABLE 9
LOOP LAYOUT RULES
(RESISTANCE DESIGN RULES)

- 1) Loop resistance should not exceed the central office (or PBX) signalling and supervisory limit of 1300 ohms.
- 2) On all loops of 10,000 feet or longer, "500-type" telephone sets should be used rather than older types (such as type 302).
- 3) No bridged tap longer than 6,000 feet should be used on nonloaded loops.
- 4) All loops of 18,000 feet or longer should be loaded.
- 5) With regard to loading:
 - a) H88 loading should be used (88 millihenry load coils at 6,000 feet spacing which results in a 1 KHZ line impedance of 1126 ohms from a 470 ohm line, and a wavelength of about ten miles).
 - b) load spacing deviation should not exceed 500 feet
 - c) central office (PBX) end sections should equal 3,000 feet
 - d) customer end section plus bridged tap length should equal at least 3,000 feet, but should not exceed 15,000 feet
 - e) no bridged taps should be connected between load coils
 - f) no loaded bridged taps should be used

2.4 FUNCTIONAL CONSIDERATIONS

The standard TELCO-derived phone system using a local PBX normally gives private line phone operation with several conferencing options plus the availability of paging and/or code-call to a separate intercom bus fitted with visual or audible devices. The generic concept here is to have a central amplifier paging system, operable from the voice page and code-call PBX outputs, feeding a local loudspeaker at each underground phone. This will require the paralleling of several 19 gauge wire pairs in the hardwired cable in many instances. The location of an environmentally suited loudspeaker is presumed for voice paging; the viability remaining to be determined. At a minimum, the code-call capability will be available actuating a klaxon ringer at each phone.

The use of the standard TELCO-derived system implies that backup power must be provided on an uninterruptible basis at the PBX. Also, in the event of a PBX failure, the PBX must have a "shut-down" mode which still provides skeleton underground and surface communications capability. These two considerations are, in fact, requirements of the generic system. Modern solid state PBXs require less than 100 watts of backup power for twentyfour hour operation at 20% loading. The normal backup power is provided via a single car battery and the complete power source sells for about \$2,100. This may be compared with the 2000 watt requirement which was necessary to ensure twenty-four hour operation of the present system at Sunshine (which consisted of sixteen 60 amp-hour car batteries). Provision of battery-actuated paging at each phone, which is standard practice in mine pager-phone systems, is judged to incur a substantial unneeded maintenance factor in this type mine. The presence of such a battery to provide "talk-power" for individual phones has been assessed to be unnecessary via failure mode analysis. The battery back-up for a centralized PBX is potentially the most reliable element in the system, and a simultaneous coincidence of a mine emergency and failure of both primary and back-up power is very remote. A break in the communications cable to a particular secondary (single-ended) wired phone will obviate communications to and from this phone anyway.

A failure fall-back mode of operation is normally available for every modern PBX whereby selected phones are automatically connected to outside CO trunk lines. The generic system for this type of mine will employ similar means.

3.0 FUNCTIONAL SYSTEM SPECIFICATIONS

3.1 INTRODUCTION

This section describes the functional requirements for the improvement of the communications system at the Sunshine Silver Mine. The improvements are intended to integrate the information acquired through the installation and operation of the original system with the current and projected operating requirements of the system for the next five to ten years. In particular, system modifications are needed to reduce the maintenance problems inherent in the original system and to implement desired system capabilities which had been originally planned, but never implemented, or which have arisen due to changes at the mine in the last two years.

3.2 SYSTEM OPERATION

3.2.1 STANDARD CAPABILITY

The system will operate as a "standard" telephone system, which has reduced dialing requirements. A telephone will indicate a dial-tone when taken "off-hook". Any underground telephone may then be called by dialing the three digit number assigned to the phone "XXX". The surface telephone system may be accessed by dialing a single digit access code " (TO BE DETERMINED)" followed by a three digit number assigned to a surface phone "2XX". A "busy" number (whether an underground phone, an interconnecting trunk line between the two systems, or a surface phone) will provide a standard "busy" signal. Each telephone will operate at all times with private line service. The system will provide one or more means for a phone to indicate that the caller is trying to access a "busy" phone, so that it cannot be "blocked" from contacting a particular phone during an emergency.

3.2.2 OPTIONAL CAPABILITY

The following additional system features are desirable for the system operation, but are not essential. They may be implemented if they can be economically accomplished without degrading the basic functional reliability of the system.

Call Conferencing

An underground phone may call more than one other underground and surface phones and link them into a common conversation.

Call-Code

Pressing a particular number after dialing an access code results in

buzzers on each phone emitting a pattern of tone bursts according to a predetermined sequence which corresponds to the number dialed. A person whose code was called may then pick up any phone in the system, dial an access code followed by his own code number and be connected to the calling phone.

Paging

Dialing an access code opens a voice channel to loudspeakers mounted on each phone, so that a voice page to all phones may be initiated. (Implementation of this function is predicated on the location of an environmentally suitable loudspeaker.)

NOTE: "Code-Call" and "Paging" are mutually exclusive functions (only one or the other would be implemented in any one system), since they both permit an audible "paging" function to be performed by the system independent of the normal selective dialing capabilities of the system.

3.3 EMERGENCY OPERATION

The continued operation of the communication system during emergencies is essential. The system will therefore be equipped with the following features.

Battery Backup Power

The system will operate for a period of not less than twenty-four hours under an average 25% capacity load condition (including intervals of 100% utilization) when the primary 120 VAC power is interrupted. The system may be sustained by lead-acid or similar batteries which are kept fully charged (trickle-charged) when the primary power is present. The power switchover will permit restoration of service to the system subscribers within less than one minute of the power failure. A desirable feature of the new system is that the power backup system be concentrated in a single centralized location, where it can be conveniently and routinely subjected to maintenance tests.

Loop-Back Cable Deployment

The system line routing will provide for continued system operation in the event of a primary communication cable being disconnected. The loop-back links will consist of redundant cable routing within the mine and parallel line (trunks) routing to the surface telephone system.

The underground cable loopback will consist of the cable deployment in "loops" to and from the phones (or phone taps) via alternate routes. The primary cables will be paralleled at the line terminations (so

that electrical or mechanical "switchover" of the loop-back cable is not necessary for continued system operation).

3.4 SURFACE AND UNDERGROUND COMMUNICATION LINKS

Communications between the surface and underground systems will be conducted via tie trunk lines between the surface and underground PBXs. The trunks will permit maximum utility of the cable by allocating the lines on an "as needed" basis to the subscribers. The trunks will be split into two groups. One group will operate through cable in the Jewel shaft and the other group will operate out the Con Sil shaft (of the Hecla Mining Company) with continued routing through the GTE network through Kellogg and Wallace and back to the surface PBX. The two separate routes will function interchangeably in the system. Thus, in the event that one route is disabled, the other route will provide continued operation for the system. The number of trunks will be sufficient to provide for minimal degradation of system capacity in the event that one of the underground to surface routes is disabled.

