Development of a Mine Rescue Support Vehicle

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The underground mining industry and its partners work tirelessly to improve mine safety and to develop controls that address the dangers inherent to working in the dynamic underground environment. Nevertheless, the potential for hazards exists every day for mine workers, and should accidents occur and impair the miner's ability to self-escape, specially trained mine rescue teams and support personnel respond to these events. These responders often place themselves at a high level of risk and are required to perform intense manual labor in extremely difficult and unpredictable conditions.

The highest priority of the mine rescue team is determining the location of trapped or injured miners and their subsequent rescue. Team members often must hand-carry injured miners as well as the supplies needed to accomplish the rescue, while also wearing heavy, protective self-contained breathing apparatus to guard against a potentially toxic atmosphere. Additionally, post-event mine floors often contain debris from rock falls and rib outbursts, the roof and rib support may be damaged from fire, flooding, or an explosion, and entries may be completely blocked. The presence of haze or smoke can reduce visibility to near zero, and power may need to be removed from the mine post-event, which disrupts mine ventilation and allows water levels to rise and accumulate until pumping systems are restored.

With these specialized needs of mine rescue teams responding to an emergency in mind, the National Institute for Occupational Safety and Health (NIOSH) contracted with ROHMAC, which manufactures mine-duty utility equipment and attachments, including equipment that can be operated via remote control, under extreme conditions, and in confined spaces. As a result of this contract, along with participation and substantial input from the mining industry and mine rescue community, a prototype mine rescue support vehicle (Figure 1) was successfully developed and tested in rigorous conditions to simulate the mining environment. ROHMAC is currently in the process of making further improvements to the prototype and will be applying for Mine Safety and Health Administration (MSHA) approval for permissible use. This article details the development of the prototype and describes the additional capabilities that are being integrated into the mine rescue support vehicle.

Figure 1—Prototype mine rescue support vehicle developed under a NIOSH contract.

Vehicle Features

Importantly, the key design features for the support vehicle grew out of focused and repeated discussions with mining company safety representatives, mine rescue team members, and MSHA mine emergency operations personnel. The common needs expressed by these groups were that the vehicle should be mine-worthy (built to operate reliably in the rugged post-event environment), remotely controlled (to allow machine operators to remain a safe distance from the machine), compact in size (able to navigate the tight spaces of a mine), and able to carry and operate a variety of tools and implements that might be required post-event.

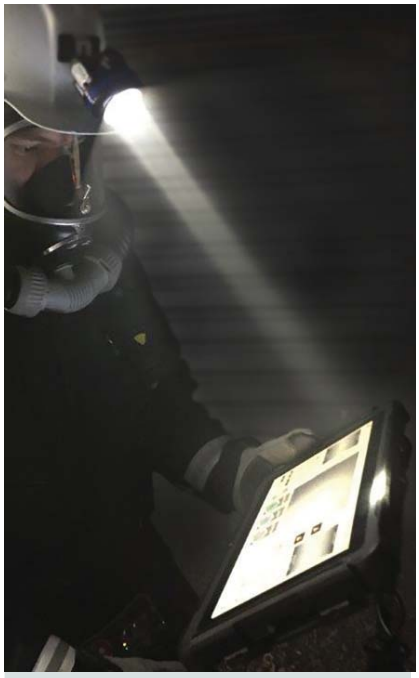

Figure 2—Operator using tablet machine control to test support vehicle prototype.

Functionally, the machine needed to also have the ability to move debris and haul supplies to increase safety and lessen the manual burden of mine rescue team members. These features would also improve the speed and efficiency of the rescue response efforts. Representatives also requested that the machine include modern video and communications equipment such as a tablet (Figure 2) to provide forward exploration capabilities and record the mine environment. Finally, the machine also needed to have the capability to tow a trailer that could serve as a means to move supplies, store accessories, and carry a stretcher to transport injured miners.

Prototype Testing

Once the prototype vehicle was developed through several iterations and design revisions, demonstrations and tests were conducted at several locations, including the Pittsburgh Mining Research Division in Bruceton, PA, the National Mine Health and Safety Academy near Beckley, WV, the West Virginia University (WVU) Academy for Mine Training and Energy Technologies (Doll's Run) near Morgantown, WV, and at an underground coal mine in the Illinois basin as part of a mine rescue training exercise.

The most extensive exercise took place at the WVU Doll's Run location (Figure 3), where representatives from the mine rescue community operated the machine under apparatus in a simulated mine environment. Theatrical smoke was introduced into the mine entries to determine the operator's ability to manage the machine controls in a low-visibility environment. Two demonstration tests were conducted in the simulated smoke environment — first with the operator using the radio remote control transmitter and secondly using the tablet machine control. After the simulated smoke testing, the smoke was evacuated from the mine and the trailer was connected to the rescue machine to test system maneuverability in the mine. The machine and trailer were able to successfully negotiate turns in this 16-ft-wide by 7-ft-high multiple entry configuration. Upon completion of the trailer towing demonstration (Figure 4), the machine was operated outside the mine and successfully moved and maneuvered through a debris pile created by mine rescue personnel.

