Title: MOBILE BREATHING-AIR COMPRESSOR UNIT WITH MEANS FOR KEEPING THE OPERATION TEMPERATURE BELOW A LIMIT VALUE

Abstract: There is described a mobile breathing-air compressor unit arranged for use in an explosive environment and including an air compression unit, an air inlet provided with a gas detector which is arranged to stop the air compression unit, means of keeping the operating temperature of the air compression unit below a limit value, a) by the air compression unit being provided with several compressors which are arranged to be subjected to a maximum load which lies considerably below the maximum capacity of the compressor, or b) by the air compression unit is provided with means arranged to carry an energy-carrying fluid across a heat-exchanging surface on each of the compressors, or c) by each of the compressors is provided with a temperature controller effecting operation at intervals of each of the compressors, or a combination thereof; and the breathing-air compressor unit being arranged in a transport container. There is also described a method of producing compressed breathing air by the use of a mobile breathing-air compressor unit.

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European (AT, BE, BG, CH, CY, CZ, DE, DK, EE, ES, FI, FR, GB, GR, HR, HU, IE, IS, IT, LT, LU, LV, MC, MK, MT, NL, NO, PL, PT, RO, SE, SI, SK, SM, with international search report (Art. 21(3))
Mobile breathing-air compressor unit with means for keeping the operation temperature below a limit value

The invention relates to a mobile breathing-air compressor unit including an air compression unit, an air inlet provided with a gas detector which is arranged to stop the air compression unit, means of keeping the operating temperature of the air compression unit below a limit value, a) by the air compression unit being provided with several compressors which are arranged to be subjected to a maximum load which lies considerably below the maximum capacity of the compressor, or b) the air compression unit is provided with means arranged to carry an energy-carrying fluid across a heat-exchanging surface on each of the compressors, or c) each of the compressors is provided with a temperature controller effecting operation at intervals of each of the compressors, or a combination thereof; and the breathing-air compressor unit being arranged in a transport container. There is also described a method of producing compressed breathing air by the use of a mobile breathing-air compressor unit.

In certain work situations it is necessary to supply a person with breathing air through a pressure air tube to a protective mask. This may be because the ambient air contains harmful substances in particulate or gaseous form, or the ambient air contains too little oxygen. Typical work situations in which this is the case are surface treatment, for example sand blasting and painting, and operations in closed spaces.
with remains of harmful substances or substances consuming oxygen, for example maintenance work in a chemical tank or oil tank. The requirements for the quality of breathing air are often contained in public standards, for example NS-EN 12021.

In such situations the need for a supply of breathing air is temporary and there will often be a need to arrange a mobile breathing-air compressor near the work site.

In explosive environments, for example on an installation for oil and gas exploration and/or production, there are strict requirements for technical equipment. There are, among other things, requirements for spark-free operation of electric equipment, and there are requirements for the surface temperature of surfaces which may be exposed to explosive substances. Such requirements are specified in accordance with, among other things, ATEX standard 94/9/EC, NS-EN 13463 and in regulation 543 "Equipment and safety system for use in an explosive area" by the Directorate of the Norwegian Labour Inspection Authority.

It is common knowledge that when air is being compressed, heat is generated. Additionally, frictional heat develops to a certain extent in a compressor. This may result in a compressor developing a relatively high surface temperature, and there is therefore a need to cool the compressor.

To reduce the development of frictional heat it is an advantage to use oil lubrication. Oil lubrication can also be used as a means to cool the air during the compression phase. For compressors which are to supply breathing air there is a requirement for the maximum values for the content of oil vapour in the output air, and this requirement results in oil-free compressors being preferred in the production of breath-
ing air, alternatively the air being passed through an oil filter.

A compressor makes much noise and the work environment requirements dictate careful suppression of noise in a compressor, for example to below 80 dB measured 1 metre from the sound source. This creates challenges regarding cooling of the compressor and associated equipment, among other things. For a compressor installed temporarily, air cooling will be the most obvious for the very fact that the access to other cooling means is much more complicated than the access to air.

Temporary installation of the breathing-air compressor means that the compressor is often moved. Thus, it is desirable that compressors of this kind are compact, in order thereby to reduce the transport volume to a minimum, and robust, in order thereby to stand moving under partially rough conditions, for example when being moved at sea when used on surface installations for subsea oil and gas fields.

The invention has for its object to remedy or reduce at least one of the drawbacks of the prior art.

The object is achieved through features which are specified in the description below and in the claims that follow.