3.5 EQUIPMENT

3.5.1 TELEPHONES

The telephones installed underground will be standard "industrial grade" telephone instruments. The chassis will be suitably rugged to withstand the normal handling and use experienced in the mine environment. Chassis will be sealed, "dust-proof" and "splash-resistant" enclosures. The circuitry will consist of standard TELCO assemblies and will not need extensive modification (beyond what a mine electrician could routinely perform) prior to installation. The telephones will function as DTMF (Touch-Call or Touch-Tone) dialing instruments with standard two-wire installation and operation. A sealed dial pad is a desirable feature for the hardware.

3.5.2 PBX

The PBX will be a "generic" limited capacity switch capable of expansion to fifty subscribers (the largest current estimate for the projected growth of the Sunshine system). The PBX will be commercially available and suitable for installation without modification. The standard features for the PBX "class of service" operation will include:

Trunk Access Restriction where only certain phones in the system can access particular trunks (such as the outside line trunks).

Executive Override where certain phones in the system can enter into

ongoing conversations (usually preceded by a warning tone to the original call participants, so they know someone else is joining the conversation).

Camp on Busy where certain "busy" phones can be programmed to dial back a calling party. Immediately at the end of the conversation, the called phone and the calling phone both ring, so that the called person can be contacted before he leaves the phone.

Code-Call where certain phones can be programmed to page individuals by initiating tone or bell signaling on all of the phones in the system in predetermined patterns. A person whose code is called, dials an access code followed by his code and the phone of the calling party is automatically dialed by the PBX.

Paging where certain phones in the system can initiate voice paging messages to loudspeakers on all of the phones by dialing an access code and then speaking into the microphone on the telephone handset.

Other features such as "call transfer" (the ability to transfer a call from one phone in the system to another), "call conferencing" (the ability to link multiple phones in common conversations), self-diagnostics (the ability of the PBX to automatically isolate equipment or line failures), battery back-up switchover (automatic reversion to emergency power) and programmable default operations (automatic linkage of selected system phones to the outgoing trunk lines in the event of a PBX failure) are additional desirable features of the system.

The PBX will operate in a suitably controlled "office" environment (temperature, dust and humidity controlled). However, the ability to operate in abnormal environmental extremes is considered a desirable feature which enhances the reliability of the system during emergencies.

Minimal power consumption is a desirable feature to reduce the battery backup requirements for the system.

3.5.3 CABLE

The cable will be commercially available multi-pair bundles with 19 AWG solid copper conductors. The individual wire and cable bundles will be coated with a "water proof" and "chemically resistant" sheath. Cable deployed in shafts will be "fire retardant" and have a self-sustaining length suitable to minimize the labor required during the installation procedure. The cable in shafts will also have a sheath (bore-hole armor) which will withstand the expected shaft environment. The cable will consist of twisted pairs which may be shielded depending on the

installation site. It is desirable that the cable be delivered continuously wound on spools and suitably marked with length appropriate for pre-determined specific locations in the mine cable-plant installation so as to improve the efficiency of the installation procedure.

3.5.4 ENVIRONMENT

The cable, telephones and junction boxes will be rated to operate in an environment which has the following range of conditions:

Temperature	-40 to 140 degrees Fahrenheit
Humidity	100% (condensing)
Contaminants	Dust, condensing and dripping water (alkaline and/or acidic)
Altitude	+/- 4000 feet

3.5.5 MAINTENANCE AND INSTALLATION REQUIREMENTS

The equipment will be installed and maintained according to procedures jointly devised by the contractor, subcontractor and mine personnel. Hardware will be suitable for a board or module fault level diagnosis and substitution replacement maintenance procedure. A system providing "central office" cable plant testing is a desirable feature of the system.

3.5.6 CALL RECORDING COMPATABILITY

The PBX will operate compatibly with standard telco (FCC approved) call recording equipment, which will permit a detailed "real time" listing of the operation of individual subscriber instruments and trunks in the system.

4.0 EVALUATION OF AVAILABLE EQUIPMENT AND SYSTEMS

The requirements for Sunshine and other deep-vein metal mines embrace fifty phones or less underground with approximately eight miles of transmission plant. In this section we will evaluate selected systems/equipment components with respect to their functional and economic viability toward application in this type mine. For this purpose, both generic TELCO derived and available specialized mine phone systems will be discussed.

The systems/components are partitioned into categories of:

- 1) transmission plant
- 2) terminal (centralized) and subscriber (phone) equipment

Equipment being evaluated for applicability includes:

- 1) transmission plant
 - hard-wired multi-pair cable
 - subscriber carrier multiplex equipment
 - Anaconda S6A (or B) or equivalent (previously determined by ADL to be the most suitable multiplex equipment for mine use)
- 2) terminal and subscriber equipment
 - conventional TELCO or TELCO-compatible EPABXs
 - Gai-tronics Mine Dial/Page Phone II System
 - MSA Multi-Phone (Pager V)
 - Femco AMCS System

4.1 TRANSMISSION PLANT ECONOMICS

For deep-vein metal mines, virtually all mines will require new wiring to accommodate a multi-channel telephone system unless multiplexed subscriber equipment is used. The cost of 19 AWG multi-conductor cable is variable especially when considering the purchase of large quantities. Following are exemplary prices obtained

from the North Supply Company (1980 catalog) for 1000 foot lengths of cable:

<u>Pairs per Cable</u>	<u>Cost per Foot (\$)</u>
1	0.085
3	0.165
6	0.223
12	0.341
18	0.452
25	0.601
50	1.025
75	1.535
100	1.940

Additionally, recent estimates of cable installation labor costs for this type mine (based on a rate of \$180/man shift for electricians and hoistmen and labor estimates obtained from the Hecla Mining Co.) include the following:

- installation in tracked unobstructed drift with \$0.52/foot with available supporting structures (including the cost of periodic junction boxes)
- installation in obstructed drifts with air doors, \$1.03/foot overhead water and air lines, with usable messenger cable
- installed in shafts (suspended in split-socks, \$1.56-\$2.40/foot from J hooks, minimum 500 foot sections)

Considering that the Sunshine mine may be typical of deep-vein metal mines with 77% relatively unobstructed drifts and the balance consisting of shaft or obstructed drift installation, the average cost of cable installation is \$0.83/foot.

Considering carrier equipment, an eight-channel system such as the S6A with seven usable channels for voice circuits, is estimated to cost \$9,000 per system including spares and a back-up power supply, or \$1286 per private phone line installed.

