March 2024

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7. (a) Describe TWO possible sources of contamination of compressed air used for breathing. (4)

(b) State THREE contaminants that may be found in compressed air, outlining the effect of the contaminant on the user when the compressed air is used for diving (SCUBA) purposes. (6)

Nov 2020

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Question 7. Many simply state the possible contaminants, the question asks for sources. Several concentrate on the effects of contaminants on the system rather than the user.

Compressed Breathing Air Contamination in SCUBA Diving

(a) Two Possible Sources of Contamination of Compressed Air Used for Breathing:

1. **Intake Air Contamination:**
   - The air used to fill the breathing cylinders comes from the surrounding environment. If the air intake is located in an area with high levels of pollutants like:
     - Carbon monoxide (CO) from vehicle exhaust fumes
     - Industrial emissions containing harmful chemicals
     - Dust or other particulates

These contaminants can enter the compressed air system and pose a health risk to divers.

2. **System Contamination:**
   - Contamination can also occur within the air compression and storage system itself. Sources include:
     - **Oil leaks:** From compressor lubricants entering the air stream.
     - **Rust or corrosion:** Degradation of system components releasing particles into the air.
     - **Improper maintenance:** Failure to properly clean and maintain filters and separators within the compressed air system.

(b) Three Contaminants and their Effects on SCUBA Divers:

1. **Carbon Monoxide (CO):**
   - **Effect:** CO binds to hemoglobin in the blood more readily than oxygen, reducing the blood's ability to carry oxygen to vital organs.

- **Symptoms:** Headache, dizziness, nausea, fatigue, confusion, and in severe cases, unconsciousness and death. Even low levels of CO can impair judgement and coordination, increasing the risk of diving accidents.

2. **Hydrocarbons (Oil Vapors):**
   - **Effect:** Oil vapors can irritate the respiratory system, causing coughing, wheezing, and shortness of breath. In severe cases, they can lead to fluid buildup in the lungs (pulmonary edema).
   - **Symptoms:** May not be immediately noticeable during the dive, but symptoms can develop after surfacing.
3. **Nitrogen Dioxide (NO2):**
   - **Effect:** NO2 irritates the respiratory tract, causing coughing, chest tightness, and shortness of breath. High exposure can lead to fluid buildup in the lungs (pulmonary edema).
   - **Symptoms:** Similar to hydrocarbon exposure, symptoms may develop after surfacing.

Additional Points:

- Regular testing of compressed breathing air is crucial to ensure it meets safety standards and is free from harmful contaminants.
- Divers should use reputable dive centers that maintain their equipment properly and use high-quality breathing air.

Remember, breathing contaminated air underwater can be life-threatening. Divers should be aware of the risks and take steps to minimize them.

Nov 2023

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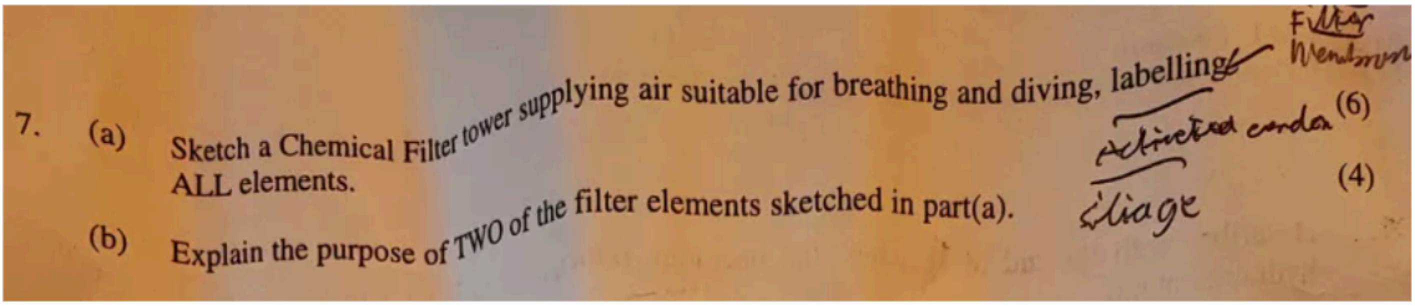

7. (a) Sketch a Chemical Filter tower supplying air suitable for breathing and diving, labelling ALL elements. (6)

(b) Explain the purpose of TWO of the filter elements sketched in part(a). (4)

(a) Chemical Filter Tower for Breathing Air: Elements Explained

A chemical filter tower used for purifying compressed air for breathing and diving applications typically consists of several key elements:

1. **Pre-filter:** This is the first stage and typically uses a high-efficiency particulate air (HEPA) filter. It removes dust, particles, and other airborne contaminants from the incoming air stream.
2. **Moisture Separator (Optional):** In some systems, a moisture separator may be included before the chemical filters. This separator removes excess moisture from the air, which can help prevent corrosion within the system and improve the effectiveness of the subsequent chemical filters.

