Coal Mine Rescue and Survival Systems

Equipment developed with tools of America's aerospace technology is being applied to coal mine rescue and survival systems – including transmission of radio messages through the earth and life support capability

Special Report

A task force rolled out of Charleston into the mountains of West Virginia in January of this year to test a technological system for rescuing trapped miners.

Some 22 trucks were loaded with equipment developed with the tools of aerospace technology and tailored to the task of locating and opening an underground trap sprung on men by a coal mine disaster. The equipment ranges from sensitive electronic devices to hard-driving drills.

It included electronics that can detect and locate the thump from a miner's pick far below ground, transmit radio messages through the earth, and drills that can bore a hole 2,500 feet straight down and rig it for rescue. Other parts of the system apply underseas life support technology to underground survival.

With only short notice, the team of experts and equipment converged on a previously undisclosed coal mine location to carry out a realistic lifesaving simulation. The test was aimed at evaluating and further refining the system.

The evaluation test was the high point in a 9-month-long program launched by the Interior Department's Bureau of Mines to turn a conceptual study of coal mine rescue systems into hardware. The program is being carried out under a $3.4 million contract to Westinghouse Electric Corporation's special systems division at the company's Defense and Space Center in Baltimore.

The evaluation test staged in January will put the search and rescue components to the test. The survival systems will be evaluated in separate tests later.

COAL – THE NEED AND THE HAZARD

Coal mining is an industry of necessity and hazard.

Necessary because the country will consume half a billion tons of coal in 1971 for industrial purposes and power generation. And even if the most optimistic projections for the growth of nuclear energy are fulfilled, the demand for coal will double by 1980 and increase another 40 per cent before the year 2000.

Although coal mining has the most stringent regulations of any of the mining industries, it is still the most hazardous. The very process of ripping coal from a subterranean workplace not only churns up a volatile black dust but also releases explosive methane gas.

Thirty-two times in the past two decades the hazards of coal mining have come into sharp public focus. These were the occasions of major mine disasters. Some 555 men were killed.

The good side of the statistics is that 1,690 miners involved in those major disasters walked out unaided and unharmed. Another 100 were rescued.

A study shows 126 miners, about 20 per cent of those whose cause of death is known, could have been saved with the proper knowledge, training, or equipment. The coal mine survival and rescue system could add favorably to the lifesaving odds.

ORIGIN OF CONCEPTS

In early 1969 the Bureau of Mines asked the National Academy of Engineering to survey the nation's storehouse of technology and recommend the most up-to-date means available for survival and rescue of trapped miners. In March of the same year the Academy established a Committee on Mine Rescue and Survival and sent them on a wide search in fields ranging from earthquake measurement to petroleum drilling.

One of the objectives of the committee was to define a mine rescue and survival system that could be developed in approximately one year using existing technology. A report describing the system was published in November, 1969.

The concepts described in the report became the development guideposts for the Mine Rescue and Survival System. The following spring, the Bureau selected Westinghouse from among the firms competing for a contract to turn the Academy concepts into workable hardware.

Westinghouse Electric Corporation

Modular Portable Survival Shelter Under Construction

CAPABILITIES

The request for proposals issued by the Bureau of Mines on February 20, 1970 offered what Westinghouse management considered exceptional opportunities for its high technology defense divisions' capabilities. The survival habitat and underground breathing apparatus concepts described in the Academy report, although dealing with different problems and a different environment, were still closely related to technologies developed at the Westinghouse Ocean and Engineering Center.

The company's Georesearch Laboratory in Boulder, Colorado, has already accumulated extensive experience in seismic communications techniques. This experience, coupled with work the Westinghouse Defense and Space Center had

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done in through-the-earth communications, enabled it to match and in some cases exceed the capabilities called for in the Academy of Engineering report.