A mobile breathing-air compressor unit is provided, comprising an air compression unit, a filter unit, an air accumulator and one or more breathing-air outlets, and arranged in a transport container. To meet relevant requirements for breathing-air quality there is arranged an air inlet with a gas detector for automatic warning and stopping of the breathing-air supply on detection of an undesired admixture of gas, for example gases containing hydrocarbon. Further measures to guarantee the air quality include filters, drying
devices, CO oxidation devices and oil collectors. To satisfy the requirements for operation in an explosive area, all the electric equipment is built for spark-free operation in accordance with the regulations in force. Beyond that, the breathing-air compressor unit is arranged for operation alternating between several air compression units, possibly for operation control to prevent a load exceeding 2/3 of the maximum load of the unit, in order thereby to provide a breathing-air compressor unit in which the surface temperature of any element which may get into contact with hydrocarbons does not exceed a set limit value. Temperature controllers are connected to a control unit.

In a first aspect, the invention relates more specifically to a mobile breathing-air compressor unit including an air compression unit, a filter unit, an air accumulator and one or more breathing-air outlets, characterized by the breathing-air compressor unit including:

- an air inlet which is provided with a gas detector which is arranged to stop the air compression unit;
- means of keeping the operating temperature of the air compression unit below a limit value
  a) by the air compression unit being arranged with several compressors which are arranged to adjust, by means of output control, the load on each of the compressors to a proportion of the maximum capacity of the compressor, or
  b) by the air compression unit being provided with means arranged to carry an energy-carrying fluid across a heat-exchanging surface on each of the compressors, or
  c) by each of the compressors being provided with a temperature controller which is arranged to operate each of the compressors alternately and at intervals, in order thereby to make the uninterrupted operating time of each of the compressors be restricted to not exceeding a limit value, or
d) a combination of two or more of the means a), b) and c'); and by
the breathing-air compressor unit being arranged in a transport container.

The energy-carrying fluid may be atmospheric air which is carried from a cooling-air inlet on each of the compressors and through a cooling-air duct to a common cooling-air outlet arranged remotely from the compressors. Alternatively, the energy-carrying fluid may be a cooling medium circulating through a heat exchanger.

The load on each of the compressors may be adjusted to a maximum of 2/3 of the maximum capacity of the compressor.

The transport container may be a standardized 6-foot container.

The breathing-air compressor unit may be provided with an energy supply unit arranged for multi-AC operation in the voltage range of 400-690 V with a frequency range of 50-60 Hz.

The breathing-air compressor unit may be provided with an air-drying unit and a CO oxidation unit.

The filter unit may be arranged to at least retain hydrocarbon-containing material which is supplied with the compressed breathing air.

In a second aspect, the invention relates more specifically to a method of producing compressed breathing air by the use of a breathing-air compressor unit in an explosive area, characterized by the method including the following steps:
- supplying air through an air inlet while detecting explosive gas mixed into the air supplied;
- compressing the air in one or more air compression
units, the operating temperature of each of the air compression units being kept below a limit value by

a) arranging several compressors in the air compression unit and loading, by means of output control, each of the compressors to a proportion of its maximum capacity, or

b) cooling each of the compressors by means of an energy-carrying fluid which is arranged for heat exchange with a heat-exchanging surface on each of the compressors, or

c) by means of at least one temperature controller on each of the compressors, driving each of the compressors alternately and at intervals, in order thereby to make the uninterrupted operating time of each of the compressors be limited, or

d) a combination of two or more of the steps a), b) and c).

The energy-carrying fluid may be atmospheric air which is carried from a cooling-air inlet on each of the compressors to a common cooling-air outlet arranged remotely from the compressors. Alternatively, the energy-carrying fluid may be a cooling medium circulating through a heat exchanger.

The load on each of the compressors may be adjusted to a maximum of 2/3 of the maximum capacity of the compressor.

The operating temperature limit value may be 200 °C measured on an external surface of the air compression unit.

In what follows is described an example of a preferred embodiment which is visualized in the accompanying drawings, in which:

Figures 1, 2 and 3 show perspective sketches of a device according to the invention seen at different angles, in which a surrounding transport container has been removed for reasons of exposition;
Figure 4 is a view corresponding to figure 1, but the transport container is shown with an open front; and Figure 5 shows, in the same manner, a view corresponding to figure 2.

In figures 4 and 5, the reference numeral 1 indicates a transport container provided with a frame 11, side walls 12, roof 16, floor 17 and doors 15. The transport container 1 forms a closed space when the doors 15 are closed and is arranged to be ventilated through several vents 18, 18', 18", 18". The transport container 1 is provided with hoisting attachments 13 and fork-lift channels 14 to be used when moving the transport container 1.

