file

Meeting Respiratory Air Standards Consistently and Economically

Where human health and safety are concerned, there is a need for equipment that can deliver respiratory air of a quality that meets or exceeds all applicable breathing air standards.

By **J. T. Vanchuk**, CRSP, Vice-President, Robbins Aviation, Inc., Vernon, CA.

PURIFICATION of compressed air must be accomplished economically even though excessive amounts of contaminants, such as oil vapor, organic vapor, acid gases, particulates, moisture, etc., may be present in the input air. When providing life support to people working in potentially hazardous environments, one cannot risk installing and operating a compressed air purification system without assurance the equipment selected will perform efficiently, safely, and economically—producing a product that consistently complies with accepted standards, practices, and regulations.

In general, those charged with the responsibility of providing pure compressed air for respiratory purposes have approached the problem with good intentions and a sincere desire to resolve the problem consistent with safety, economy, and efficiency based upon the information available to them at the time.

For varied reasons, unfortunately, not everyone has attained these objectives. Attempts to adapt existing compressed air systems used for non-respiratory air applications to fill the needs for breathing air have encountered impediments that preclude the production of pure breathing air on a sustained basis.

Usually, low pressure (100 to 150 psig or 340 to 510 kilopascals) plant air systems are used to power production or maintenance equipment, and, in some cases, a lubricant is added to the air stream. In most cases, the air stream contains a high quantity of moisture. Sometimes instrument air lines are tapped because it is recognized that this air must be relatively free of oil and moisture.

The usual approach to providing respirable air from a breathing equipment system is to tap off a line from the low-pressure distribution system of choice (100 to 150 psig or 340 to 510 kilopascals) and route the air through a series of filters and sorbents and class the effluent air as respiratory quality air.

Filters and sorbents on air streams of low pressure and high velocity soon become ineffective and if an air quality assurance program is followed it becomes quickly apparent that the spent sorbents and filters must be replaced on a basis of high frequency with the associated costs and expensive downtime.

A well-designed purification system must handle the maximum flow and pressure of the compressor consistent with providing adequate dwell-time of the air in the purification media to permit optimum removal of the entrained contaminants, including moisture.

Respiratory Air Standards

The respiratory air standards currently in effect were established by the Compressed Gas Association and have been adopted by OSHA, NIOSH, ANSI, and NFPA. A new *Purity of Compressed Air* standard recently developed by the Canadian Standards Association has been adopted in Canada. For detailed information, please refer to: Compressed Gas Association Pamphlet G-7 *Compressed Air for Human Respiration*[1]; Compressed Gas Association Pamphlet G-7.1 *Commodity Specification for Air*[2]; Canadian

AIR QUALITY

According to CFR 1910.134 (d) Compressed air, compressed oxygen, and liquid oxygen used for respiration shall be of high purity. Oxygen shall meet the requirements of the United States Pharmacopoeia for medical or breathing oxygen. Breathing air shall meet at least the requirements of the specification for Grade D breathing air as described in the Compressed Gas Association Specification G-7.1.[3]

EDITOR'S NOTE: Mr. Vanchuk was vice-president at Robbins Aviation at the time this material was prepared.

SAL 000057021

Standards Association Standard Z180.1 *Compressed Breathing Air.*[3]

The accepted breathing air quality standards are basic minimums and when contemplating the installation of an air purification system or package, consideration must be given to the removal of contaminants in addition to those spelled out in the applicable standard. For instance, should a plant require purified compressed air, yet the ambient air to be compressed contains contaminants, such as hydrogen sulfide, chlorine, vinyl chloride, acrylonitrile, etc., it is not sufficient to comply with the accepted breathing air standards; it is essential to assure oneself that contaminants not specified in the respiratory air standard be removed to a specified level, *e.g.*, non-detectable or to one-half the action level, throughout the service life of the purification media.

Moisture is a major contaminant that is sometimes ignored or treated lightly. Excessive water vapor in compressed respiratory air is as much a contaminant as is excessive oxygen, though for different reasons. Water vapor can condense due to low ambient temperatures and pressure drops caused by the expansion of the air. Condensed water may turn into ice and affect valve and regulator operation. It will also cause internal corrosion of purifier chambers, storage vessels, distribution pipeline systems—an undesirable result from any stand-point.