Finally, the report said the development of a rescue and survival system required systems management to achieve economically efficient integration of all components into a total system. The company quickly pulled in one of its most effective systems management specialists from California - - Robert P. Taber - - and put him to work at the company's special systems division in Baltimore.

Mr. Taber, a veteran of the company's Polaris program participation, assembled a team of systems management personnel to guarantee that the hardware was not a conglomeration of components but a smoothly functioning system. Aside from developing systems hardware, the team also began undertaking research on the geological characteristics of major coal mining areas, their accessibility to nearby airports, and even some limited studies of the behavioral patterns of trapped miners.

The coal mine rescue and survival system has three basic objectives:

1) To enable coal miners who have survived a disastrous explosion to survive the equal dangers that immediately follow, including carbon monoxide poisoning, smoke inhalation or suffocation, roof falls, and additional explosions.
2) To enable miners to receive and send emergency communications regarding their locations, available escape routes, nearby dangers that should be avoided, or advice on rescue.
3) To provide an escape shaft if operating shafts or tunnels cannot be safely reopened.

Immediately prior to a coal mine disaster, there could be several crews of 8 to 15 men working in an area within one or two miles - - but separated by as many as five or ten miles of tunnels. In addition to the larger work crews, smaller teams of two to four men could be engaged in coal hauling, maintenance, mine construction, or inspection.

Suddenly, an explosion occurs at one of the working faces where the coal is removed from the seam. Those who survive the blast may escape to the surface. Others may find their way to a refuge chamber, or to specially designated areas equipped for construction of barricades to keep out poisonous gas while awaiting rescue.

Smaller groups of men moving from one area to another might be trapped in locations without any special equipment. Their location may be completely unknown by other miners or those on the surface.

It is probable that power will be disrupted by a mine disaster or, if not, disconnected as a safety precaution. As a result standard telephone communications systems between surface and mine are not available during such emergencies.

Rescue forces on the surface will have information on the location of rescue chambers, preferred barricade areas, and sections of the mine being worked. All coal mines are required to maintain current maps of their network of tunnels.

SUBSYSTEM FOR SURVIVAL

In the aftermath of a fire or explosion, the coal miner may find a basic lifesaving link is missing: a supply of breathable air. To meet that need, law requires that each miner be provided with an emergency breathing device called a self-rescuer.

The self-rescuer filters out poisonous carbon monoxide but depends on oxygen remaining in the mine atmosphere. Although self-rescuer units have saved many lives, the National Academy of Engineering says they are "only marginally adequate for the job for which they are intended."

Personal Breathing Apparatus - the personal breathing apparatus designed by Westinghouse for coal mine emergencies provides a new meaning for the old acronym SCUBA: Self Contained Underground (instead of Underwater) Breathing Apparatus.

The new equipment is indeed self-contained. It not only provides a supply of oxygen, but filters out carbon dioxide after each breath and enables its user to rebreathe the unused oxygen.

The closed-circuit system uses standard materials such as lithium hydroxide to filter out carbon dioxide and chlorate candles to produce oxygen by chemical reaction. Chlorate candles are widely used as oxygen generators in aircraft.

The personal breathing apparatus consists of a mylar hood with fog-proof goggles and a rubber neck seal, connecting hoses, and a canister worn slung across the chest. Its design is such that it does not prevent its user from hearing or talking.

The unit is about the size of a cigar box when stowed in its carrying case or 10 by 11 by 3.25 inches. It weighs 7 pounds.

Survival Shelters - personal breathing apparatus is designed only to enable a coal miner to escape or reach safe refuge where he can await rescue. A refuge area could be a safer part of the mine or a place where materials are stashed to erect a barricade of brattice cloth and wood framing to keep out smoke and toxic gases.

From 1909 to 1961 more than 1,000 coal miners were rescued from behind barricades. Others died because their barricades were improperly erected.

Because of the life-saving potential of refuge areas and chambers, the National Academy of Engineering recommended development of advanced survival shelters. The Westinghouse Ocean Research and Engineering Center has applied its undersea life support expertise to designing two types of survival shelters.

