White Paper

Self-Rescue Equipment and Skill Development for Mine Escape

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Abstract

The underground environment is a challenge for all kinds of equipment, and especially for workers who earn their living removing materials from below the earth's surface. Equipment must be designed to perform reliably as needed, and withstand the daily rigors of underground mining. This is particularly important for self-rescue equipment used by miners in emergency situations to facilitate their escape. Self-rescue devices that supply oxygen have been installed by mines around the world for escape operations, but they need to be upgraded from time to time, and miners must receive training in their proper usage. This white paper explains how they work, some of the latest technology, and proper training procedures.

A Brief History

Driven by the needs of the coal mining industry, Self Contained Self Rescuers (SCSRs) have been installed in all operating underground coalmines in the United States. After 2006, the "Miner Act" ensured that a substantial number of SCSRs were placed in mines and readily accessible by the miners. These devices are carried by each miner to his daily task, and more are stored in strategic locations to facilitate escape actions. The cached SCSRs allow miners to replace an expended SCSR with an unused device as needed along escape routes.

Mine escape in the event of an explosion or fire is a fundamental part of miners' survival training, and the primary action they are expected to take. Besides the danger of being trapped, miners must avoid breathing in contaminated air, which requires protection from such an atmosphere. SCSR units are designed to provide 60 minutes of protection under specific breathing demands. The SCSR caches provide additional
units, the specific number depending on the distance miners must travel in their egress from a hazardous area.

**Basics of SCSR Operation**

SCSRs are portable devices that provide breathable air. Generally, these devices include a mouthpiece and nose-clip that isolates the human respiratory tract from a contaminated atmosphere. This type of design eliminates the issues involved with an individually fitted facepiece, which usually requires the wearer to be clean-shaven to get a good facial seal.

There are two types of SCSRs, which can characterized by the methodology used to supply breathable air. Oxygen can either be supplied from a cylinder or can be produced in a chemical reaction chamber (cartridge) that is part of the SCSR.

**KO₂ Oxygen-Generating SCSR.** In this type of device oxygen (O₂) is generated in a cartridge by a chemical reaction between potassium dioxide (KO₂) and the water vapor and carbon dioxide (CO₂) in exhaled air. Alternating between inhalation and exhalation, breath flows from a breathing bag through the KO₂ cartridge, and then to a heat exchanger and back again. The water vapor and CO₂ are absorbed in the KO₂ cartridge to release its chemically bound oxygen. Thus, KO₂ is both an O₂ source and a CO₂ absorber. A valve controls the air volume in the breathing bag.

**Bottled Oxygen Source.** Instead of generating O₂, the SCSR can supply it from a compressed oxygen cylinder. In this type of SCSR oxygen is supplied from the cylinder to the breathing circuit through a lung demand valve (LDV) and breathing bag. Oxygen from the breathing bag is inhaled through the inhalation tube and mouthpiece. Breath is exhaled through the mouthpiece into a CO₂ scrubber (canister). Exhaled air passes through the mouthpiece into the canister where some of the CO₂ is removed in a reaction with lithium hydroxide (LiOH). Then the scrubbed breath enters the breathing bag and is mixed with oxygen from the oxygen cylinder via the LDV.
Both methodologies and the resulting SCSR designs have advantages and disadvantages. Both types are approved and in use throughout the mining industry.

**SCSR Design and Evaluation**

The critical characteristics of an SCSR fall into three major categories: durability, comfort and performance. These characteristics affect the ability of a miner to safely escape from an atmosphere that is Immediately Dangerous to Life and Health (IDLH).

In the evaluation of different SCSR designs, the primary focus should be an assessment of characteristics that affect "life support" in IDLH atmospheres. This was most certainly the focus in Draeger’s latest SCSR design, the Oxy K Plus S. This is a KO₂ oxygen-generating type of SCSR. It addresses not only the ability to quickly put the unit on, but includes other features that provide superior performance under actual life-threatening conditions when stress and anxiety are high. In addition, materials and construction details are designed to withstand the challenging environment of underground mining, where the unit is exposed to dirt, sudden and hard impact, and exposure to the elements. It's this combination of characteristics that make the Oxy K Plus S the ideal SCSR for sustaining life and facilitating mine escape in an emergency.

Durability. There are several areas of SCSR design that influence durability. For example, the Oxy K Plus S incorporates a tough protective case that is separate from the KO₂ cartridge. The use of composite materials increases case strength and reduces the transfer of impact shock to internal components. By providing superior impact resistance and component protection, this design assures the availability of life-saving oxygen even after years of wear and tear on the job.
Figure 1. Draeger Oxy K Plus S protective case.