Damp, dark compressed air lines and storage vessels are ideal environments for growth of micro-organisms, so it is essential for the protection of the human respiratory system that compressed air be dried prior to storage and distribution.

The most efficient adsorbents used for removing oil vapors and noxious gases have a high affinity for water, hence, it is impossible to prevent sorption. Oil vapor and noxious gases cannot be removed without removing the water vapor as well. In addition, the elimination of carbon monoxide is usually accomplished by catalytic oxidation to carbon dioxide and a catalyst ordinarily used for this purpose requires the compressed air be exceedingly dry (a moisture content no greater than −50 F or −10 C dewpoint). Because of the foregoing reasons, we believe that the breathing air standards should be specific on the permissable moisture content (−65 F or −18.3 C dewpoint) and that contaminants other than those listed in the respiratory air standards shall not exceed the odor threshold or 1/10 the threshold limit value documented by the American Conference of Government Industrial Hygienists (ACGIH).

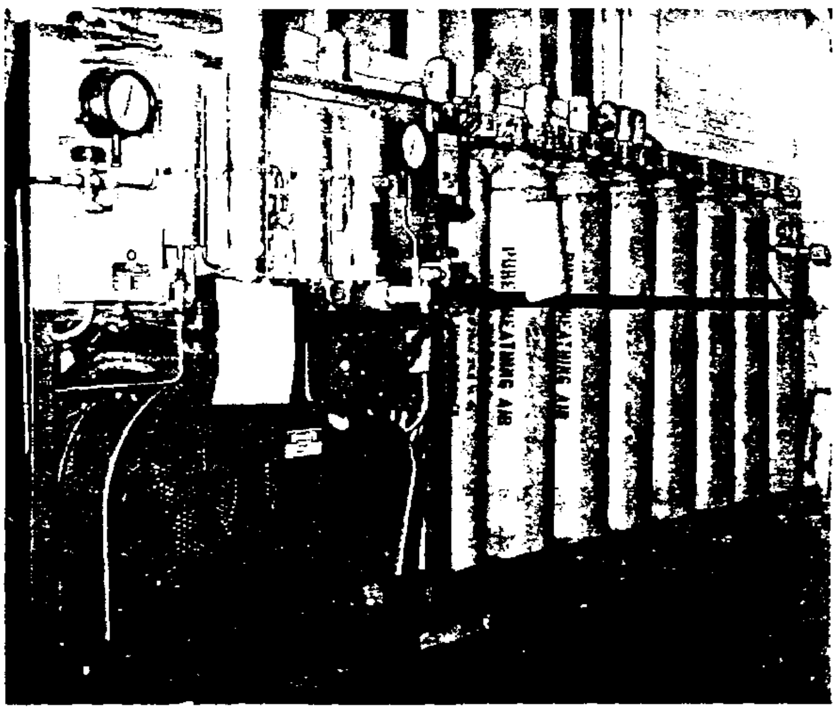
Purchases of compressed air purification equipment are often made on the basis of "low bid." This can prove disastrous and costly. Anyone who buys respiratory air purification equipment that is not properly engineered to remove contaminants consistently to the levels specified in the accepted standards and the purchaser's own specifications for air purity, is taking an unnecessary risk.

There is the impression that purification of compressed air can be accomplished simply by placing certain sorbents in pressure vessels and assembling them into a train downstream of the compressor. This is not true nor should it be acceptable to any prospective purchaser of an air purification system.

The purchaser should prepare and issue detailed purchasing specifications and should demand that the manufacturer of such a system have proven capability in this highly specialized field. Numerous cases are documented where people have been hurt or killed by contaminated compressed breathing air. This need not happen, but it does with an ever increasing frequency.

Solving the Problem

By compressing the air to the



The breathing air processing station at the New Orleans' Fire Department has an RAF compressor/purification unit plus downstream high pressure pure air storage tanks.

SAL 000057022

2,800-5,000 psig (9,520 to 17,000 kilopascals) range, processing it through a properly engineered purification system, and storing it in clean, high pressure storage vessels for subsequent use in self-contained breathing apparatus, or regulating the pressure so the air can be used with a clean low pressure distribution network, most of the problems we have discussed can be minimized or even eliminated depending upon the care the entire breathing system is given.