In the internal space of the transport container 1 is arranged an air compression unit 2 including four identical compressors 21, each connected to a driving motor 22. Each compressor 21 with its associated motor 22 is installed as a removable and vibration-suppressing unit in a rack 26.

Each of the driving motors 22 is connected to an air-inlet channel 233 connecting the cooling-fan casing, known per se, of the driving motors 22 to a first vent 18 for the supply of cooling air from the surroundings, indicated by the arrow 23a. The motor-cooling air 23a is carried from the driving motor 22 into the internal space of the transport container 1.

The compressors 21 are connected to said first vent 18 via a breathing-air inlet channel 27 for the supply of breathing air from the surroundings, indicated by the arrow 23b. The inlet channel 27 is provided with a gas detector 231 arranged near the first vent 18. The inlet channel 27 is also provided
with a filter of a kind known per se (not shown) to retain particles et cetera which may harm the compressors 21.

On each of the compressors 21 is arranged an inlet for cooling air, indicated by the arrow 24. The cooling air 24 is taken from the space formed by the transport container 1. The cooling air 24 is carried across surfaces arranged for heat exchange with portions of the compressor 21 which are, as experience has shown, heated under the production of compressed breathing air 93 internally in the compressor 21. Used cooling air 25 is carried through a common outlet channel 28 to an outlet at a second vent 18'.

At each of the compressors 21 is arranged a temperature controller 232 for monitoring the temperatures of the compressed breathing air 93 leaving the compressor 21 and of the outgoing used cooling air 25 in the immediate vicinity of the compressor.

The compressed breathing air 93 is carried through two identical combined filter and dehumidification units 4 for drying the breathing air and removing any content of hydrocarbons in gaseous or liquid form, then through a CO oxidation unit 5 for converting carbon monoxide (CO) into carbon dioxide (CO₂), further through a further filter unit 6 for removing CO₂, when the content exceeds a given limit value, and also extra filtering of hydrocarbons, and to a breathing-air accumulator 7 serving as a supply buffer.

A breathing-air cooler 3 is arranged with a heat exchanger 31 which is supplied with air 32 from the internal space of the transport container 1. Used air 33 is carried out of the transport container 1 through an outlet discharging at the second vent 18'. The cooled breathing air 93 is carried through a coalescer 34 before it is carried to the breathing-
Externally on the transport container 1 is arranged a user interface 9 including several air outlets 91 in the form of prior art tube connections known per se, each provided with a pressure relief valve 911 for relieving a connected tube (not shown) before it is disconnected, and a control panel 92 provided with operating condition indicators and operator controls.

A second temperature controller 71 is arranged on the breathing-air supply from the breathing-air cooler 3 to the breathing-air accumulator 7.

An energy supply unit 8a is connected to the energy-demanding units, such as the motors 22 and the breathing-air cooler 3. The energy supply unit 8a is arranged to be connected to AC sources of different working voltages and frequency ranges.

A control unit 8b is connected to the energy supply unit 8a, motors 22, gas detector 231, breathing-air cooler 3, temperature controllers 232, 35, external control panel 92 and also other units that require monitoring, output control signals or are to be controllable.

Further vents 18*, 18** are arranged in one of the doors 15 and also in one of the side walls 12 of the transport container 1 to provide satisfactory supply of cooling air to the air-consuming units 21, 3.

When the mobile breathing-air compressor unit according to the invention is to be used, it is put in a suitable place at the working area which is to be supplied with breathing air, connected to an accessible power supply and put into an operative state. By means of the control unit 8b the desired mode of operation is selected to provide a safe operating
state under the prevailing conditions, the compressors 21 of the air compression unit 2 being operated alternately and at intervals, possibly at a maximum load which lies below the maximum design load of the compressor 21, while the temperature condition is monitored by means of the corresponding temperature controller 232. By a temperature condition exceeding a predetermined limit value, for example 200 °C measured in the compressed breathing air 93 or 80 °C measured in the used cooling air 25 in the immediate vicinity of the compressor 21, the compressor 21 in question is stopped.

The gas detector 231 continuously monitors the inlet of breathing air 23b for content of hydrocarbons or other undesired gases. On detection of a predetermined limit value, all the air compression units 2 are stopped immediately.

The compressed breathing air 93 undergoes prescribed dehumidification, cleaning and cooling in the units 4, 5, 6, 3, 34 that follow, guaranteeing thereby that the breathing air 93 has a prescribed quality when it is delivered at the air outlets 91.

