Fresh air for breathing – equipment for air supply on earth-moving machinery during rehabilitation work on contaminated sites

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Abstract

During rehabilitation work carried out on contaminated sites hazardous substances or harmful microorganisms are emitted from the polluted base surface, masonry or groundwater. This frequently leads to fumes developing in the operator’s cabs of the earth-moving machinery, causing a corresponding health hazard for the driver. In order to minimize this risk, earth-moving machinery and vehicles used on polluted sites must be equipped with “equipment for air supply”. The equipment for supplying fresh air for breathing basically comprises of a specially sealed operator’s cab (for maintaining slight gauge pressure in the cab), an air supply unit which uses a filter system (activated carbon filter and/or particle filter) or compressed air system. Requirements put on the design, arrangements for the operation of such equipment (e.g. air volume/h, gauge pressure and monitoring measurements, where to place the equipment on the earth-moving machinery etc.) are, in Europe, at present only to be found in German health and safety regulations. There are, however, plans to take up such requirements in an annex to the European Standard EN 474-1 “Earth-moving machinery – General safety requirements”.

This paper presents the basic requirements put on the different types of equipment for air supply on earth-moving machinery and vehicles.

Keywords: occupational safety and health protection, work on contaminated sites, equipment for air supply, earth moving machinery, vehicles.

1 Introduction

During rehabilitation work on contaminated sites, e.g. the excavation of contaminated soils, the demolition of industrial sites, the sanitation of collapsed
drainage pipes, sometimes 30 m deep inside a household or industrial waste deposit, the workers are exposed to the hazardous substances out of the soil, masonry, pipes, tanks, barrels, waste and so on.

The results of a research programme to quantify the exposure to aromates within the rehabilitation of gas stations (fig. 1) demonstrated, that, in comparison to the other jobs on this site, in the most cases operators of excavators and loaders have to suffer the highest exposure to the hazardous substances. According to an 8-hours working day, they work the longest time and in the closest position to the source of emission, they open new surfaces, where hazardous substances can release as dump or dust. In other words: the operators of earth moving machinery are always at the focal point of the emission. So it is evident, that they need to be provided with clean air for breathing.

Figure 1: Benzene exposure and duration of exposure of machine operators, planners and workers within the remediation of gas stations.

This requirement could be easily complied with using personal air supply devices. The operator’s field of vision is already impaired by the cabin and the working equipment of the machinery. Wearing filter masks or other personal air supply devices will cause an additional decrease of the field of vision. Therefore, the use of personal air supply devices by earth-moving machinery operators is not adequate to the requirements of a safe construction site. These arguments and 2 fatal accidents, where workers had been run over by excavators, whose operators had been wearing filter masks, led to the development of equipments for supply of air on earth-moving machinery.
There are 2 different types of such equipments: filter equipments and compressed-air equipments.

The filter equipments are devices, where fresh air is cleaned from unhealthy material by the filter and supplied to the operator’s cab by a blower (fig. 2).

![Filtering equipment (Fa. SEKA)](image)

**Figure 2:** Filtering equipment (Fa. SEKA).

Compressed-air equipments are units, where clean compressed air is supplied to the operators cab by tubes and armatures either directly or by compressed-air-bottles (fig. 3).

![Compressed air equipment (Fa. Wölfle)](image)

**Figure 3:** Compressed air equipment (Fa. Wölfle).
To produce the clean air for breath, special compressors are necessary (fig. 4). The filling of the bottles on the machinery (fig. 5) takes about 20 minutes, and the volume of 3 or 4 bottles will give a supply of air for about 4 hours, depending on the maximum bottle pressure and the leakage of the cabin.

Figure 4: View into an “air station“: on the left side: compressor for breathable air.

Figure 5: Filling a compressed-air device on a loader (Fa.Wölfle).

