Underground mine fire preparedness

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Part 4 of 4: Suggested improvements and implications for training miners in fire-fighting preparedness

This is the fourth and final article in a series that discusses underground fire-fighting preparedness. As with the previous three articles, it is based on interviews with 214 miners at 7 underground coal mines (referred to as Mines "A" through "G") conducted by researchers of the National Institute for Occupational Safety and Health's (NIOSH) Pittsburgh Research Center [Vaught et al. 1996]. The first article presented an overview of the study conducted by NIOSH on mine fire response preparedness and provided a general perspective on underground mine fires. The second article discussed miners' preparedness to evacuate a fire and their experience with incipient fires. The third article described miners' experiences in fighting underground mine fires and presented their perceptions of training and readiness for fire-fighting. This final article in the series offers suggestions to improve mine fire-fighting preparedness.

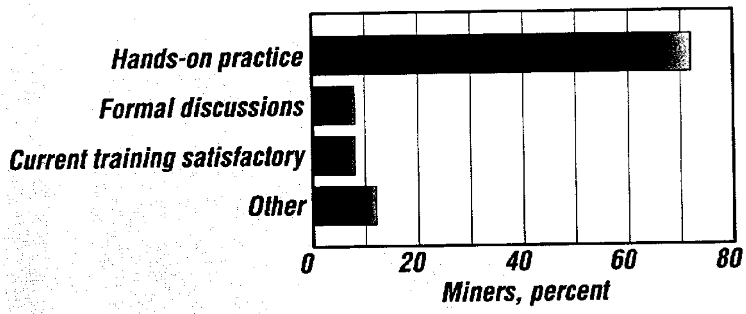
One of the final questions that interviewers asked the 212 respondents (2 miners did not complete the interview) was what, in their opinion, could be done to improve fire-fighting response. Figure 1 shows that only 8% of the miners were satisfied with the fire-fighting training they were receiving, and a portion of them called for less complacency and more involvement by the rank and file. One-half of those individuals who felt that training at their operation was adequate were from Mine A, where hands-on practice was emphasized. Another 8% suggested that a formal discussion of techniques would be useful. One person even recommended that, in these formal discussions, management find a way to let workers draw upon their collective knowledge:

> "Well, it might not hurt to have something once a month that was using all the experiences of every miner and what they had their biggest problem with and what they would have done to alleviate some [of the problem]."

Seventy percent of miners interviewed indicated a desire for hands-on experience, either in extinguishing a real fire or at least in handling fire-fighting equipment. Two miners commented:

> "I'd say either hold actual drills ... or have ... somebody up on top show you the proper use of a fire extinguisher ... There are a lot of people [who] don't know how to use them."

Figure 1.—Training improvements



"I think if they went to hands-on training, or even a special class—like so many people at a time and just let them use a fire extinguisher. Let them experience high-expansion foam. A section of people, they know about the fire suppression systems on different pieces of equipment, but to actually activate it, I don't think there's too many people that's actually done it."

A fire brigade member at one mine carried the notion of what would constitute good hands-on training a step further:

"Start out with several individuals per unit. Teach them at least the basics, as far as putting on the air equipment, the bunker gear, give them just the basics of really being a fireman... And that's the key, as opposed to waiting 35 or 40 minutes for somebody else to show up. By that time, it could be so far out of control that it can't be handled by anybody, I think."

Apparently, most of the miners had given some thought to ways in which the work force could become better prepared to fight fires. Their suggestions ranged from simple ideas, such as seeing for themselves where various fire-fighting equipment is found at the mine to full-scale drills underground using nontoxic smoke generators.

Besides identifying ways in which training could be enhanced, most workers also suggested organizational and technological improvements that might be made at their mine to enhance fire-fighting capabilities. Many of these items dealt with better communications and ranged from such things as developing a crew plan to regularly cleaning and maintaining signs. Other concerns voiced by some respondents were perceived shortcomings in equipment availability or a lack of adequate water pressure at their mine. Thus, although the need for hands-on training was uppermost in the minds of those miners interviewed, several thought of ways to augment this instruction by improving the system.