One is a 15-man portable shelter to provide refuge near the mine face as work advances. Westinghouse life support engineers also drew up specifications for a large, centrally located, permanent chamber that could accommodate 50 men for two weeks.

The portable shelter can be folded into six modular packages with rubber-tired wheels that can be removed once the module is in place. The arched walls of the structure are made of steel and are ribbed for strength.

When the six modules are assembled, the bulkheads installed at each end, and the whole unit bolted to the mine floor, it provides a quonset-type structure 48 feet long, nine feet wide, and five and a half feet tall at its center. Beneath the floor of the shelter are stored food,

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Westinghouse Electric Corporation

Transmitting with a Pick

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water, and medical supplies.

The portable shelter is also equipped with a hand-cranked atmosphere conditioner to provide fresh oxygen to the interior of the shelter or directly to breathing masks until the shelter interior is cleared of smoke or carbon monoxide. Each of the modules weighs about 4,100 pounds and can be wheeled into place by small, electrically powered vehicles or by several men.

The large, permanent shelter is designed as a 75-foot-long tunnel in rock with reinforced concrete blast walls on each end. The shelter design calls for an 8-inch pipeline to the surface to provide a channel for fresh air, communications, and additional supplies.

The pipeline would link the survival chamber with a small building housing a compressor and heating equipment to provide conditioned air. As a precaution, the shelter is also outfitted with equipment to make it self-sufficient for five days - - time enough to make the pipeline usable again.

The permanent shelter is designed to provide much more in comfort and convenience than the smaller shelter. The Design calls for such things as more comfortable bunks, better lighting, and temperature control.

COMMUNICATE AND LOCATE

Once the coal miner has survived the dangers immediately following an explosion and has found safe refuge, the focus shifts to the surface where rescue operations have begun. The Coal Mine Rescue and Survival System could put tools in the hands of the rescue team that were not available before.

Westinghouse Electric Corporation

A Voice Through the Earth

One of the most valuable tools is a newly developed emergency communications system. Communications is not only the key to locating trapped miners, but a means of providing information that could enable them to survive.

The emergency communications system developed by the Westinghouse Georesearch Laboratory in Boulder, Colorado, consists of two different types of equipment. One system permits through-the-earth transmission of voice or beacon messages and the other enables rescuers to detect seismic vibrations set off by a thump from a pick, a sledge hammer, or a heavy timber.

Through-the-Earth Communications - last year several Westinghouse Georesearch engineers sat in a passageway of the Eagle Coal Mine in Colorado and listened to some raspy rock music coming from their receiver. What made the incident unusual was that the music was being transmitted through 270 feet of earth, rock, and coal from equipment on the surface directly above.

Anyone who has been confronted with the sudden silence of a car radio on entering a tunnel knows that radio waves cannot travel through earth. Yet research has shown that very low frequency waves, not much different from the frequency range of the human voice, can be transmitted through the earth.

The electromagnetic communications equipment developed by Westinghouse calls for each miner to be equipped with a miniature receiver attached to his headlamp battery case. The receiver is no larger than a transistor radio and has a retractable ear plug.

In case of an emergency the miner would immediately turn on the receiver and begin listening for instructions. The tiny unit is a receiver only, so the miner would have to use the other means provided to send messages back to the surface.

Miners who reach survival areas will have a more powerful receiver and a push-button beacon transmitter at their disposal. Those trapped elsewhere in the mine can use any heavy object available as a transmitter by slamming it against the mine wall to communicate by the seismic technique described later.

The electromagnetic transmitter sends beacon signals rather than voice to conserve its two-week battery power supply. This unit is equipped with six buttons marked "yes," "no," "unknown," "repeat," "good," and "bad."

When one of the buttons is pushed in response to a question from above, the underground transmitter sends a signal to the surface receiver where it is decoded and a corresponding indicator lights up on a display panel.