2 Common requirements

The following description of the common requirements for the equipments for air supply on earth moving machinery and vehicles, used in Germany, is based on the German guidelines "BGI 583 – Anlagen zur Atemluftversorgung auf..."
Erdbaumaschinen und Spezialfahrzeugen des Tiefbaus" (BGI 581 - equipments for air supply on earth moving machinery and special vehicles used in underground engineering) [1].

Operator’s cabs and the supply of fresh air shall be designed that during machine operation the pressure inside the cab shall be 100 Pascal at minimum and shall not exceed 300 Pascal. A control unit indicating the pressurized air within the cab (fig. 6) shall be fitted within the operator’s direct view. The range shall be between 0 Pascal and 400 Pascal. The lowest and highest limits shall be clearly indicated and marked durable.

![Figure 6: The white box - control unit for cabin pressure and air volume or O₂ / CO₂ (Fa. SEKA).](image)

A warning light and an acoustical warning device (e.g. horn) shall be available in addition to the control device, which is warning the operator in case of pressure-loss below the lower limit respectively pressure increase above the upper limit. The warning device shall indicate its warning with a time delay less than 5 s.

A minimum of 12 m³ fresh air per person and hour shall be provided for a pressurised cab. The volume shall be measured by a measuring device with threshold-alarm-setting, which indicates a pressure-loss below the limit by an optical and audible warning signal. By maintaining the fresh air volume of 12 m³ per person and hour an alternative measuring device with threshold-alarm setting can be used, measuring the oxygen (O₂) or the carbon dioxide (CO₂) instead of volume measurement. The concentration shall be as follows:
- oxygen shall not be below 19 vol %
- carbon dioxide shall not exceed 0.5 vol %

The measuring device shall indicate if these limits are falling short or exceeded by an optical or audible warning signal. The measuring device shall self monitoring malfunction for the device, which shall be indicated by an alarm signal.
If the volume of fresh air supplied to the operator’s cab exceeds 20 m³ per person and hour the above mentioned measurement concerning O₂ or CO₂ can be omitted. The volume of supplied fresh air shall not exceed 120 m³/h. There shall be a uniform and smooth fresh air supply within the operator’s cab to avoid draught.

The fresh air supplied to the operator’s cab must be heated and the cab enclosure shall be air-conditioned by an adequate device. Circulated air within an air-conditioned cab shall be filtered by a mechanical (particle-) filter.

Within the operator’s field of vision a warning sign with the inscription

| Fresh air supply unit shall be in operation in case of a closed cab |

shall be fitted. A communication between the machine operator and accompanying personnel outside the machine has to be guaranteed.

A storage device for a compressed-air unit (to be used for self rescue) shall be fitted within the operator’s cab, easy accessible.

![Figure 7: Position of the compressed-air unit does not affect the field of vision essentially (Fa. Wölfle).](image)

Figure 7: Position of the compressed-air unit does not affect the field of vision essentially (Fa. Wölfle).

Cab doors, windows and openings, including their closing devices, shall be designed, that no hazard arises for the operator in case of opening under pressurized conditions (e.g. in case of sudden burst).

Filter-, compressed-air and air-conditioning-equipment shall be designed noise-protected, and placed so that the permissible sound pressure level (Lₚₐ) of 85 dB(A) at the operator’s ear is not exceeding during machine operation.

Filter-, compressed-air and air-conditioning-equipment shall be placed in a position, that the operator’s field of vision is not essentially restricted (fig. 7).
Aids shall be used to compensate restricted visibility (see EN 47.1-1, clause 3.7.1).

Filter-, compressed-air and air-conditioning-equipment shall be fitted vibration resistant and within an accelerative force of at least 3 g. Filter-, compressed-air and air-conditioning-equipment shall be fitted shock- and vibration proof by use of suitable mountings. Armatures which are fitted outside the cab, shall be secured against unauthorized usage and protected against mechanical damage.

The attachment of filter or compressed air units shall not obstruct access to other maintenance and service areas of earth-moving machinery or derivated machinery and affect the roll-over projection devices (ROPS, TOPS) and falling object projection devices (FOPS).