We recommend high pressure purification because research and more than 30 years experience have proven that the most efficient and economical way to purify compressed air consistently, is to squeeze the contaminants, including moisture, out of the air stream by using high pressure in the purification train.

Use of high pressure compressors will tend to force most of the moisture and condense some gases and vapors out of the air stream during the compression process. These condensates are then drained off from the compressor sumps and permit a relatively dry compressed air stream to be presented to the purification system, enabling the sorbents to operate at optimum efficiency in purifying the compressed air for human respiration.

When using this proposed high pressure purification package, distribution line pressure drops will not occur when the pressure in the high pressure storage vessels of appropriate volume is in the range of 2,800 to 5,000 psig (9,520 to 17,000 kilopascals). Located between the discharge side of the storage vessels and the distribution pipeline system is a pressure regulator of proper pressure rating and flow capacity. The stored high pressure air is regulated down to 80 to 100 psig (272 to 340 kilopascals) and flowed into the breathing air distribution network, maintaining an even flow and working pressure.

The automatic hi-lo pressure switch on the compressor is designed and installed to sense a pressure drop of 200 to 300 psig (680 to 1020 kilopascals) in the high pressure storage vessels, transmitting a signal to start the compressor to bring the storage vessel pressure back up to the designed working pressure and volume based upon the projected maximum breathing load.

Another point that the designer of a breathing air distribution system should consider is having sufficient compressed breathing air stored in a storage vessel to enable a crew of employees to operate in complete safety, assured that they have a reliable supply of safe, pure breathing air for at least a four-hour period. This is necessary in case the atmosphere is toxic and an orderly, properly sequenced process shutdown is required, or in the event the breathing air package is down for maintenance, or a power outage occurs shutting down the compressor. Work can continue to an orderly, safe conclusion, or the crew can escape to a fresh air base without panic or agitation knowing that they have an ample supply of pure breathing air.

The Compressor

There is no such thing as a "breathing air" compressor. A compressor by itself will not likely be able to compress breathing quality air.

Assuming an "ideal" compressor, one that will not, by virtue of its operating characteristics, add contaminants during compression—the air it delivers will be of no better quality than the air it takes in and compresses. However, all of the contaminants initially present in the ambient air are now present in the compressed air in concentrated form.

A filter in a compressor will only remove some particulates and suspended liquids. Filters will not remove oil vapors, organic vapors, acid gases, carbon monoxide, etc. Therefore, a compressor equipped with a filter (either intake or discharge), is not a "breathing air" compressor.

Sometimes it is assumed that water lubricated compressors are "breathing air" compressors because the air is being "washed" as it passes through. This "washing" process will only remove particulates in the one to two micron range and, in some cases, with an efficiency as low as 65 per cent.

If the seal water contacting the compressed air is not potable, then it is possible to add contamination to the compressed air. Potable water in an industrial complex is expensive and not always readily available to the site of the compressor.

It is not likely that any type of compressor using mechanical filtration or a water seal alone can produce compressed air to comply with the accepted breathing air standards.

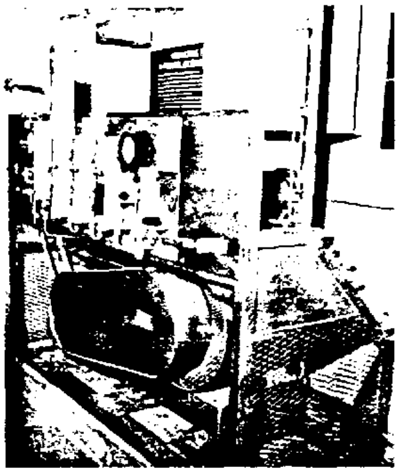
Compression, purification, and storage/distribution are separate steps of a process and one alone can not produce compressed air that is pure enough to intentionally put into people's lungs.

To produce compressed air, consistently and economically complying with the accepted breathing air standards, an air compressor must be used in conjunction with a properly engineered purification train and storage/distribution facility so that the owner may be assured of operating safely, efficiently, and realize a return on his investment.