By providing for the temperature in the areas that the ambient air with a possible content of explosive substances, for example hydrocarbons, may get into contact with, to be kept below a prescribed limit value, the desired effect is achieved, namely that the mobile breathing-air compressor unit may be used in places which are under the strictest requirements for technical equipment with respect to explosion safety etc cetera, while the security of supply of breathing air is taken care of at the same time.
**Patent claims**

1. A mobile breathing-air compressor unit including an air compression unit (2), a filter unit (6), an air accumulator (7) and one or more breathing-air outlets (9), characterized in that the breathing-air compressor unit includes:
   - an air inlet (23b) which is provided with a gas detector (231) which is arranged to stop the air compression unit (2);
   - means of keeping the operating temperature of the air compression unit (2) below a limit value
     a) by the air compression unit (2) being arranged with several compressors (21) which are arranged to adjust, by means of output control, the load on each of the compressors (21) to a proportion of the maximum capacity of the compressor (21), or
     b) by the air compression unit (2) being provided with means arranged to carry an energy-carrying fluid (24) across a heat-exchanging surface on each of the compressors (21), or
     c) by each of the compressors (21) being provided with a temperature controller (232) which is arranged to generate signals to a control unit (8b) for operation at intervals of each of the compressors (21) in order thereby to make the uninterrupted operating time of each of the compressors (21) be limited, or
   - d) a combination of two or more of the means a), b) and c); and that the breathing-air compressor unit is arranged in a transport container (1).

2. The mobile breathing-air compressor unit in accordance with claim 1, characterized in that the
energy-carrying fluid is atmospheric air which is carried from a cooling-air inlet (24) on each of the compressors (21) and through a cooling-air channel (28) to a common cooling-air outlet (25) arranged remotely from the compressors (21).

3. The mobile breathing-air compressor unit in accordance with claim 1, characterized in that the energy-carrying fluid is a cooling medium circulating through a heat exchanger (31).

4. The mobile breathing-air compressor unit in accordance with claim 1, characterized in that the load on each of the compressors (21) is adjusted to a maximum of 2/3 of the maximum capacity of the compressor (21).

5. The mobile breathing-air compressor unit in accordance with claim 1, characterized in that the transport container (1) is a standardized 6-foot container.

6. The mobile breathing-air compressor unit in accordance with claim 1, characterized in that the breathing-air compressor unit is provided with an energy supply unit (8) arranged for multi-AC operation in the voltage range of 240-690 V with a frequency range of 50-60 Hz.

7. The mobile breathing-air compressor unit in accordance with any one of the preceding claims, characterized in that it is provided with an air-drying unit (4) and a CO oxidation unit (5).

8. The mobile breathing-air compressor unit in accordance with claim 1, characterized in that the
filter unit (6) is arranged at least to retain hydro-carbon-containing material which is supplied to the filter unit (6) together with the compressed breathing air (93).

9. A method of producing compressed breathing air (93) by the use of a breathing-air compressor unit in an explosive area, characterized in that the method comprises the following steps:
   - supplying air through an air inlet (23b) while detecting explosive gas mixed into the air supplied;
   - compressing the air in an air compression unit (2), the operating temperature of the air compression unit (2) being kept below a limit value by
     a) arranging several compressors (21) in the air compression unit (2) and loading, by means of output control, each of the compressors (21) to a maximum of 2/3 of its maximum capacity, or
     b) cooling each of the compressors (21) by means of an energy-carrying fluid (24) which is arranged for heat exchange with a heat-exchanging surface on each of the compressors (21), or
     c) by means of at least one temperature controller (232) on each of the compressors (21), providing a signal to a control unit (8b) in order thereby to generate operation at intervals of each of the compressors (21) in order thereby to make the uninterrupted operating time of each of the compressors (21) be limited, or
     d) a combination of two or more of the steps a), b) and c).

10. The method according to claim 8, characterized in that the energy-carrying fluid is atmos-
pheric air which is carried from a cooling-air inlet (24) on each of the compressors (21) to a common cooling-air outlet (25) arranged remotely from the compressors (21).

11. The method according to claim 8, characterized in that the energy-carrying fluid is a cooling medium circulating through a heat exchanger (31).

12. The method according to claim 8, characterized in that the load on each of the compressors (21) is adjusted to a maximum of 2/3 of the maximum capacity of the compressor (21).