System Improvements

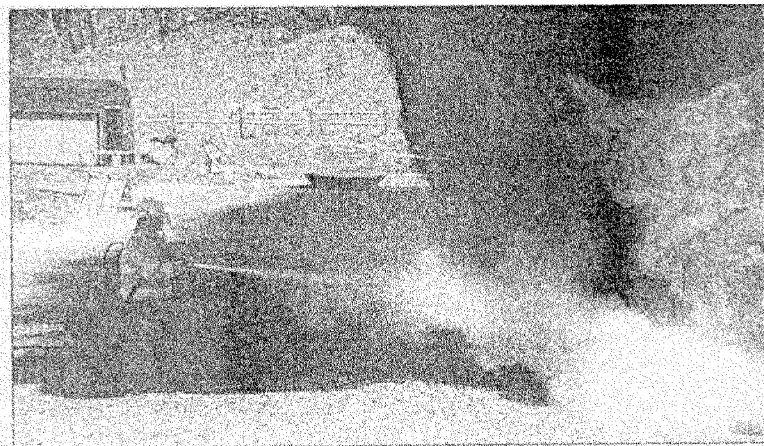
In a mine fire, early detection maximizes the potential for escape from, and control of, the fire because more time is available to successfully execute these procedures [Kissell and Litton 1992; Conti and Litton 1992]. Generally, miners responding during the incipient stage of a fire (a fire too small to present a significant threat) increase their chances of extinguishing the fire, provided that they have adequate fire-fighting equipment and skills [Conti 1994]. To optimize the detection process, the choice of fire sensors (smoke, carbon monoxide, thermal) to detect a fire plays a major role. However, this choice is also tempered by the reliability and sensitivity of the detectors used. A related factor is the number of sensors required, because cost, both in capital expenditures and in labor needed to maintain a system, increases as the number of sensors increase. Several mine fire detection research studies are reported in Conti and Litton [1993], Dobroski and Conti [1992], Edwards and Morrow [1995], Egan [1993], and Litton et al. [1991].

Additionally, an operation should have a preventive maintenance schedule in place to ensure that all detection and suppression devices work properly [Grannes 1988; Grannes et al. 1990]. Moreover, because early detection is of little value unless a quick response is mobilized, a mine should have an established warning and communication protocol that is tested and refined, as needed. Evacuation of personnel from an underground mine can require considerable time. Therefore, it is important that a warning alarm signal be able to quickly reach all workers underground and those on the surface [Hjelmstad and Pomroy 1991; Zamel 1990]. Recent research has shown that the alarm mode of commercial smoke sensors can be interfaced with a portable remote (wireless) transmitter to trigger either a partial or full mine-wide alert. This warning system is undergoing testing at NIOSH's Lake Lynn Laboratory near Fairchance, Fayette County, PA [Mattes et al. 1983; Conti and Yewen 1997]. Preliminary test results indicated that underground receivers could be used to flash cap lamps and activate remote stations when an encoded signal was received. Examples of remote stations that could be activated might include strobe lights with audio outputs to indicate evacuation routes and the inflation of positive-pressure inflatable escape devices [Weiss et al. 1996]. This technology displays the ability to transmit from compact, portable, and semiportable receiving and decoding equipment. This paves the road to transceiver applications, such as emergency two-way messaging for refuge stations or mine rescue operations; remote monitoring of fire sensors and sump pumps; and remote control and monitoring of other mine equipment, such as conveyor belt systems and haulage traffic control.

Additional areas for research include transmitter designs for very large mines with and without adverse geology, vehicle paging and tracking, a motionless detector (to alarm if personnel become motionless) or a receiver with manually operated distress buttons, automatic "tag-in and out" with addressable paging numbers, and tracking of underground miners that could send out a beacon on command from a locator interrogator for mine rescue purposes.