Figure 4—Prototype machine towing trailer into simulated mine entry.

Demonstration and testing sessions were successful, with many mine rescue representatives expressing optimism that the prototype machine could significantly improve the mine rescue and recovery process. Mine rescuers offered positive feedback and requested minor changes to the machine to improve design and incorporate additional features that would enhance the machine's utility.

Figure 3—Testing of support vehicle at WVU Doll's Run Academy.

Prototype Machine and Trailer Design

The prototype machine design was based upon the ROHMAC MICROTRAXX product line of compact remote-control track loaders used in underground mines and confined spaces. The machine is track-driven, enabling it to traverse difficult terrain, has a tool carrier that allows for multiple attachments, and is sized to fit on a standard mine elevator (sometimes the only way to access the mine) as requested by mine rescuers. The power source (a three-cylinder diesel, naturally aspirated engine) is one of the most compact diesel engines approved by MSHA for use in underground mines. It was modified to meet permissible approval requirements, including surface and exhaust gas temperature controls. The machine employs water-jacketed components from the exhaust manifold to the point where the exhaust gases are cooled. Once cooled, the exhaust gases are discharged to the rear of the machine and mixed with airflow from the engine cooling fan for dilution. Compressed air was chosen to power the air-driven starter motor, and to operate the engine safety shutdown circuit. Air is commonly used for these systems on permissible diesel mining equipment. However, due to concerns relating to operation in poor atmospheric conditions, an on-board air compressor was not included on this machine. Instead, the air tank can be recharged by portable tanks,

cylinders, or compressed air lines when the on-board supply becomes depleted.

The engine control panel contains all necessary gauges, override, and stop switches as well as an emergency intake shutdown actuator and a manual fire suppression actuator. The portable fuel tank holds six gallons and operates the rescue support vehicle for four hours. When mine rescuers need to refuel the machine, these fuel tanks can be changed out using dry quick connect fittings, making it possible for a rescue team exiting their shift to take the fuel tank out to be refilled, and for the incoming team to bring a full tank in for use during their shift. The diesel engine drives a variable displacement hydraulic pump that powers the machine functions. Hydraulic valves control the right and left track motors forward, reverse, and high/low speed functions, the bucket lift and tilt up and down, and the grapple open and close functions. A hydraulic power takeoff (PTO) is also available to power a winch, drill, saw, or a variety of needed hydraulic tool implements.

When the operator is in visual range (i.e., has line-of sight), the machine can be operated by radio remote control, which uses joysticks and switches to command the machine functions. For extended ranges, the operator can control the machine by way of a remote tablet interface, which includes machine function control and video. The machine is equipped with LED lighting and four video cameras to document conditions as it moves throughout the mine. The video cameras are housed in a dual enclosure which includes an emitter used to permit video visibility in low-light conditions.

Based on input from mine rescue teams, the trailer design includes these features:

- A deck height of 22 inches so that fiber optic cable reels for the mine rescue communications system can be carried and kept within the desired height envelope of the trailer.
- An arm for unspooling the fiber optic cable.
- Tire balls in the trailer tires to prevent flats.
- Removable sideboards that convert the trailer to a flatbed, with the sideboards also functioning as stretchers.
- A tailgate designed to be laid down, extending the deck length to eight feet.
- Hydraulic lines from the front to the rear of the trailer so that PTO accessories can be operated without disconnecting the trailer.
- An aluminum body to keep the weight down, but with a load capacity of 1,000 pounds.

Machine Status

Based on the above final specifications and extensive industry feedback and requests, the mine rescue support vehicle is currently being modified by ROHMAC and will include the following upgrades:

- Due to concerns raised about the limited on-board air supply and restart ability, a hydraulic start and safety control circuit will replace the air systems, thus allowing the hydraulic pump to recharge the system on-board.
- Changes to the exhaust treatment system are underway to improve operating efficiency, enhance gradability, and extend operating times before required service.
- Components are being relocated to save space and improve serviceability.
- Technology is being added to transmit video data from the machine in a format that can be sent to a command center.

ROHMAC is currently working through the application process for MSHA-permissible approval of the machine. With the machine having been designed and built to meet the requirements of other permissible machinery used in underground coal mines, NIOSH anticipates that the vehicle will be available for use in the future.

Disclaimer

The findings and conclusions in this paper are those of the authors and do not necessarily represent the official position of the National Institute for Occupational Safety and Health, Centers for Disease Control and Prevention. Mention of any company or product does not constitute endorsement by NIOSH.

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