Steps and access systems to filter- or compressed-air-equipment and platforms for their assembly and maintenance shall comply with ISO 2867 "Earth-moving machinery: accesses systems".

Openings for assembly and maintenance of filter- or compressed-air-equipment shall comply with ISO 2860 "Earth-moving machinery - Minimum access dimensions".

For the maintenance of filter - or compressed-air-equipment safe platforms with a minimum surface of 500 x 400 mm shall be provided.

Filter- or compressed-air-equipment shall have facilities for a safe transport. At the outside of the operator’s cab a green light with at least 5 W shall be fitted, showing persons outside that the equipment for air supply is in operation and in safe function.

3 Special requirements for filter equipments

The filtering system (fig. 8) consists at least of

- a ventilator,
- a prefILTER of dust, mostly constructed as a cyclone filter,
- a particle filter against fine dusts (Classification “S” or HEPA “H 13”, according to Europe. Standard EN 1822),
- a gas filter (if protection against volatile substances is necessary).

The filters shall be arranged in the following order in relation to the flow direction: prefILTER → particle filter → gas filter

Filters shall be wear- and vibration-resistant (fig. 9). Filter systems shall be so designed and installed that

- a permanent sealing of the filter in the housing is guaranteed,
- exhaust emissions are not sucked or pressured into the operator’s cab.

A monitoring unit shall be in the operator’s direct view, which indicates that the particle filter or, if required, the gas filter is fitted. Important information, e.g. about the filter-operation and filter-assembly shall be indicated by a sign permanent affixed to the filter housing.
Figure 8: View into a filtering device: 2 particle filters; one for the contaminated “fresh air” and one for the circulated air within the air-conditioned cab- 1 gas filter (box, made of high-grade stainless steel and filled with activated carbon) on the left side.- prefilter (cyclone) is integrated, but cannot be seen in this picture. (Fa. SEKA).

Figure 9: Left: wear- and vibration resistant construction of gas filter-units; right: particle-filter for the contaminated "fresh" air and top of the cyclone-prefilter. (Fa. Hauser).
4 Special requirements for compressed-air equipments

A monitoring unit, indicating the pressure of the compressed-air-bottles, shall be in the operator’s direct view. The measuring device for the air pressure shall have a threshold-alarm-setting, which indicates a pressure-drop below 20 bar by an alarm signal.

Compressed-air equipment used for breath-supply from compressed-air bottles shall have information about the maximum permissible bottle pressure (fill pressure). A safety valve shall avoid an increase of fill pressure of more than 10%. The bracket shall be solid affixes to the main structure of the base machine.

5 Conclusions

Equipments for air supply on earth moving machinery increase the safety in a twofold manner:

1) The operator, who is supposed to have the highest exposure to the released hazardous substances and would therefore suffer the highest health risk, can be protected by technical equipment which causes no additional strain on his health like personal protection equipment.

2) The operator does not have to wear a mask, which produces a high risk to the other workers because of the enormous decrease of the field of vision.

The described systems are not cheap: about 20.000 Euro for a filtering device and about 40.000 Euro for a compressed air system, calculated for the installation only on one machine.

But, imagine the situation, that the operators are wrapped up in chemical protection suites and that they would have to wear filter masks or other personal air supply devices, while operating an excavator or a loader. This will cause a serious decrease not only of the safety, but also of the motivation of the operators, because it is not very comfortable, staying at least 8 hours a day in a „personal sauna“.

Because of this additional strain on the health of workers wearing protective suits and respiratory protective devices, there are associated regulations governing limits on wearing periods and work intervals. Regarding these circumstances, it is easy to realize, that performance will be seriously reduced, with the result, that the remediation project will cost more money, when the safety system does not fulfil an adequate standard. So it is evitable, that an investment in equipment for air supply on earth moving machinery will be profitable within a short period.

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