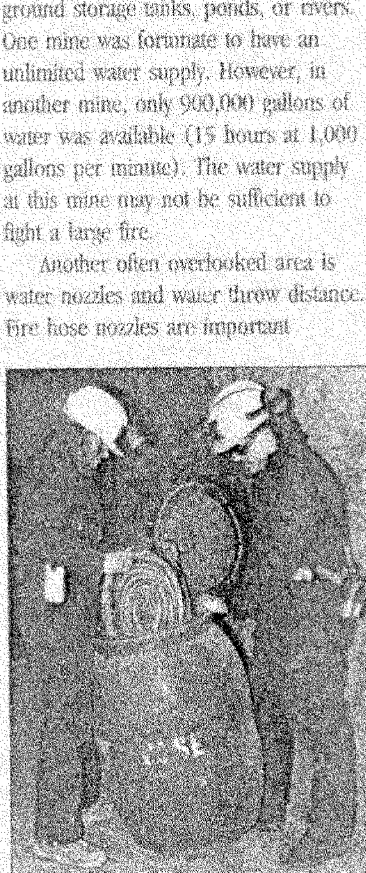
Personnel must also be trained to properly respond to a warning signal from a fire detection system. When miners are not properly trained, the potential for disaster is imminent. As an example, on March 9, 1994 [Roberts et al. 1994], more than 180 feet of conveyor belt was destroyed at the Bullitt Mine in Virginia by a fire caused by contact between belting and an energized trolley wire. During the event, the carbon monoxide monitoring system responded at 9-ppm warning; however, the alarm warning was dismissed as "probably welding smoke." A short time later, the miner who was welding inadvertently discovered the fire while answering the mine phone. The miner immediately initiated fire-fighting activities. Typically, fire warning systems (smoke and carbon monoxide) respond to an incipient fire, but these responses are often dismissed as glitches in a sensor or planned maintenance activities in the area. It is important that any warning coming from an underground fire sensor be immediately investigated and that standard procedures are developed for responding to sensor warnings and alarms.

Water is the most practical and effective extinguishing agent. Once a fire has passed its incipient phase, a well-prepared operation will have adequate quantities and pressure plus the means to deliver the water to the fire site. Such a system would include large-diameter supply lines, portable fire hydrants, and high-pressure hoses with suitable nozzles [Conti 1994; Mitchell



1996]. Rather than the required minimum 50 gallons per minute water flow per hose, this system can deliver hundreds of gallons per minute (using several hoses) for sustained periods. Thought must also be given to water reserves. How long can fire-fighting efforts be sustained? In a review of the fire preparedness at four mines [Conti 1994], water supplies for underground fire-fighting were either large above-ground storage tanks, ponds, or rivers. One mine was fortunate to have an unlimited water supply. However, in another mine, only 900,000 gallons of water was available (15 hours at 1,000 gallons per minute). The water supply at this mine may not be sufficient to fight a large fire.

Another often overlooked area is water nozzles and water throw distance. Fire hose nozzles are important



components of fire-fighting equipment; however, many mines consider them a low-priority item. Several mines that experienced problems with plastic nozzles that either leaked or melted during fire-fighting activities have replaced plastic with brass nozzles. The water throw distance in underground mines is generally limited by the roof height, water pressure, hose size, and water nozzle. Therefore, throw distance in low coalbed mines would be shorter compared with a higher coalbed mine for the same water pressure, hose size, and nozzle.

When an underground mine fire cannot be directly combated due to heat, smoke, or hazardous roof conditions, high-expansion foam may be one way to remotely quench the fire. Foam is a convenient means of conveying water to a fire [Havener 1975]. It blocks air currents to the fire and radiant energy from the fuel. High-expansion foam cannot control a fire unless the foam plug reaches the fire. To effectively use the foam method for remotely fighting fires in underground mine entries, it may be necessary to construct a partition or seal in fresh air some distance from the fire site. This is done to separate the foam generator and its operators from smoke and toxic fire products. In addition, foam could flow back over the foam generator, rendering the fire attack ineffective. In past practice, concrete block, wood, plastic sheeting, brattice, or similar materials have been used for such partitioning. Building these partitions can be labor-intensive and time-consuming. An inflatable feed-tube partition for high-expansion foam generators was developed [Conti and Lazzara 1995]. The inflatable partition is a lightweight, portable, rectangular inflatable bag that can be used by fire-fighters to rapidly seal large openings, such as those in underground mines, and to simultaneously provide a feed tube for a high-expansion foam generator. Additional information on the use of foam and partitions can be found in Mitchell [1996] and Conti [1994, 1995].