The shelter transmitter is also equipped with a manual key to answer questions by a number of pulsed responses. The manual key might be used to indicate such things as the number of men in the shelter or how many are injured.

Seismic Communications - the seismic communications system developed for the Coal Mine Rescue and Survival program is similar to equipment used to measure and locate the origin of earthquakes. In this case, however, the tremor being detected is man-made, perhaps by no more than a miner's pick.

The devices used to detect these tiny man-made tremors are called geophones and are capable of sensing vibrations and converting the energy into electrical signals. By installing a number of geophones on the surface, enough information can be fed into the system's small computer to analyze the location of the signal's origin from below.

The seismic signaling system is doubly effective when an isolated miner is also equipped with the miniature portable voice receiver - - enabling him to both transmit and receive. The seismic system serves still another purpose when used in conjunction with receivers and beacon transmitters located in refuge areas.

Once communications are established with a shelter and its occupants are safe, rescuers might call on them to install a geophone from their cache and connect it to their transmitter and receiver. The geophone would provide an underground sensing station to detect and relay vibrations from miners who might be trapped nearby.

THE RESCUE DRILLS

Trapped coal miners most often come out the way they came in - - through the mine shaft. However, fires or cave-ins sometimes prevent reopening the mine shaft and tunnels.

An alternative is to drill a hole from the surface down to the miners and pull them out. As part of the Coal Mine Rescue and Survival program, two drills have been designed and built for this purpose using advanced techniques developed for the petroleum industry and the Atomic Energy Commission's underground test program.

One of the drills is designed to rapidly bore a hole nine inches in dia-

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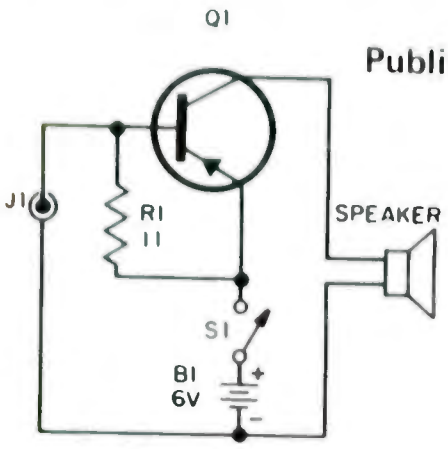
SCIENCE PROJECTS