Step One—Compression

Compression makes it possible to store air in a reduced space, but more importantly, it prepares the air for purification. This is accomplished in part by "squeezing out" the contaminants—as in wringing out a wet sponge. Our experience has shown that the most economical pressure for purifying compressed air to acceptable purity levels (or better) is in the range of 2,800 to 3,500 psig (9,520 to 11,900 kilopascals). For this reason, it is important that the compressor have a working pressure rating of no less than 3,000 psig (10,200 kilopascals).

The compressor should be equipped with an intake filter, automatic stop-start pressure switch.



Shown is one part of the breathing air processing station at the Los Angeles City Fire Department—the compressor/purification unit. The compressor prepares the air for purification the removal of *all* harmful matter.

high air temperature shutdown switch, low oil level or pressure shutdown switch, pressure gages, and an automatic drain system on the condensate traps. In keeping with good design, the compressor should be equipped with interstage and after-coolers along with pressure relief valves. In selecting the size and type of compressor that will be used with a breathing air system ask these basic questions:

- What is the application?
- How many standard cubic feet of air will be needed per shift, week, month or year?
- What is the real need?
- How much space is available to house the compressor?
- What is the cost per square foot of floor space allocated to the breathing air system?
- Should one central system be designed or should several smaller capacity compressors be installed at strategic locations throughout the plant or building?

Step Two—Purification

Purification is the removal of *all* harmful matter. What matter is classed as harmful depends upon the end use of the purified air. In the case of compressed air for human respiration, purification is an overall process, which consists of removing from the air stream particulates, mists, liquid contaminants (water and oil), organic vapors and gases, acid gases, hydrocarbons, carbon monoxide, other noxious materials and eliminating odors to recognized acceptable levels of breathing air purity. *Anything less is NOT purification.* While filtration is a vital phase of purification, filtration alone will *not* make compressed air safe for human respiration.

Correct location of the compressor contributes significantly to efficient operation of the entire air purification system. The compressor should be bolted to a flat, level surface in a covered area with ample space around it for good ventilation and general accessibility for ease of maintenance. The ambient temperature should be as cool as possible—though never below freezing. Equally important is the selection of a good environment for the compressor intake, which should be positioned so that the air drawn in is as clean as possible. This means that the intake must be above floor level—preferably eight feet (2.4 meters) or higher—and well removed from all possible sources of ambient contamination including contaminants from neighboring operations. The intake should be equipped with suitable filters for particulates and if located outdoors the inlet must be hooded to keep out windblown dirt, insects, birds, snow, and rain.

Purification systems for respiratory air must include all of the equipment necessary to achieve optimum purification of the compressed air so that it consistently meets the minimum accepted air quality standards. Primarily, the purification system must consist of a mechanical device to remove liquid water and oil, a filter for solid particles, a device for removal of water and oil vapors, noxious gases, including carbon monoxide, and odors. A dewpoint of at least −65 F or −121 C (atmospheric) or lower should be maintained consistently in order to permit the sorbents to function at optimum levels.

Excessive moisture encountered during the air purification process can cause some contaminants that have been adsorbed to be displaced and flow downstream. In addition, moisture in a purification system may cause corrosion, which is extremely harmful to the inside of air receivers, control valves, and regulators. To ensure safe, efficient performance, the purification system should also have inlet and outlet shutoff valves, a system bleed valve, a pressure gage, a relief valve, as well as a visual or audible method to indicate the need for renewal of the purification media. Highly desirable is an automatic drain system for waste liquids.

The need, or desirability, for all of this equipment might be questioned and it is a fallacy for anyone to maintain that the more accessories the better, or safer, the unit. Each item must make its own specific contribution to the overall operation. If it does not, then it should not be included. Conversely, it would not be prudent to attempt to operate without any item that does play a part in ensuring operating safety, efficiency or the quality of the effluent air.

As a matter of policy, we do not recommend truck mounting respiratory air purification equipment. Taking a mobile air purification package to a fire, or other emergency, is extremely hazardous because many toxic gases not readily identifiable are produced during combustion or mixing of chemicals and may severely tax the capability of the purification system especially if the sorbent life was near its end-point at the outset of the emergency. In addition, it is not good practice to permit a compressor to ingest high concentrations of corrosive or potentially flammable gases or vapors.