3. **Carbon Monoxide (CO) Filter:** This filter media contains specialized materials that selectively adsorb carbon monoxide (CO) from the air stream. This is crucial as CO can be highly dangerous for divers, reducing the blood's ability to carry oxygen.
4. **Hydrocarbon (Oil Vapor) Remover:** This filter element utilizes media that absorbs or chemically reacts with hydrocarbon vapors, such as those from compressor oil. These vapors can irritate the respiratory system and pose health risks to divers.
5. **After-filter:** The final stage often includes another HEPA filter to capture any residual contaminants that may have passed through the previous stages.
6. **Pressure Regulator:** This valve regulates the compressed air pressure to a level suitable for breathing applications (typically around 3000 psi or 20.7 MPa).
7. **Pressure Gauge:** This gauge indicates the pressure of the compressed air leaving the filter tower, allowing divers to verify the air supply is within the safe operating range.

(b) Purpose of Two Filter Elements:

1. **Carbon Monoxide (CO) Filter:**
   - **Purpose:** This filter selectively removes carbon monoxide (CO) from the air stream. CO is a highly toxic gas that binds to hemoglobin in the blood more readily than oxygen. This reduces the blood's ability to carry oxygen to vital organs, leading to dizziness, confusion, unconsciousness, and even death in severe cases. Even low levels of CO exposure can impair a diver's judgment and coordination, increasing the risk of accidents. The CO filter media typically contains specialized materials like activated alumina or zeolites impregnated with specific chemicals that react with and trap CO molecules as the air passes through.
2. **Hydrocarbon (Oil Vapor) Remover:**
   - **Purpose:** This filter element removes harmful hydrocarbon vapors, primarily from compressor lubricants, that can contaminate the compressed air. These vapors can irritate the respiratory system, causing coughing, wheezing, and shortness of breath. In severe cases, they can lead to fluid buildup in the lungs (pulmonary edema). The specific media used in this filter may vary, but it often involves activated carbon or other adsorbent materials that trap the hydrocarbon molecules on their large surface area.

April 2021

April 2021

6. Explain the maintenance and inspection that should be carried out on SCUBA cylinders. (10)

March 2020

March 2020

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SCUBA cylinders require regular maintenance and inspection to ensure diver safety. Here's a breakdown of the key procedures:

Visual Inspection (Annual):

- **Frequency:** Performed annually by a qualified technician trained in cylinder inspection.

- **Process:** The technician will thoroughly inspect the cylinder's exterior for any signs of damage, including:
  - Dents, gouges, cracks, or bulges
  - Corrosion or pitting
  - Damage to threads or valve connection points
  - Fading or peeling of paint or markings (may indicate underlying corrosion)
- **Internal Inspection (Optional):** In some cases, an internal inspection using a borescope or other specialized tools may be recommended, especially for older cylinders or those with a history of heavy use.

Hydrostatic Testing (Every 5 Years):

- **Frequency:** Required every five years by most diving regulations.
- **Process:**
  - The cylinder is emptied of any remaining air.
  - It is filled with water to a pressure exceeding its normal working pressure (typically by a factor of 1.5).
  - The cylinder is carefully examined for any signs of permanent deformation or leaks during pressurization.
  - If the cylinder passes the test, it will be stamped with the new test date.

Valve Maintenance:

- **Frequency:** Regular maintenance is recommended, typically every year or two, by a qualified technician.
- **Process:** The technician will disassemble, clean, lubricate, and inspect the valve components for wear or damage. They will also ensure proper operation and replace any worn components if necessary.

Additional Maintenance Tips:

- **Record Keeping:** Maintain a logbook to record all inspections, maintenance procedures, and test results performed on the cylinder.
- **Proper Storage:** Store cylinders in a cool, dry, and well-ventilated area away from direct sunlight and excessive heat.
- **Handling:** Always handle cylinders with care to avoid any damage. Use proper lifting techniques and avoid dropping or dragging them.
- **Diver Responsibility:** Divers should visually inspect their cylinders before each dive for any obvious signs of damage.

Importance of Maintenance:

Regular maintenance and inspection of SCUBA cylinders are critical for diver safety. These procedures help identify any potential weaknesses or damage that could lead to a catastrophic failure during a dive. By following these guidelines and using reputable dive centers that maintain their equipment properly, divers can minimize risks and ensure a safe and enjoyable diving experience.

March 2021

6. Describe the effects of EACH of the following contaminants when found in air required for breathing and diving use:

(a) oil vapour; (4)

(b) water vapour; (4)

(c) overheated oil. (2)

Contaminant Effects in Breathing Air for Diving:

(a) Oil Vapour:

- **Effect:** Oil vapors from compressor lubricant can irritate the respiratory system, causing coughing, wheezing, and shortness of breath. In severe cases, they can lead to fluid buildup in the lungs (pulmonary edema).
- **Mechanism:** Oil molecules can coat the delicate lining of the lungs, hindering the normal exchange of oxygen and carbon dioxide. Additionally, some oil components can trigger an inflammatory response in the lungs, leading to fluid buildup and breathing difficulties.