A proactive strategy

Because detecting and extinguishing a mine fire may require the involvement of a complex system, current research is aimed at developing and evaluating formal fire preparedness checklists. The chief advantage of such a strategy, using a carefully defined and preset protocol, is that it could highlight any strengths and weaknesses of a site in some systematic way. In addition, there would be less chance that problem areas might go undiscovered and therefore uncorrected. A few of the topics that we cover in the checklist include a complete evaluation of the mine water system, fire-fighting equipment, supplies and responders, detection and suppression systems, housekeeping, and the use of fire-resistant materials.

Mitchell [1996] states that "the best facilities and equipment can never compensate for poor preparation." A large part of mine fire preparedness, therefore, is worker capability. A large part of worker capability is experience, motivation, and training. One of the most interesting observations from the interviews of 212 underground miners is that 45% of these miners reported having dealt with a fire that could have gotten out of hand. Additionally, 30% of the respondents were involved in at least one incident that they believed might better have been handled differently. It appears from these statistics that, although there are many successes, there is also room for improvement in how people respond to fires underground. A very interesting observation concerning training needs, in view of this fact, was made by the person who suggested that companies find a way to let workers learn from others' experiences.

Perspective

Over the past 2 decades, the number of reportable underground coal mine fires has significantly declined. As mentioned in the first article of this series, a total of 164 fires were investigated by the Mine Safety and Health Administration (MSHA) from 1978 to 1992 [Pomroy and Carigiet 1995]. An additional 25 fires were investigated in 1993-95. This is an average of 10.5 fires per year, compared with 32.4 fires per year for the preceding 15-year period [McDonald and Pomroy 1980]. Industry efforts to provide better fire protection has played a significant part in this trend. At the same time, the number of mining jobs has also declined partly due to fewer operating mines. It can be argued that these factors have caused a change in people's thinking. At one time, miners might have held the notion that if their mine were sealed due to a fire, they could go to work at another operation. Now they are more likely to regard sealing the mine as an end to a career in mining. Whereas miners might once have been reluctant to endanger themselves in a fire-fighting effort, they are now more likely to think about saving the mine in order to save their jobs. Each incident that occurs, therefore, may be dealt with by a group of first responders intent on extinguishing the fire. Thus, it becomes critical to first understand their capabilities and then to enhance them, where necessary.

In a sense, each occurrence of fire underground, no matter how small, presents a teachable moment for the work force. Safety and training personnel should consider recording the particulars of these events to assess what was done correctly and where mistakes were made. Teaching points could then be derived and passed on in safety talks or embedded in fire drills. Thus, miners at an operation would be exposed to ongoing learning opportunities that draw upon things that have actually happened to people whom they know in their own work setting. Another use of such a compilation would be as a data base to indicate, over time, whether improvements in worker responses were being achieved.