2000
1800
1600
1400
1200
1000
800
600

COST PER PHONE - DOLLARS (BASED ON 50 PHONES)

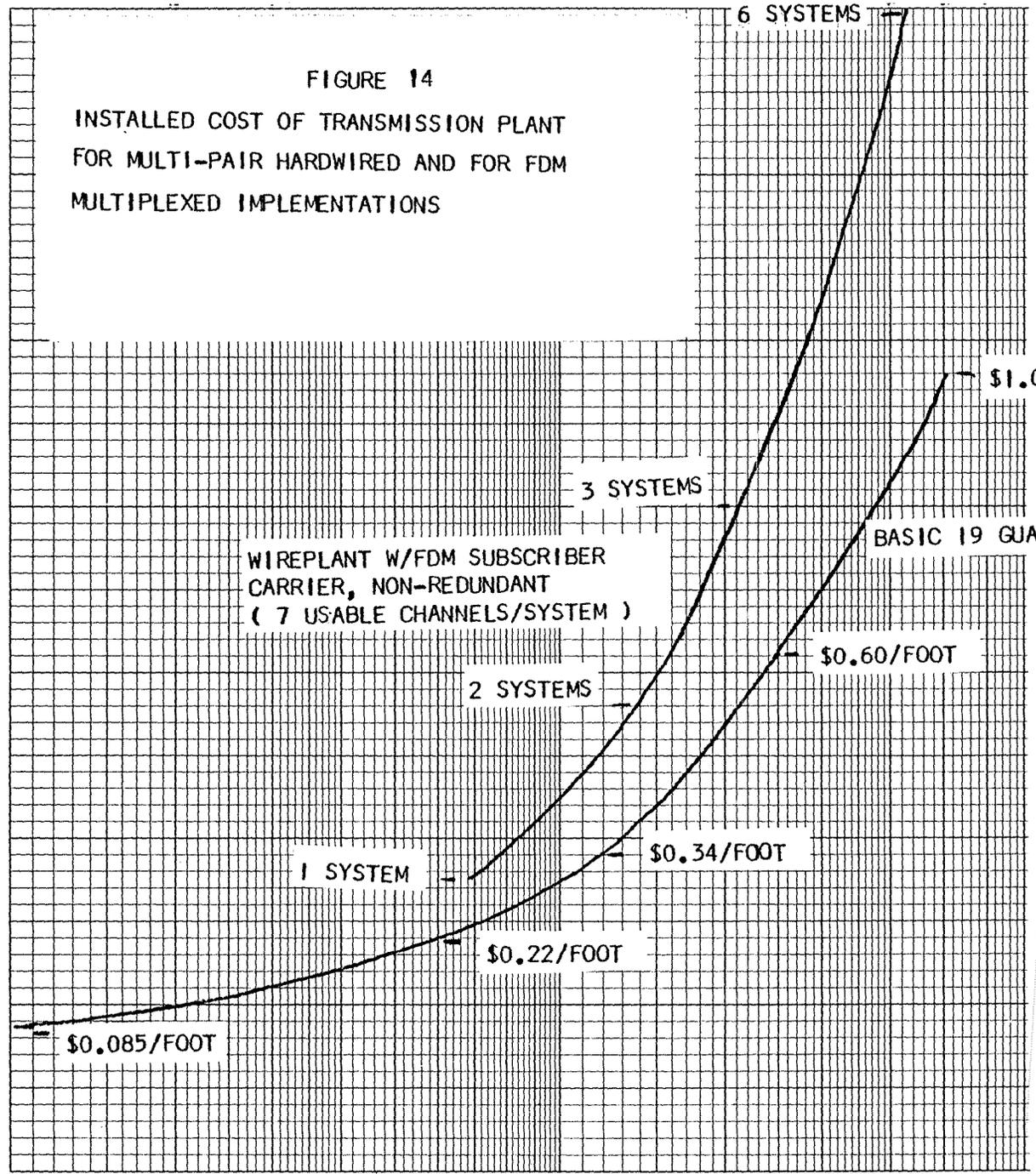


FIGURE 14
INSTALLED COST OF TRANSMISSION PLANT
FOR MULTI-PAIR HARDWIRED AND FOR FDM
MULTIPLEXED IMPLEMENTATIONS

WIREPLANT W/FDM SUBSCRIBER
CARRIER, NON-REDUNDANT
(7 USABLE CHANNELS/SYSTEM)

BASIC 19 GAUGE WIREPLANT

NUMBER OF PAIRS (OR CHANNELS)

-85-

The above cost data has been summarized in Figure 14. Note that the differential cost of providing private lines via FDM multiplexing versus hardwiring increases with the number of pairs, and is considerably more expensive than hardwired. The data in this figure is parametric with the number of phones with the cost being normalized per phone for a fifty-phone system. As the maintenance costs are expected to increase as well when using the carrier equipment, the carrier multiplexing is hereby eliminated from further consideration for new, permanent transmission plant installations (the equipment does offer utility for temporary expansion of system capabilities in a particular mine section, where a temporary increase in communication or monitoring capability using existing cable plant is desired, but the cost of running new dedicated lines cannot be justified; decreasing the number of FDM channels to achieve cost parity without decreasing the number of phones creates intermediate distributed switching nodes which violate the vulnerability and maintenance criteria. For the size system we are addressing (fifty phones and eight miles of wireplant) the installed wireplant cost always equals or exceeds the total equipment cost for the system.

For the hardwired system, considering that an average fifty pair cable need not be run everywhere for a fifty phone system, (planned cable pairs vary from 12-pair to 75-pair for the Sunshine evaluation system) the hardwired wireplant costs per phone are expected to run between \$1200 and \$1550 per phone.

4.2 EQUIPMENT COSTS

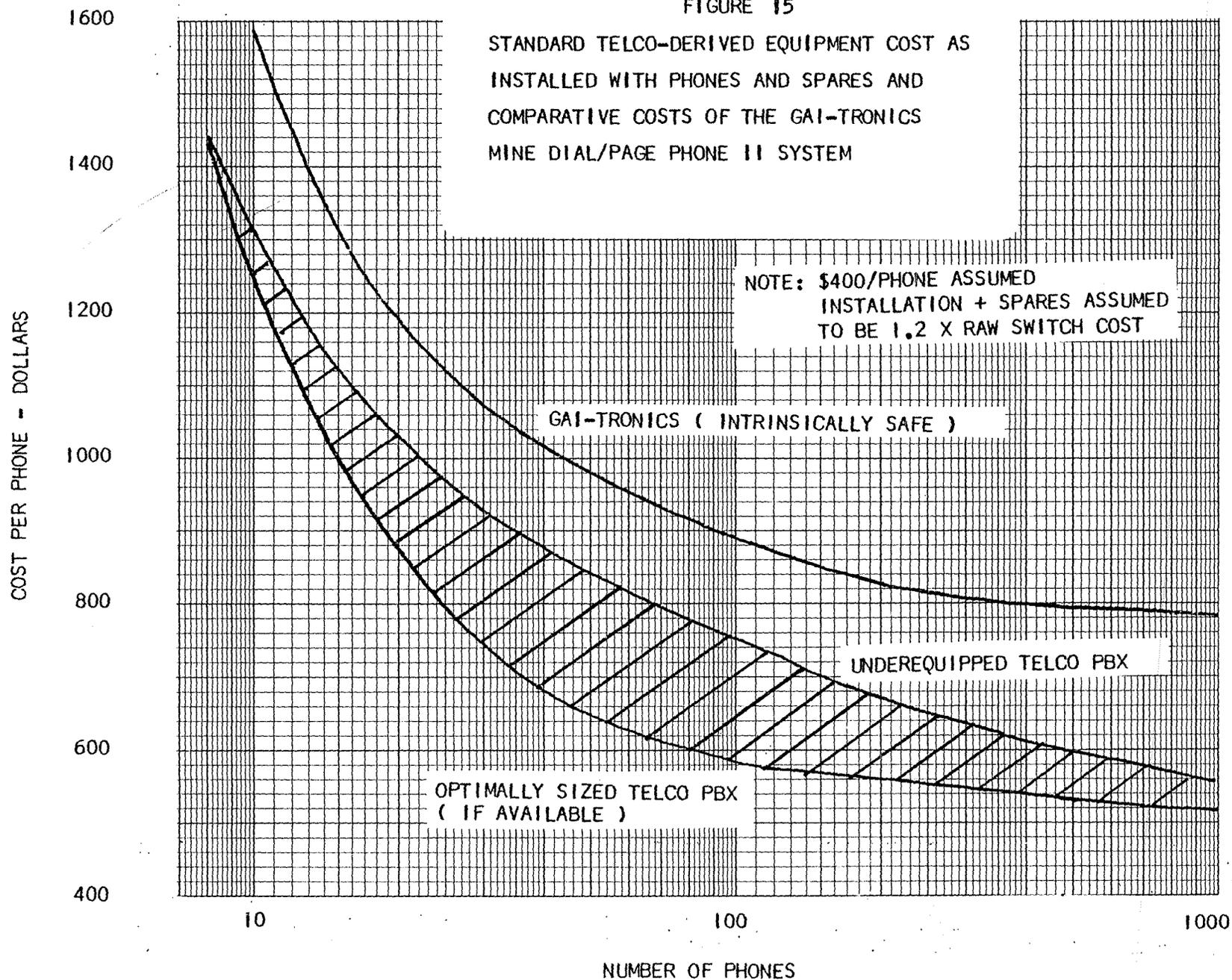
The costs of centralized EPABX systems including phones have been estimated for a variety of line sizes. These estimates assume that a suitable weatherized phone costs \$400 and that installation plus spares runs 20% above the raw switch cost. This data is shown plotted in Figure 15. The EPABX costs vary according to whether or not a switch is available that is optimized to the required line size, with the alternative being the use of an under-equipped larger switch.