13. The method according to claim 8, characterized in that the limit value of the operating temperature is 200 °C measured on an external surface of the air compression unit (2) or in the compressed breathing air (93).
**INTERNATIONAL SEARCH REPORT**

**INTERNATIONAL APPLICATION**

**Application No.**
PCT/NO2009/000272

**A. CLASSIFICATION OF SUBJECT MATTER**

IPC: see extra sheet
According to International Patent Classification (IPC) or to both national classification and IPC

**B. FIELDS SEARCHED**

Minimum documentation searched (classification system followed by classification symbols)

IPC: A62B, F04B, F04C

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

SE, DK, FI, NO classes as above

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

**C. DOCUMENTS CONSIDERED TO BE RELEVANT**

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<tr>
<th>Category*</th>
<th>Citation of document, with indication, where appropriate, of the relevant passages</th>
<th>Relevant to claim No.</th>
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<td>Y</td>
<td>US 4293281 A (LAMOREAUX), 6 October 1981 (06.10.1981), column 4, line 13 - line 17; column 5, line 1 - line 7, figures 1-4, abstract</td>
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<td>US 3646934 A (FOSTER), 7 March 1972 (07.03.1972), column 1, line 5 - line 10; column 2, line 8 - line 12; column 2, line 41 - line 58, figures 1-4, abstract</td>
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<td>Y</td>
<td>US 4080103 A (BIRD), 21 March 1978 (21.03.1978), column 1, line 31 - line 35; column 2, line 11 - line 19; column 2, line 37 - line 39, column 4, lines 8-16; figures 1,3</td>
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Further documents are listed in the continuation of Box C. See patent family annex.

* Special categories of cited documents:
  "A" document defining the general state of the art which is not considered to be of particular relevance
  "E" earlier application or patent but published on or after the international filing date
  "L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)
  "O" document referring to an oral disclosure, use, exhibition or other means
  "P" document published prior to the international filing date but later than the priority date claimed

**Date of the actual completion of the international search**

6 November 2009

**Date of mailing of the international search report**

09-11-2009

**Name and mailing address of the ISA/Swedish Patent Office**

Box 5055, S-102 42 STOCKHOLM
Facsimile No. +46 8 666 02 86

**Authorized officer**

Jenny Mardberg / JA A
Telephone No. +46 8 782 25 00

Form PCT/ISA/210 (second sheet) (July 2009)
INTERNATIONAL SEARCH REPORT

C (Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

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<td>Y</td>
<td>US 6099268 A (PRESSED, 8 August 2000 (08.08.2000), page 13, line 20 - line 25; page 26, line 7 - line 14, figures 1-5, abstract)</td>
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International patent classification (IPC)

A62B 7/02 (2006.01)
F04B 35/06 (2006.01)
F04C 23/00 (2006.01)

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Cited literature, if any, will be enclosed in paper form.
INTERNATIONAL SEARCH REPORT

Box No. II Observations where certain claims were found unsearchable (Continuation of item 2 of first sheet)

This international search report has not been established in respect of certain claims under Article 17(2)(a) for the following reasons:

1. ☐ Claims Nos.:
   because they relate to subject matter not required to be searched by this Authority, namely:

2. ☐ Claims Nos.:
   because they relate to parts of the international application that do not comply with the prescribed requirements to such an extent that no meaningful international search can be carried out, specifically:

3. ☐ Claims Nos.:
   because they are dependent claims and are not drafted in accordance with the second and third sentences of Rule 6.4(a).

Box No. III Observations where unity of invention is lacking (Continuation of item 3 of first sheet)

This International Searching Authority found multiple inventions in this international application, as follows:

The invention according to claim 1 comprises alternatives of one or more of a number of different special technical features.

The following separate inventions were identified in claim 1:

1. ☐ As all required additional search fees were timely paid by the applicant, this international search report covers all searchable claims.

2. ☒ As all searchable claims could be searched without effort justifying an additional fees, this Authority did not invite payment of any additional fees.

3. ☐ As only some of the required additional search fees were timely paid by the applicant, this international search report covers only those claims for which fees were paid, specifically claims Nos.:

4. ☐ No required additional search fees were timely paid by the applicant. Consequently, this international search report is restricted to the invention first mentioned in the claims; it is covered by claims Nos.:

Remark on Protest

☐ The additional search fees were accompanied by the applicant's protest and, where applicable, the payment of a protest fee.

☐ The additional search fees were accompanied by the applicant's protest but the applicable protest fee was not paid within the time limit specified in the invitation.

☐ No protest accompanied the payment of additional search fees.
1: Alternative A directed to means for keeping the operating temperature of an air compressor unit below a limit value by means of output control.

2: Alternative B directed to means for keeping the operating temperature of an air compressor unit below a limit value by heat-exchanging.

3: Alternative C directed to means for keeping the operating temperature of an air compressor unit below a limit value by interval drive.
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