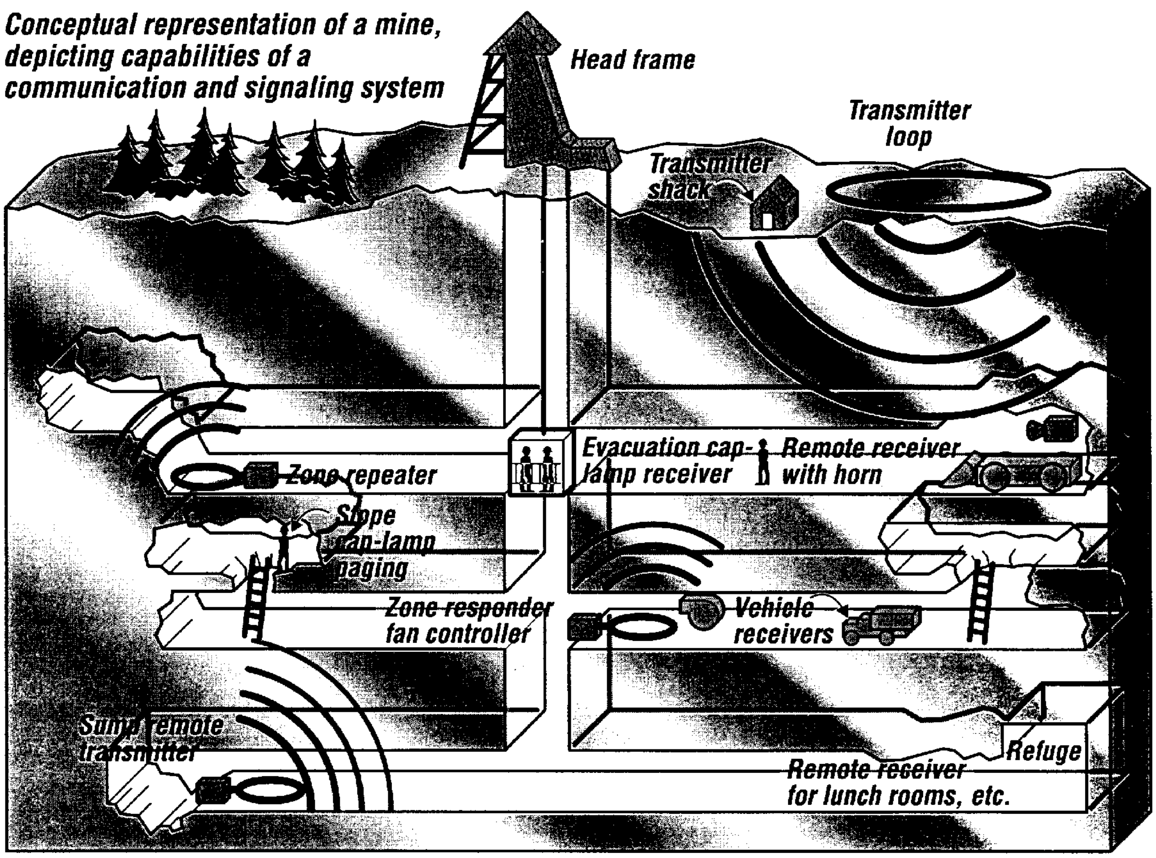
A major drawback to learning fire response procedures "on the job" is the lack of structured practice. There are some aspects of fire preparedness that require cognitive knowledge, and others that demand motor task skills. Safe evacuation, for instance, depends on knowledge of a mine's escapeways. However, at three of the sites in this sample, a sizable portion of those interviewed had not walked their escapeways within the past year. A successful attempt to put out a fire might well hinge upon the responder having some skill in the use of a fire extinguisher. Many miners sampled, however, had only used one in an emergency. That is hardly the situation in which to learn good technique. However, the percentages of miners that had some fire response training as either a volunteer fire-fighter or as part of a mine fire brigade are perhaps reflective of firms encouraging employees to expand upon skills that may be of direct, long-term benefit to both the work organization and the community.

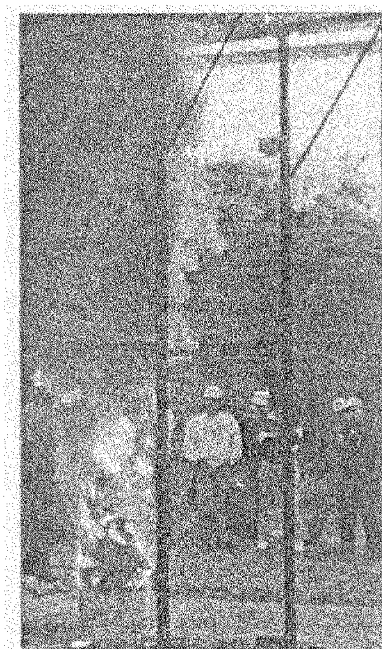
It appears from the data gathered in this study [Vaught et al. 1996] that there are two types of missed opportunities at some operations. On one hand, good fire drills could incorporate not only an opportunity to learn from the experiences of others through discussions or reenactment of past incidents, but might also provide a variety of hands-on experiences in using emergency equipment as well. The better structured and preplanned they are, the more teaching that could take place in a reasonable timeframe. On the other hand, occurrences of incipient fires provide opportunities to look back, evaluate, and enhance prevention, detection, and response capabilities.