Note that the Gai-tonics system is roughly \$100/line more expensive than the standard TELCO under-equipped system (analysis based on private communication with consultant R. A. Kuehn); probably due to the intrinsically safe barrier block plus the cost of implementing some of the paging/all-call features. Economically, the Gai-tonics system is judged to be a viable candidate compared with standard TELCO derived systems. This system violates the procurability criteria for this type system; however, the phones themselves, neglecting the paging features, can be made compatible with a TELCO interface on an individual phone basis.

Note that for a fifty phone system the installed costs plus spares is

FIGURE 15

STANDARD TELCO-DERIVED EQUIPMENT COST AS
INSTALLED WITH PHONES AND SPARES AND
COMPARATIVE COSTS OF THE GAI-TRONICS
MINE DIAL/PAGE PHONE II SYSTEM



NOTE: \$400/PHONE ASSUMED
INSTALLATION + SPARES ASSUMED
TO BE 1.2 X RAW SWITCH COST

GAI-TRONICS (INTRINSICALLY SAFE)

UNDEREQUIPPED TELCO PBX

OPTIMALLY SIZED TELCO PBX
(IF AVAILABLE)

COST PER PHONE - DOLLARS

NUMBER OF PHONES

-87-

estimated to run \$850-\$1000 per phone. Except for the existing sixty line Wescom 503 PBX at Sunshine and the ITT TD 120, all available PBX's known to the Contractor were under-equipped 100-120 line units; therefore, the under-equipped curve is considered to be the most representative for assessing system cost. This would not be true if only a fifty phone system capacity would ever be needed; but, due to the probable integration of both surface and underground systems employing a single switch in a large number of situations, additional support for using this bound is derived.

No pricing information is available for the Bell ICS system as it is presently unavailable for sale (or lease) in the Coeur D'Alene district, so it cannot be considered for the Sunshine system at this time.

The MSA Multi-Phone at \$800/phone raw (based on private communication with MSA) or an estimated \$960/phone installed (including spares) is a viable economic contender. It has the added advantage of requiring only a six pair cable for an almost arbitrarily large number of phones. This system currently has several functional drawbacks (including the lack of a TELCO interface and undetermined reliability in deep-vein mines such as Sunshine). Further the uniqueness of this system violates the procurability criteria for this system.

The Femco AMCS system at an estimated \$2,800 to \$3,500 (based on a private communication with Femco) per phone raw is judged to be too expensive for use as a communication system alone. The LST interface capability provides for a substantial reduction in system cost by permitting the digital telephones to operate as small switches, however, its uniqueness, lack of a TELCO interface and unproven environmental reliability preclude it for use in Sunshine at this time. Its greatest value is expected to be in applications where its substantial data handling capabilities can also be utilized.

The combined total cost of equipment, cable, and installation for a system the size of Sunshine is estimated to be between \$2,050 and \$2,550 per phone (\$102,500 to \$127,500).

4.3 EQUIPMENT APPLICATION PHILOSOPHY

The application of available equipment to the Sunshine evaluation system involves a particular philosophy, which is:

- 1) conformance with the procurable system criteria of Section 1.0 in terms of multiply sourced generic functional equivalents

- 2) the initial upgraded system implementation, to serve the evaluation needs, will make only the minimum changes to the existing system necessary to simplify the system operation and maintenance; and to enable the upgraded functional configuration
- 3) defining particular procurable component equipments, beyond the initial Sunshine upgraded test-bed, for recommendation to the industry will involve a continuing dialog with selected manufacturers over the duration of the program
- 4) individual phone instrument candidates, and candidate loudspeakers for paging may be purchased in limited quantities and subjected to the operating environment in order to assess their applicability for the system

Generic functional equivalent component equipment candidates expected to be suited to this type system include:

PBX Switches

ITT TD series (TD-120 and TD-60)
Mitel SX series (SX-100 or SX-200)
Wescom 580 DSS series (580VS)
Northern Telecom SL-1
Digital Telephone Systems D1200 series (D1203)
Automatic Electric GTD series (GTD-120)
Bell Dimension series
ITT CS1024

Telephone Instruments

Allen-Tel Products weatherized telephone
Gai-tronics Mine Dial/Page telephone w/69001 interface card
Northern Telecom A0304518 weatherized telephone

5.0 DESCRIPTION OF THE EVALUATION SYSTEM AT SUNSHINE

The system configuration proposed for implementation at Sunshine is of the two-PBX generic type depicted in Figure 13. This new system is actually a simplification of the existing "red" phone system at the mine. The presence of two existing usable PBXs at the mine is coincidental, as the governing reason for this proposed usage stems from the long off-premises loopback run from the Hecla Con-Sil mine back to the Sunshine Jewell complex via GTE. The GTE problem is compounded by the fact that two exchanges are involved (Sunshine is served out of Kellogg, whereas Con-Sil is served out of Wallace). Additionally, intervening mountain peaks render the possible use of a mine-owned microwave system impractical. Additional reasoning for the use of the two-PBX system at Sunshine includes:

- 1) inadequate subscriber line capacity in the existing surface GTD 120 PBX is available to provide for both surface and underground phones

the GTD switch currently is fully loaded (all 120 lines are being used for surface communication requirements); conversely the switch has more than adequate trunk capacity with only seven of the available sixteen trunks being used

- 2) existence of the Wescom 503; which is already located underground in a protected and airconditioned room and which is more than adequately supplied with uninterruptable backup power (after the subscriber equipment is removed); this PBX is suitably sized for the system (sixty line capacity with twelve trunks) and contains the requisite paging and code-call capabilities for the new system

The new system, once the new transmission plant portion is installed, is very adaptable to phased implementation with minimum interruption to ongoing mine activities and is expected to require minimal adjustment by the miners followed by quick acceptance. The existing "red" phone system was installed during the previous strike, however, the new system is expected to be installed during normal on-going mining operations (which will require most of the installation to occur on week-ends and on "grave-yard" shifts).