(b) Water Vapour:

- **Effect:** At normal diving depths, moderate levels of water vapor in compressed air are not a significant health concern. However, excessive water vapor can:
  - **Reduce Oxygen Availability:** High humidity in the air reduces the partial pressure of oxygen, potentially leading to a lower oxygen concentration available for divers at depth. This can increase the risk of hypoxia (oxygen deficiency) and its associated symptoms like dizziness, confusion, and unconsciousness.
  - **Corrosion:** Excess moisture can contribute to corrosion within the diving equipment, including regulators and cylinder valves.
  - **Frost Formation:** At very cold water temperatures, high water vapor content in the breathing air can lead to frost formation within the regulator, potentially hindering airflow and compromising breathing performance.

(c) Overheated Oil:

- **Indirect Effect:** While overheated oil itself won't be present in the breathing air, it's an indicator of a potential problem with the compressor. Overheated oil can decompose and generate harmful byproducts like hydrocarbons and aldehydes. These contaminants can then enter the compressed air stream through leaks or inefficiencies in the filtration system, posing similar health risks as oil vapor exposure (irritation, inflammation, pulmonary edema).
- **Additional Concern:** Overheated oil may also reduce the effectiveness of the lubrication process, leading to increased wear and tear on the compressor components. This can increase the risk of component failure and potential leakage of oil or other contaminants into the air stream.

Key Takeaway:

Maintaining clean, dry, and contaminant-free breathing air is crucial for diver safety. Regular maintenance of the compressor system and proper filtration are essential to minimize the presence of harmful vapors and ensure divers have a safe and reliable air supply during their dives.

June 2021

June 2021

6. Describe, with the aid of a sketch, a three-stage air compressor system, suitable for compressed air diving equipment. (SCUBA). (10)

A three-stage air compressor system designed for SCUBA diving applications prioritizes safety, efficiency, and air purity. Here's a breakdown of its key components and functions:

1. Intake and Pre-filtration:

- **Function:** The system draws in ambient air through an intake filter. This filter removes dust, particles, and other airborne contaminants from the incoming air stream.

2. Compression Stages (Three Stages):

- **Function:** The core of the system involves three progressively smaller pistons or compression chambers that work sequentially to compress the air in stages.
    - **First Stage:** The air enters the largest piston chamber and undergoes initial compression. This stage typically uses a relatively cool-running oil-lubricated design.
    - **Second Stage:** The partially compressed air from the first stage is further compressed in the second stage. Interstage cooling (using an air-to-air or water-cooled heat exchanger) may be employed between the first and second stages to remove some heat generated during compression.
    - **Third Stage (High-Pressure Stage):** The air undergoes final compression in the smallest and most robust piston chamber. This stage reaches the highest pressure required for SCUBA diving applications (typically around 3000 psi or 20.7 MPa). High-grade oil-free lubricants or specialized piston ring designs are often used in this stage to minimize oil contamination in the compressed air.

3. Aftercooling and Moisture Separation:

- **Function:** After the final compression stage, the hot, high-pressure air is routed through an aftercooler. This heat exchanger significantly reduces the air temperature, which helps to condense and remove most of the water vapor present in the air.
- **Moisture Separator:** A separator vessel efficiently removes the condensed water from the compressed air stream. This is crucial because excess water vapor can be detrimental for several reasons (see previous answer on contaminant effects).

4. Filtration and Air Purification:

- **Function:** The compressed air then passes through a series of filters to remove any remaining contaminants, including:
    - **Oil Removal Filter:** This filter removes any residual oil vapors that may have escaped the compressor or originated from previous stages. Activated carbon or other specialized media may be used for this purpose.

- **Carbon Monoxide (CO) Filter:** This filter selectively removes carbon monoxide, a highly toxic gas that can be present in trace amounts in compressed air and pose a significant health risk to divers.
- **After-filter:** A final high-efficiency particulate air (HEPA) filter may be included to capture any remaining particles or contaminants.

5. Air Storage and Delivery:

- **Function:** The purified, compressed air is then stored in high-pressure SCUBA cylinders designed to safely contain the pressurized air.
- **Filling System:** A compressor filling station equipped with a pressure regulator and pressure gauge allows for safe and controlled filling of the SCUBA cylinders to the appropriate pressure for diving.

Additional Considerations:

- **Safety Features:** Three-stage compressor systems typically incorporate safety features like pressure relief valves, over-temperature shutdowns, and alarms to ensure safe operation.
- **System Monitoring:** Gauges and monitoring systems may be integrated to track air pressure, temperature, and other parameters throughout the compression process.
- **Maintenance:** Regular maintenance of the compressor system, including filter changes, oil changes (if applicable), and system inspections, is crucial to ensure optimal performance and air quality.

By utilizing a three-stage design with proper filtration and cooling, this type of air compressor system delivers the clean, high-pressure air required for safe and enjoyable SCUBA diving experiences.