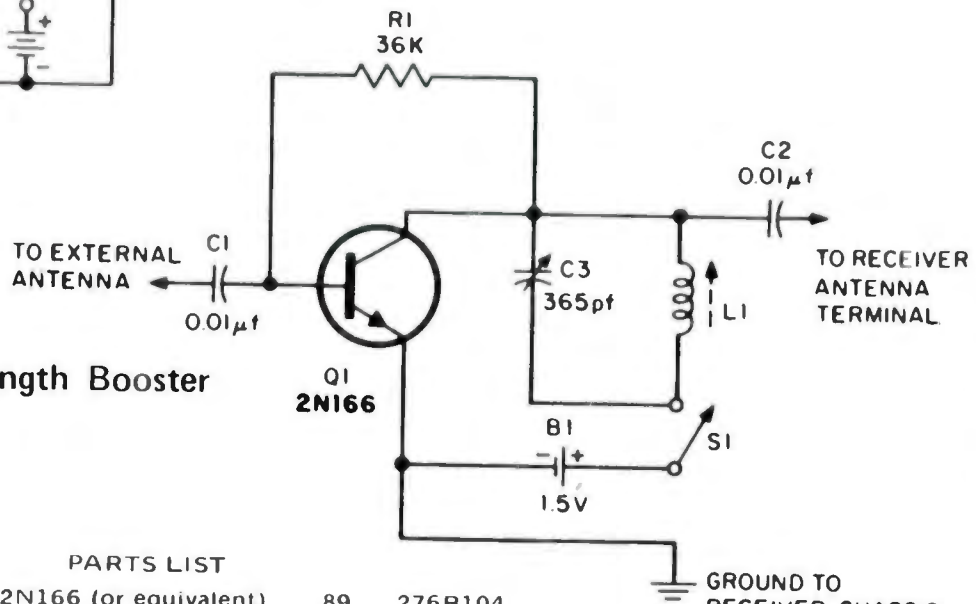
For Students and Hobbyists



Public Address System

PARTS LIST

Q1, Power transistor, 2N174 (or equiv.)	1.69	276B105
R1, Resistor, 10 Ohms, ½ watt	.25	271B000C
J1, Phone input jack	.99	274B346
S1, Toggle switch, SPST	.39	275B602
B1, Four "D" cells	.19 ea	23-466
Battery holders (2)	.39 ea	270B439
Speaker, 2¼", permanent magnet	.98	40B246



Signal Strength Booster

PARTS LIST

Q1, Transistor, 2N166 (or equivalent)	.89	276B104
R1, Resistor, 39,000 Ohms, ½ watt	.25	271B000C
C1, C2, Capacitors, .01 uf	2/.45	272B1051
C3, Capacitor, 365-pf variable	.59	272B134
L1, Ferrite-Loopstick antenna	.79	270B1430
S1, Switch, SPST	.39	275B602
B1, Battery, 1.5 volts, "D" cell	.19	23-466
Battery holder	.39	270B439

Public Address System

This miniature public address system (PA) can be built right into a speaker enclosure, including power supply and other components.

The system operates when the power supply switch, S-1, is turned to the "ON" position and microphone input is supplied at "J-1", the input jack.

In operation, the power transistor, 2N174, is connected directly to the 6-volt battery power supply which in turn drives the speaker. A carbon mike of good sensitivity should be used for best results.

A low-cost speaker enclosure may be built from plans featured in the January/February, 1969, issue of Electronics Digest, "Easy-to-Build Speaker Enclosure." Reprints of that project may be obtained for fifty cents postpaid by writing to: Reprints, Electronics Digest, P.O. Box 9108, Fort Worth, TX 76107.

Signal Strength Booster

This low-cost preamplifier circuit can give a small AM radio receiver a sufficient "boost" in signal sensitivity to allow tuning in of many distant stations. It is also a useful gadget for the experimenter to have at hand.

The entire circuit, which can be assembled in about one hour, can be built into an aluminum mini-box (Allied Radio Shack Cat. No. 270-235 @ .99) and attached to the back of the radio set.

For best reception, the ferrite-loopstick, L1, and the 365-pf variable capacitor, C3, should be peaked at the center of the band for regular listening, or at any particular frequency you wish to tune in with greater sensitivity.

NOTE: Catalog numbers are Allied Radio Shack Electronic Parts Accessories and Kits, Spring/Summer, 1971, No. 212, available at their stores throughout the U. S.

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Westinghouse Electric Corporation

Drilling Rigs for Rescue

meter through to the trapped miners. Such a hole would provide a means of supplying fresh air, food, medical supplies, and wire communications.

Following this, crews would put the second drill into operation but proceed at the slower pace required to drill a 28½-inch-diameter hole for pulling the miners out in a personnel capsule.

The smaller drill, called a search and probe unit, can bore as fast as 100 feet every hour. The larger rescue drill operates up to 17 feet per hour.

The primary differences between the coal mine rescue drilling rigs and similar rigs in use by the petroleum industry are portability and versatility. All of the complex heavy equipment requires 22 trucks for transportation.

But the units can be broken down into modules and flown by C-130 to a nearby airstrip and carried in by heavy-lift helicopter. When transported in by truck, the drills can be put into operation in a few hours.

The drilling systems were designed and developed by Rowan Drilling Company of Houston, Texas. Rowan is also under contract to operate the drilling rigs during the evaluation test to be staged in West Virginia in January of 1971.