By and large, the picture that emerges from this study is one of variability from mine to mine. Significantly greater percentages of interviewees had walked their escapeways at some operations than at others. The same was observed for those who recently participated in fire drills. The broad types of training offered to the work force also varied, with some mines relying heavily upon discussions and lectures as the main vehicle for developing fire response skills. Some mines tended to more formally integrate learning from their ongoing fire and smoke experience as a means for maintaining fire prevention, detection, and response communications within the work force. With little variability, all mines seemed to take the threat of smoke and fire seriously. However, the median frequency of reported smoke at two mines was at least once per week, whereas at another it was about once per year. The most consistent part of this picture is captured by the percentage of miners (70%) across all seven mine sites who have, at some time during their career, fought a fire underground. This suggests that fire is a constant (i.e., fires will always occur).

At times, little difference is found during the incipient phase between most fires that go unreported and one that results in a mine being sealed. It is simply that the latter either were not detected quickly enough or were not responded to properly. To achieve enhanced mine fire preparedness, mining companies will need to sharpen their strategy with regard to available technology and equipment while investing increased time and effort in

Conceptual representation of a mine, depicting capabilities of a communication and signaling system





their human resources. In other words, a growing number of mine sites are preparing themselves to deal with the unexpected. If these efforts continue, the number of reportable incidents will likely decline even further, and there should be even less chance of another disaster or permanent mine sealing.

In short, long-term, systematic improvements in mine fire preparedness imply a complementary focus on technology and the performance of this technology within the work site. An important premise of the work summarized in this series of articles is that the ongoing study of how miners make use of critical prevention, detection, and response systems offers important insight into both incremental and breakthrough technologies (engineering, education, and public policies) to enhance worker safety and health.

Summary

The following summarizes the key points in this series of four articles:

- Although the number of underground coal mine fires has dropped drastically in recent years, the potential for disaster is still present when a small mine fire occurs. Even a small fire causes disruption of production, which can be costly. Thus, it is important to have a work force that is well trained to prevent, detect, and fight a fire and for miners to know their escape routes and mine evacuation plan.
- A mine fire can occur at any time in any place with any of the equipment, causing partial or total evacuation of mining personnel two-thirds of the time.
- Approximately 85% of reported fires were first detected by mining personnel who saw smoke, smelled smoke, or saw the fire start.
- Water is still the most used fire suppression agent for fires beyond the incipient stage.
- Elapsed time between the onset of a fire and its detection is critical because fires tend to grow quickly in size and intensity.
- The ability of workers to effectively use fire suppression equipment is a critical component of preparedness, and a large part of worker capability is experience, motivation, and training.
- The percentage of miners who said that they had been caught off guard by the sight or smell of smoke in the last 6 months ranged from 18% to 68%, depending on the mine.
- The most commonly cited sources of smoke were belt rubbing and hot metal.
- Approximately 21% of the miners said that they had donned either a filter or a self-contained self-rescuer in an emergency.
- Approximately 70% of the interviewed miners had been involved in helping extinguish a mine fire (regardless of the size) during their mining career.
- About 8% of the miners felt that their current mine fire-fighting training was satisfactory.
- Across the seven mines, approximately 72% of these miners indicated a desire for hands-on training either in extinguishing a fire or at least in handling fire-fighting equipment.
- There were large levels of variability among the seven mine sites, as follows:
- Significantly greater percentages of miners had walked their escapeways at some operations than at others. The same holds true for those who had participated in fire drills.
- The percentage who had to evacuate a mine one or more times because of a fire ranged from 20% to 67%.
- The broad types of training offered to the work force also varied, with some mines relying heavily on discussions and lectures as the main vehicles for developing fire response skills.
- The percentage of miners who had hands-on training (practicing with fire-fighting equipment) ranged from 15% to 85%. Those who had lectures (being told what to do) ranged from 45% to 90%, and those who had discussions (talking about *it*) ranged from 45% to 80%.
- The percentage who felt that they had an acceptable level of fire-fighting skills ranged from 57% to 89%.
- The median frequency of reported smoke at two mines was at least once per week, whereas at another mine it was about once per year. However, all mines took the threat of fire seriously.

Facilities and programs for mine personnel to learn about the hazards of mine fires, evaluate modern fire detection and fire-fighting equipment and technologies, and observe the proper methods to combat mine fires are sparse. Recent mine fire application seminars and briefings sponsored by MSHA at its National Mine Health and Safety Academy in Beckley, WV, the West Virginia University Mining Extension Service [Moser 1993], and NIOSH at Lake Lynn Laboratory [Mattes et al. 1983] are positive steps. Increasing the mining industry's awareness of the dangers of underground mine fires could reduce the risk of a major fire and improve the current state of fire preparedness.