A schematic description of the proposed system is illustrated in Figure 5.

Simplifications of the new system include:

- 1) no intercom or carrier equipment is needed which requires periodic distributed maintenance throughout the mine, except for the phones, all normal servicing of the system will be concentrated in the surface or underground PBX locations
- 2) phones will be two-wire instead of the four-wire or five-wire phones which are currently being used
- 3) distributed backup power sources are not required, so that the present distributed maintenance requirement of the power supplies and the batteries in the intercoms will be eliminated
- 4) tandem dialing will be eliminated for all calls made between underground phones; all phones requiring contact with the surface need only one level of tandem dialing instead of the two levels now required by each intercom
- 5) because each underground phone will have direct access to every surface phone, underground system phones located on the surface and surface system phones located underground will no longer be required (unless the mine wishes to provide still further redundancy in the underground and surface communication linkage); a single phone on the underground PBX system is planned for location in the Jewell shaft hoist room

Greater flexibility afforded by the new system includes:

- 1) no "party line" line blockage for underground calls
- 2) four simultaneous usable links to the surface will be available instead of the two "zoned" links now being used
- 3) calls can conveniently be made between any two company phones, whether on the surface or underground
- 4) control of all off-premises calls can be conveniently assigned or changed to any designated phone or inhibited altogether, further, incoming calls can be routed (through the surface operator) to any phone in the systems

- 5) either code-call or voice paging will be available to assist in the location of key personnel, or to relay important messages

Improved health and safety features of the new system include:

- 1) full loopback from the surface to major staging, maintenance and inventory areas underground will be immediately available
- 2) full primary loopback will be available to the 4800 level as soon as the #12 shaft is sunk to that level
- 3) party line congestion will be eliminated
- 4) the probability of calls being "blocked" will be substantially reduced

5.1 MODIFICATION IMPROVEMENTS TO THE EXISTING SYSTEM(S)

The Sunshine mine phone system will consist of an integration of currently separate surface and underground phone systems, with some improvements and modifications to each system.

For the existing surface GTD 120 system:

- 1) dial trunk cards will be added to enable the connection to the underground PBX (two each four-wire dial-dial trunks will be established via each of the Jewell and Con-Sil routes and the GTD 120 will be programmed with a service code to implement them)
- 2) an emergency backup power supply is recommended for the GTD 120 ; this will be an existing emergency power generator
- 3) a specific underground PBX failure fall-back mode assuring limited continued communication from underground to the surface will be devised and recommended for implementation by the TELCO in the surface PBX

- 4) the TELCO will be requested to provide service from the new office building to the Jewell for the three dial trunks to be implemented via that route

For the underground "red" phone system:

- 1) all transmission plant will be hardwired on a private line basis, and the intercoms and carrier equipment will be removed
- 2) the existing "red" phones will be modified or replaced sothat
 - a) two-wire operation is possible
 - b) hermetically sealed dial pads can be utilized to improve the environmental reliability of the instruments; a pad using electronic tone generation will be sought
- 3) hardwiring will be provided for each underground phone (one pair per phone)
- 4) line cards will be added to the 503 to increase the number of available lines to about fifty; additional dial trunk cards will be added to increase the number of trunks available to four
- 5) either the code-call or voice paging capability of the 503 will be implemented

The underground "black" phone system will continue to operate as it now does.

5.2 ADDITIONS TO THE EXISTING "RED" PHONE SYSTEM

Additions will be provided to the existing underground phone system so the new system will be more flexible in operation and easier to maintain. These additions include:

- 1) a separate central-amplifier "PA" system using the voice

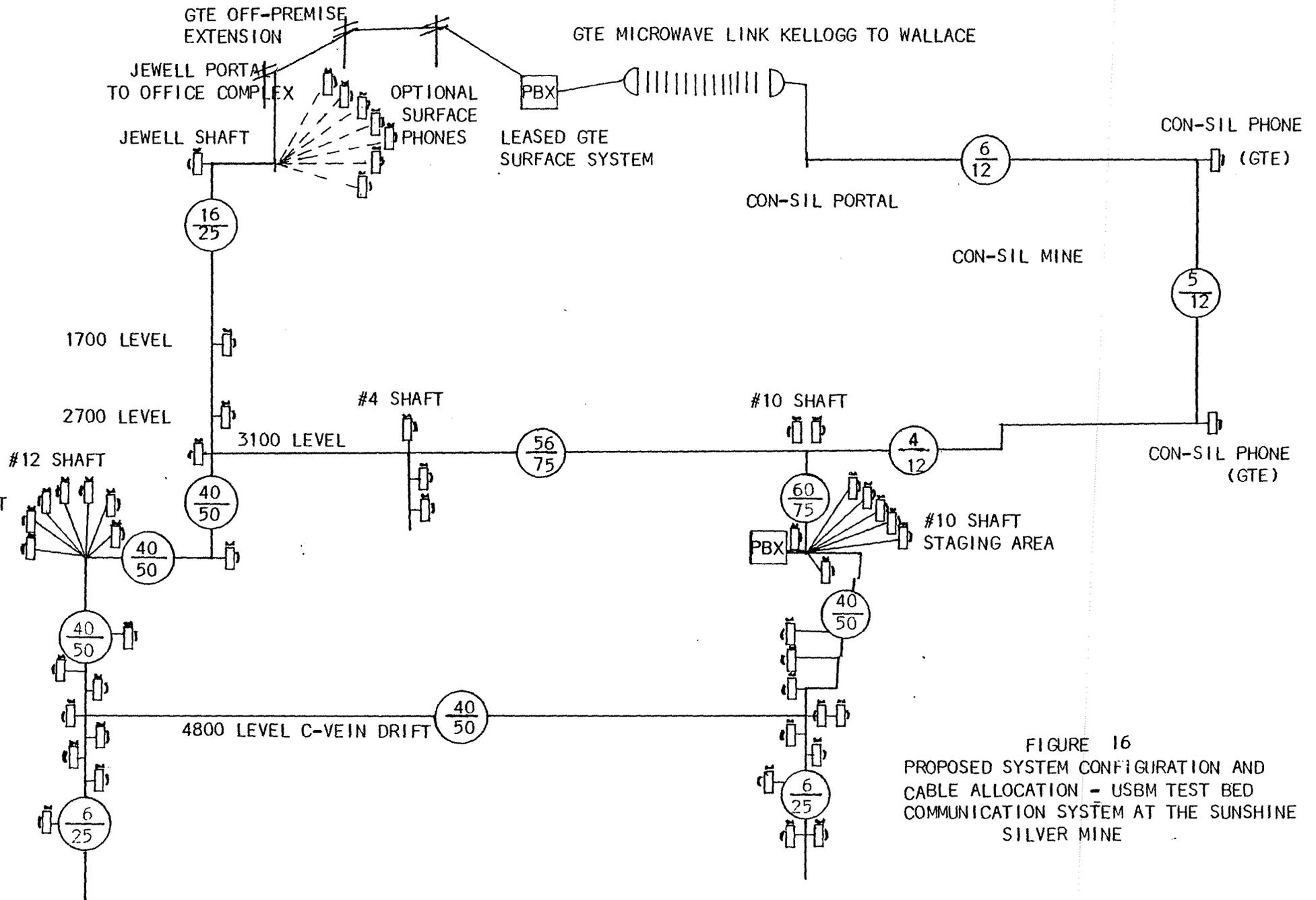


FIGURE 16
PROPOSED SYSTEM CONFIGURATION AND
CABLE ALLOCATION - USBM TEST BED
COMMUNICATION SYSTEM AT THE SUNSHINE
SILVER MINE

page and/or code-call PBX output for input to an amplifier located in the RBM room; and environmentally suited audible devices collocated with each underground phone as outputs; if a loudspeaker can be found, it will be used for both voice page and code-call, or else a klaxon will be used for code-call only

- 2) a loop-back maintenance panel to be located in the RBM room with (at a minimum) switches to open and close each looped-back line to check continuity; if practical, visual "line status" lamps will be included to show the integrity of each line leg of each loop-back circuit
- 3) a second attendant's console to be tentatively located in the 3100 level #10 shaft hoist room to aid operations in case of emergency, serving yet-to-be-determined specific functional needs; the first attendant's console in the RBM room will continue to serve maintenance needs
- 4) a dedicated private line(s) from the #10 shaft (and eventually from the #12 shaft) hoist room(s) to the surface PBX system
- 5) provision of specific underground phones to be connected directly to the four tie trunks in case of underground PBX primary and back-up power failure, as mentioned above; candidates for these phones include:
 - a) #10 shaft rescue chamber
 - b) #10 shaft "blue" room
 - c...) similar locations for #12 shaft

5.3 NEW WIRE TRANSMISSION PLANT DESCRIPTION

The wireplant runs showing both the proposed line allocation and telephone deployment for the new system are illustrated in Figure 16. The trunking runs for the linkage between surface and underground PBX's will consist of twelve-pair and twenty-five pair cable, with four of these pairs being used for the tie trunks. The Con-Sil trunk route will all be new cable which will run from the Silver Summit portal to the Silver Summit shaft, down the shaft (in three sections) and along the 3000-level to the Sunshine raise. The cable in the Con-Sil will be installed under an agreement with the Hecla Mining Company with provision of two pairs from the cable for their use. The remaining cable run from the top of the Sunshine raise to the 3100-level of the Sunshine Mine and back to the 3100 shaft will be installed by Sunshine personnel.

A new twenty-five pair cable will be installed from a junction box outside the Jewell portal to the Jewell shaft, with armored twenty-five pair cable extending down the shaft to the 3100-level, with intermediate junction boxes and shaft station phones at the 1700- and 2700-levels. Including an "underground system" phone in the Jewell shaft hoist room, a "call traffic monitor" pair and one or more monitor lines, a minimum of nine of the pairs will be used (leaving sixteen pairs for use for additional underground system phones and intercom lines).

A seventy-five pair cable will be run from the 3100-level shaft station to the #4 shaft hoistroom (with secondary existing cable feeding the #4 shaft stations) and on to the #10 shaft hoistroom and the #10 shaft. Bore-hole armor-covered seventy-five pair cable will be run down the #10 shaft from the 3100-level to the 3700-level, with non-armored cable running to the PBX in the RBM room.

A fifty-pair cable runs from the PBX in the RBM room to the vent raise on the 3700-level and down the vent raises to the 4600-level. Shaft stations on intervening levels will be fed from small three-pair secondary lines from the junction boxes at each level to the station phones. The fifty-pair cable runs from the vent raise to the shaft station at the 4600-level and down the #10 shaft in armored cable to the 4800-level shaft station.

A secondary twenty-five pair armored cable continues down the #10 shaft to the lower shaft stations.

The fifty-pair cable runs along the 4800-level from the #10 shaft station to the (new) #12 shaft station along the C-vein drift. A secondary armored twenty-five pair cable continues down the #12 shaft to phones at each of the lower shaft stations. Depending on the course

of mine development, the mine may "loop-back" the shaft stations below the 4600-level by installing a twenty-five pair cable from the #10 shaft to the #12 shaft at the 5600-, 5800-, or 6000-levels (in the event that those levels are connected between the shafts).

An armored fifty-pair cable will be run up the #12 shaft to the 3700-level (serving intermediate shaft stations), with non-armored fifty-pair cable running to the #12 shaft hoistroom and along the 3700-level to the Jewell shaft. Armored fifty-pair cable continues up the Jewell shaft to the 3100 level. The resulting fifty-seventy-five pair loop has adequate capacity to loop-back connections to all phones between and including the 3100- and 4600-levels and also the trunk cables leading up the Jewell shaft. This loop provides full redundancy for those phones in the event of a cable in the primary cable. The cable plant also retains adequate capacity to support full development of staging areas and shaft stations along the #12 shaft when the shaft is fully developed below the 3700-level and in the event that the shaft is raised to the surface.

6.0 OUTLINE OF THE EVALUATION PROGRAM AND THE DATA COLLECTION SYSTEM

6.1 INTRODUCTION

The evaluation of the new communication system at the Sunshine Mine will provide substantial insight into the operational communication requirements for deep-vein metal mines in general. Once the operational requirements have been measured (during the evaluation phase of the program), the non-recurring system costs can be factored into the evaluation process. By evaluating the types of maintenance problems encountered, a qualitative evaluation of other potential systems will also be possible.

The Contractor has designed the new system to achieve the following goals:

- 1) Eliminate the known system shortcomings (including both system maintainability and operation)
- 2) Expand the system capability for improved health and safety (by providing redundant communication paths)
- 3) Minimize the new system cost for the mine and the Bureau
- 4) Provide an adequate system capability for a thorough and accurate economic analysis of the system

The system simplifications (for both operation and equipment) have been discussed in previous sections and will not be further elaborated upon in this section, other than to comment that the proposed system configuration incorporates the following suggestions and desires of mine personnel.