Comfort. Two of the major design priorities for actual SCSR use are making sure a miner can wear the SCSR comfortably, and it does not impede escape. When using the OXY K Plus S a major comfort feature is the inhalation breathing temperature, which is very close to a normal body temperature. This is accomplished through efficient KO$_2$ cartridge design, and overall diffusion of heat through the oral heat exchanger. These features ensure a breathing air temperature that is kept in a comfortable range (96-98°F) for the wearer. Extensive testing of an OXY K Plus S with a simulator and human subjects has proven that the breathing temperature and breath resistance are well within the comfort zone during 3 mph walkout procedures. Moreover, average breathing pressures and temperatures are consistent across different OXY K Plus S units, reflecting superior design, production processes, and quality control.

Performance. The main reason for using an SCSR is for escape from IDLH atmospheres that will have a negative impact on a miner's respiratory system and survival. The primary method of eliminating these influences is by providing breathable O$_2$ to support bodily functions while avoiding the inhalation of contaminants that will adversely affect them.
In OXY K Plus S units the average generation of O₂ is greater than 70% by volume, as proven by numerous test sources. This oxygen volume is well above the minimum required to meet miners’ metabolic needs during mine escape procedures. At the same time, CO₂ contaminant in exhaled breath is reduced to nearly zero percent, which is ideal for human metabolic functions.

Of course, the ability to rapidly don an SCSR device provides the miner with a few moments of precious time in a life-saving escape scenario. While protecting the SCSR from damage, the protective case of the Oxy K Plus S has a “Flip” mechanism (Figure 2) designed to not only unseal the device, but also to separate both halves of the housing. This helps the user access the critical internal components rapidly and to don the SCSR with minimum effort.

![Figure 2. Flip mechanism of the OXY K Plus S rapidly opens and separates the two halves of its protective case.](image)

**SCSR Skills Training**

History has shown that properly trained personnel will be more capable of utilizing life support equipment effectively, which greatly increase their chance of surviving and escaping from a hazardous atmosphere. In the case of SCSRs, which are single use
devices, a fundamental training requirement is a simulator that realistically duplicates actual use conditions. This is very beneficial when it comes time to employ an SCSR in an emergency, as it makes the user aware of how an actual unit performs.

All SCSR escape devices have common operational characteristics. In addition to supplying safe breathing oxygen, SCSR processes include the creation of heat and breath resistance. Draeger has addressed these issues in its Oxy K Plus S training simulator (Figure 3), which is designed to provide the trainee with a realistic usage experience. Among other things, that means realistic simulation of breathing temperature and breath resistance, so a miner knows what to expect.

As in an actual unit, the Draeger simulator consists of a mouthpiece and nose clip. The mouthpiece replicates the one found on an OXY K Plus S, providing consistency between an actual unit and the simulator. The simulator mouthpiece has been constructed to provide usage characteristics of an actual SCSR – breath temperature and resistance. This is accomplished with a mouthpiece design that incorporates a nonhazardous heat generating material.

The simulator’s nontoxic heat generating material is activated and maintained by the moisture in exhaled breath, and will last for approximately 15 minutes. The inhaled temperature will range from 115°F (45°C) within 2 minutes to 102°F (39°C)
after 15 minutes. This temperature range is higher than the actual unit in order to demonstrate to the trainee the potential for warmer breathing air, which can occur when the user is under duress and has a higher than normal breathing rate. The design on the mouthpiece is such that breathing resistance is provided in the range of 5–6 mbar. These features have been designed with the actual OXY K Plus S characteristics in mind.

The Draeger simulator is a one-time use device; it is not designed for multiple usages or users. While it can used as a standalone device to accurately simulate breathing temperature and resistance, it can also be attached to an OXY K Plus S training unit. This provides the trainee with a complete experience in the operation of an actual unit. This full training operation includes opening the protective case, donning the SCSR, and breathing simulation. Combined, all three areas provide the trainee with the actual experience of wearing the SCSR. Other than the breathing simulator, the training unit is reusable.

Figure 4. OXY K Plus S simulator attached to a reusable SCSR training unit.
Conclusion

Good design of life-saving equipment, combined with realistic usage training, is the key to enhanced survival in the event of a mine emergency. These benefits are provided with Draeger's OXY K Plus S oxygen-generating SCSR and training simulator. With proper training a miner can quickly don the OXY K Plus S and escape an IDLH atmosphere, which is the primary purpose of any SCSR. However, the Draeger system goes a step further by designing the unit with superior protection and durability to withstand daily wear and tear in an underground mine.