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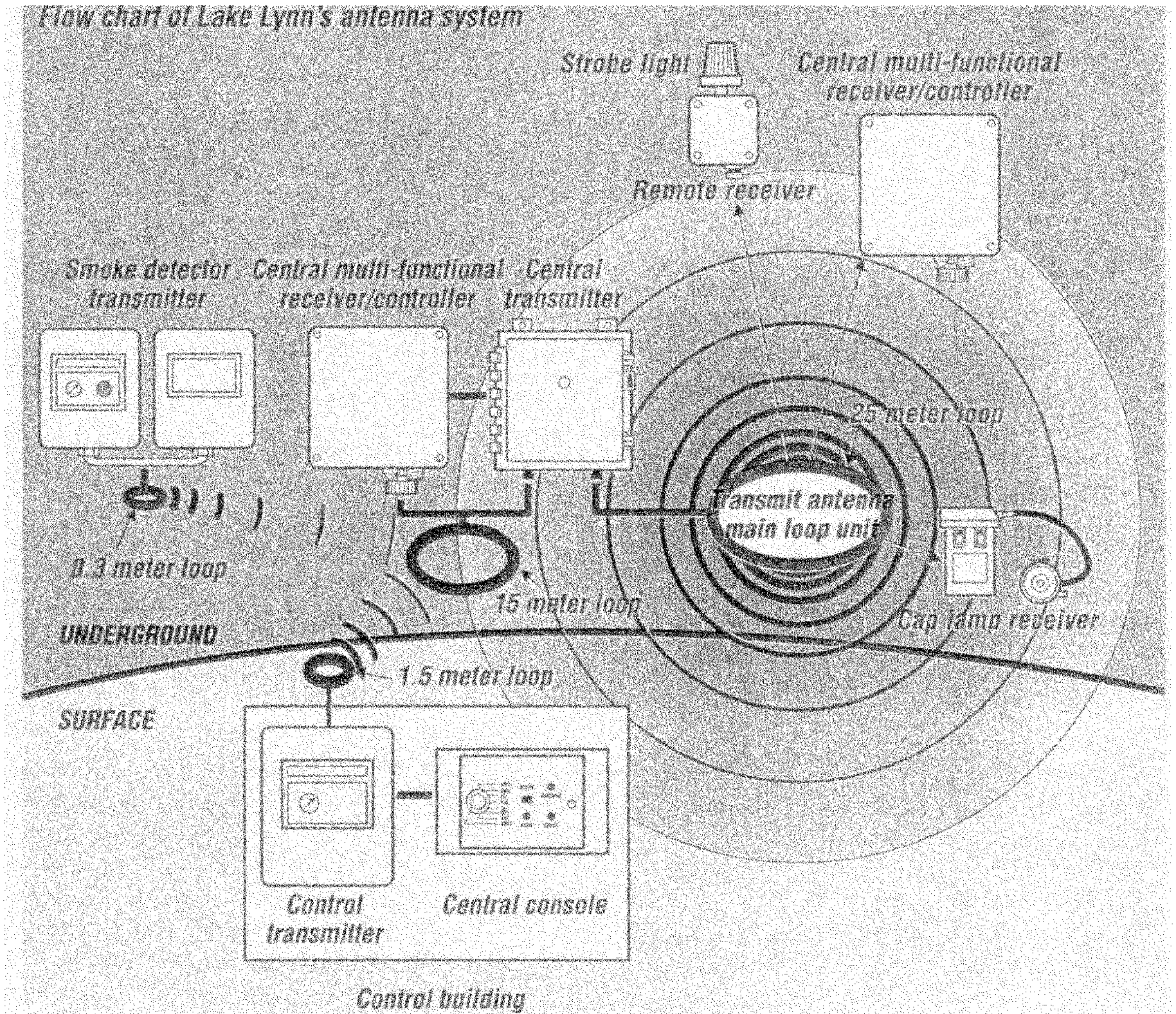

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