- 1) That the transmission plant be hardwired in lieu of using carrier equipment (which must be housed in heated enclosures at the lower levels and is difficult for mine personnel to troubleshoot)
- 2) That the tandem dialling required by the intercoms be eliminated
- 3) That some form of paging be implemented in system (and that voice paging is more desirable than bell-code paging)
- 4) That the surface and underground systems be linked (as long as class of service restrictions on the underground

phones are maintained)

- 5) That the commercial-grade dial pads be replaced with more environmenrally suited ones

Mine personnel view the proposed system as being optimum for the current and anticipated needs of the Sunshine mine. This positive endorsement is a significant indicator of favorable acceptance and support by both technical and management personnel.

The Contractor recognizes that the system may not be the least cost system available, if the present system were not already installed and if foreknowledge of the necessary communication capabilities for the mine were available. However, the proposed system plan is the most expedient means of achieving the desired system capability based on modifying the current system configuration and reusing the (proven) available equipment. Further, since the resultant functional capability is generic for other systems, the economic factors of newer systems can be accurately projected from the operational data derived from this test-bed system. The proposed system configuration is representative of the complexity of newer system hardware and cable requirements and will provide an accurate indication of the maintenance requirements for other types of centrally-controlled systems.

The proposed system permits a controlled modification of the existing system, which minimizes the impact of the system alteration on mining operations and also limits the cost for both the mine and the Bureau. In addition to the obvious benefit of reusing proven equipment in the system, the improved system operation lends itself to a methodical transition from the current configuration to the proposed configuration. Thus, the mine will be able to "conveniently" install new cable over a long period of time and the system will operate continuously throughout the transition phase. This orderly system development will minimize "surprises" in the new configuration and restrict system problems to localized areas. The new configuration also permits utilization of the present cable plant, primarily to individual instruments from junction boxes (which will replace the intercom boxes). Because the loopback cable routing is a redundant path, the full functional capability of the system will be achieved before the entire cable plant is in-place (and the system reliability has been enhanced). The evaluation process will begin once the full functional capability of the system has been attained, with appropriate consideration of the pending improvement in reliability to be gained in the completion of the loopback cable routing.

The system evaluation consists of investigating several economic factors relating to the system including:

- 1) Defining the communication requirements for a deep-vein metal mine (from call traffic data analysis)
- 2) Determining the actual non-recurring and recurring costs of installing and maintaining the system
- 3) Determining the optimum configuration for future systems

The communication requirement for a mine can be determined by monitoring the usage of a fully capable (non-blocking) system. Because single-channel systems are currently accepted, but multi-channel systems are of indeterminate value, the system usage involving multiple or simultaneous conversations is the key to measuring the actual system requirements. A conservative estimate of the value of multiple channel capability (for mining operations) is to assume that one person would be waiting for the phone during the total time that two separate conversations are in process. Similarly, three or more concurrent conversations would probably have occurred sequentially rather than simultaneously. A conservative "cost" due to the waiting period is obtained by multiplying the total time multiple conversations were in progress by the number of conversations by the cost of one person's time. It is probable that in many circumstances, more than one person would be effected by delayed communications, but there is no quantitative way of assessing this situation. A more realistic measure of cost benefit is the product yield vs a time-weighted measure of the number of simultaneous and/or blocked calls occurring during the peak periods of days. The most direct measure would be obtained by evaluating only the single-channel results first, then the multi-channel results, and then by comparing the two. This is not possible at Sunshine because usage of the existing multi-channel system has reached steady state (however, the "turn-on" effect of paging could be so evaluated). More indirect measures include:

- 1) the correlation of muck output vs number of simultaneous calls/duration during shift change periods under normal operation
- 2) correlating the difference between normal muck output and output of days when operational outages occur, with the number of simultaneous calls/duration obtained during the outage periods

The need for a non-blocking system is self-evident in that the maximum requirements for a system cannot be measured on a system which is saturated by a lower level of usage. The proposed system is essentially non-blocking in that it permits eight simultaneous underground conversations and four additional underground/surface conversations, so that twenty-two phones in the system can be simultaneously engaged in

private conversations. If this level of capacity is insufficient, the case for multiple-channel systems will be self-evident.

The system cost will be determined separately for the recurring and non-recurring expenses associated with the maintenance, installation, and acquisition of the system. The non-recurring costs will include the current cost of the hardware (or equivalent newer hardware) and the cost of installing the system. Estimates for the current cost of reused equipment and cable will be included in the total cost based on current value of equivalent new equipment and labor. The recurring costs consist of maintenance and spare parts costs and will be accumulated once the system costs of other types of systems, so that the comparative costs and capabilities of those systems can be determined.

The analysis of the communication requirements and the relative cost for varying levels of system capability will be combined to determine the most cost-effective system for use in deep-vein metal mines. This analysis will result in the initial cost and the projected payback period for the systems. Additionally, the analysis may be combined with costs for typical surface operations, so that a whole mine system cost can be compared with the cost of separate surface and underground systems. This information will provide an accurate assessment of the value of multi-channel communication systems for use in deepvein metal mines.

6.2 DATA COLLECTION SYSTEM

The system usage will be measured within the resolution of one minute periods. The "economic value" of the multiple-channel system will be determined as indicated in the preceding section. The system evaluation will be conducted over a period of time not less than one year. Thereafter, the data analysis will encompass a minimum evaluation of $(365 \times 24 \times 60) = 525,600$ discrete time increments. In addition to tracing the duration of simultaneous conversations, the system should identify the density of underground and surface conversations and the number of busy stations and busy trunks that are being encountered by third parties. The data collection system must be automated with automatic data analysis in order to minimize the cost of this effort.

Fortunately, traffic monitoring equipment directly compatible with the 503 (or other types of PBX's) is available. The equipment provides a realtime processed analysis of circuit state variations in the system. The output is provided on a serial bit stream port with a "standardized" format. Some machines also provide a sequential record stored on reels of magnetic tape. The data output is buffered for pre-determined intervals of time until it can be accessed by a central controller. Although services exist to analyze the recorded data, the Contractor proposes to create a local automatic data analysis system at

the PBX, which will be transmitted on daily or weekly intervals to the Contractor's offices in Cedar Rapids via telephone modems. The Contractor's proposal is based upon the following considerations:

- 1) A complete data log (with real time information) will be permanently stored which will permit modification or re-analysis of the system data in an efficient and timely manner.
- 2) The routine operations of handling the magnetic tape will be eliminated, thus obviating the impact of the monitoring operation on the mine.
- 3) The data can be analyzed and condensed at the mine before transmission to Cedar Rapids.
- 4) Inexpensive equipment is available which will directly interface with the contractor's computer system.
- 5) The time to retrieve and analyze the system operation and the traffic analysis system will be limited by the transmission interval, thus reducing the quantity of data lost in event of a system malfunction.
- 6) The contractor will have the data stored in a format which permits easy analysis of the data and allows varying levels of resolution analysis depending on the requirements identified in the course of the program.
- 7) The data will be available to model the operation of other types of communication systems.

In general, the proposed system allows a flexible, efficient and comprehensive system analysis to occur with thorough availability of the raw data during and after the program conclusion.

A block diagram of the proposed system is shown in Figure 17 . The system consists of a traffic measurement system, such as an ACD DTMS system, which monitors the "tip and ring" connections of the PBX line and trunk circuits for status changes. The monitoring system provides a real time or accumulated data output to a small computer (such as the 6502 microprocessor based APPLE II computer), which stores the system data on a "disc" storage unit after deciphering the DTMS data stream. The data storage will be interspersed with real time markers (with one minute resolution), so that a "pseudo real time" data listing is created. The computer will interface with a data modem linked through standard telephone circuits to a similar modem in Cedar

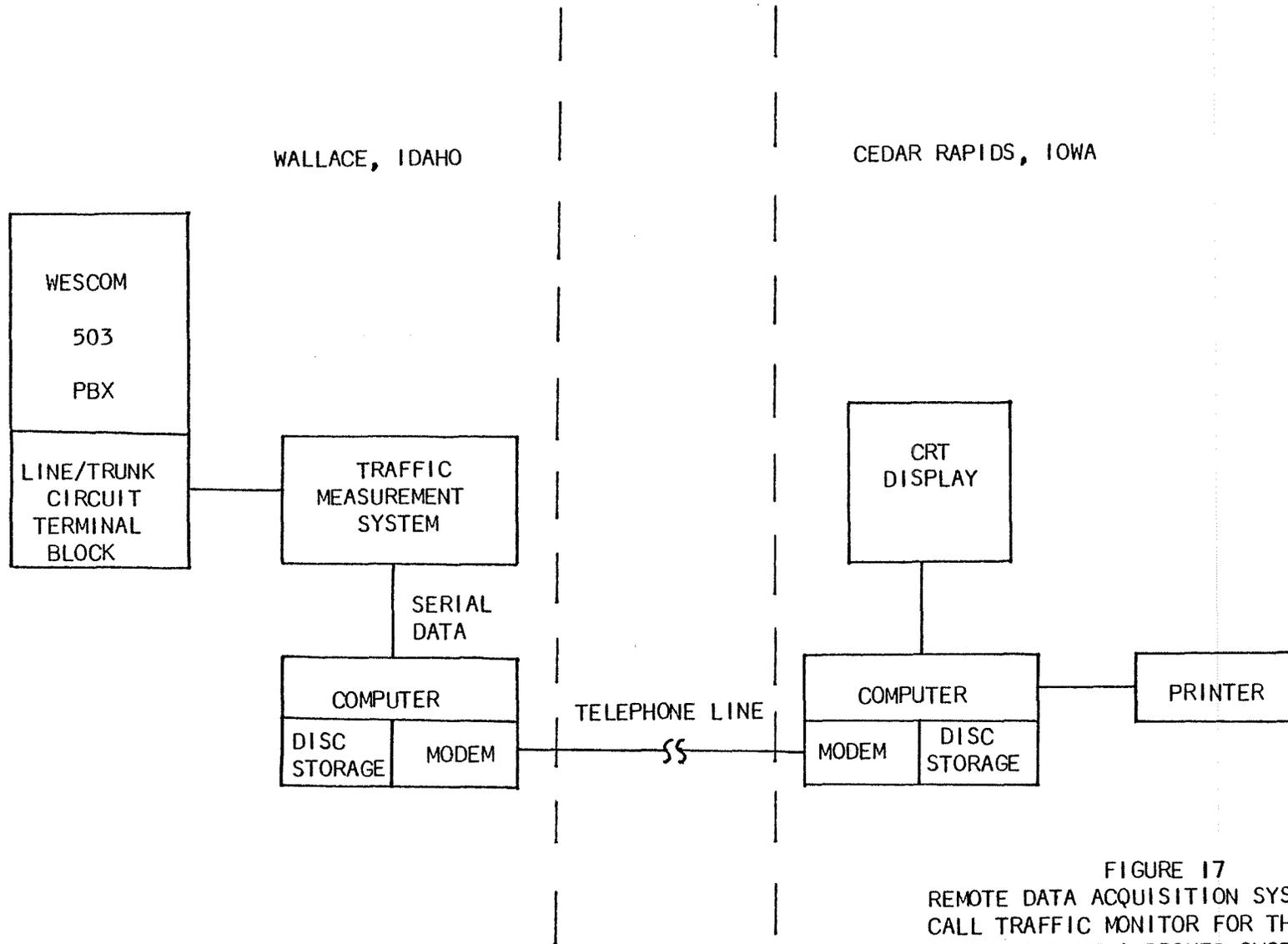


FIGURE 17
REMOTE DATA ACQUISITION SYSTEM AND
CALL TRAFFIC MONITOR FOR THE PROPOSED
SUNSHINE MINE IMPROVED SYSTEM EVALUATION
STUDY

Rapids. The data is transferred through the modems and stored on "disc" storage equipment from which it can be analyzed. During the course of the program, a library of traffic information will be accumulated which can be re-analyzed at any time that new system operational factors arise. The data library can also be applied to computer analysis of alternative system operation, such as how much blocking would occur in a five channel system, or the effect of loss of three of the underground to surface interface trunks.

7.0 SUNSHINE SYSTEM IMPLEMENTATION WORK BREAKDOWN COVENANTS AND AGREEMENTS

This section summarizes the working arrangements which exist leading into the implementation of the system outlined in this document.

7.1 CONTRACTOR, SUBCONTRACTORS AND BUREAU RESPONSIBILITIES

The prime contractor, Terry S. Cory, P.E. acting as the agent of the U. S. Bureau of Mines and assisted by his subcontractors, Columbia Telecommunications, Inc. and Richard J. Mahany, will supervise the design, procurement, installation, test, maintenance and evaluation of the system outlined in this document. The contractor will arrange the procurement of all equipment, hardware, cable and services required for the system other than those listed in the following sections. Additionally, the contractor will provide any necessary technical services to assist in the execution of the work tasks outlined below.

7.2 SUNSHINE MINING COMPANY RESPONSIBILITIES

The Sunshine Mining Company will permit the system implementation and support that effort by performing the following work tasks:

- 1) Provide a workshop area for performing maintenance and test of system hardware (the maintenance area will be supplied with test equipment by the contractor).
- 2) Install cable for the new system according to the system installation schedule (to be jointly determined by the contractor and the mine).
- 3) Provide the services of Billy Arthur (or a suitable substitute) to perform routine maintenance of the system and to assist non-mine technical personnel in planning, installing, testing and servicing the system hardware.
- 4) To assume the non-recurring and recurring GTE charges incurred in linking the underground and surface telephone systems.
- 5) Provide Billy Arthur (or a designated substitute) for maintenance training from Columbia Telecommunications on multipair cable and basic PBX and telephone instrument troubleshooting.

7.3 HECLA MINING COMPANY RESPONSIBILITIES

The Hecla Mining Company will install loopback trunk cable from the Sunshine Raise at the 3000 level to the Silver Summit shaft, up the shaft and out the portal. Hecla will install all junction boxes and permit the connection of GTE service (from Kellogg) to the portal junction box. The contractor will supply the necessary cable and hardware (either directly or on a reimbursable basis with Hecla) required for the installation, in addition to reimbursing Hecla for all labor charges incurred during the installation (or any subsequent maintenance) of the cable and associated hardware. Hecla will provide an itemized billing of the charges to the contractor.