Sorbents for air-purification systems should exhibit the following properties:[3]

1) Activity or ability to sorb the contaminants at a high rate;

2) Capacity or ability to sorb appreciable quantities of the contaminant;

SAL 000057024

The fill station—for filling the portable cylinders with compressed and purified air for breathing—is part of the air processing equipment of the Los Angeles City Fire Department.

3) Retentivity or ability to retain the sorbate once it has been sorbed;

4) Hardness or ability of granules to retain their size and shape when subjected to crushing and abrasion;

5) Stability or ability to retain these properties under normal conditions of storage and use.

Subjecting purification media, vessels, and piping to the rigors of shock and vibration created by transporting a purification unit at highway speeds over rough terrain to the scene of an emergency does not constitute normal conditions of storage and use. The recommended practice is to install permanently, the air purification package and move air cylinders to the use-point to meet the demand for breathing air.

Storage—Distribution

Once compressed and purified, the air is generally stored in a large stationary receiver, or cascade system of sufficient capacity to satisfy the end use under normal and emergency operating conditions. For obvious reasons, receivers or cascade cylinders should be used for the storage of PURIFIED AIR ONLY and should never be filled directly from the compressor, by-passing the purification stage.

Storage and distribution systems for breathing air must be designed, sized, and installed with meticulous care ensuring that the hardware selected will not corrode internally or off-gas, thereby defeating the entire purification system. The new Canadian Standard Z180.1 includes a complete section describing the design, material selection and fabrication of storage and piping systems used for respirable air.

Good practice dictates that high standards of cleanliness must be observed throughout all phases of air purification. Leak checking should be a continuing practice and done with an inert leak detector. Soapsuds, for example, should *NEVER* be used.

Ambient air-borne contaminants can enter a pressurized system through loose connections or even through minute pinholes in vessels or tubing. Water vapor contamination of pressurized "dry" gas systems is a surprisingly common occurrence. Many people erroneously subscribe to the premise that "The pressure inside is greater than that on the outside, hence, nothing can get in"—a premise that is not always true. Diffusion of a gas molecule from a region of high concentration to a region of low concentration is an established fact and the phenomenon is described in Fick's Law.[5]

Breathing air distribution systems can become contaminated downstream of the primary purification system, and therefore good practice would indicate that a secondary purification tower be installed on long pipe runs or branch lines of a breathing air distribution network.

If there is any reason to suspect that any portion of the air purification network has become contaminated, that portion and everything downstream must be completely disassembled and thoroughly cleaned using the proper procedure.

Regulations and standards refer to testing or analyzing the breathing air to determine compliance with the applicable standard or regulation. These points should be kept in mind:

1) The analysis must cover the entire spectrum of allowable contaminants listed in the applicable standard or regulation.

2) The analysis must include the contaminant of special interest if it is not named in the applicable standard or regulation, *i.e.*, vinyl chloride, acrylonitrile, etc;

3) If the air analysis indicates failure in a single component, then the entire sample is considered as having failed and does not comply with the applicable standard;

4) For ease of interpretation, analysis reports must be in the language and form common to the field of respiratory protection and industrial hygiene.

Occupational safety and health regulations clearly indicate the minimum quality of compressed air for human respiration acceptable to a specific jurisdiction. Despite all the efforts and good intentions to institute and administer an approved program of respiratory protection utilizing self-contained breathing apparatus or air-supplied respirators, the program could be placed in jeopardy if the compressed breathing air is shown to be below the accepted minimum standards. Ω

VM pls order

REFERENCES

1. *Compressed Air for Human Respiration*, CGA Pamphlet G-7, Compressed Gas Association, 500 5th Ave., New York 10036.

2. *Commodity Specification for Air*, CGA Pamphlet G-7.1, *ibid.*

3. *Compressed Breathing Air*, Standard Z180.1, Canadian Standards Association, 178 Rexdale Blvd., Rexdale, Ontario, Canada M9W 1R3.

4. *Respiratory Protective Devices*, 1963, American Industrial Hygiene Association, 66 S. Miller Rd., Akron, OH 44313.

5. Bird, R.B., W.E. Stewart, and E.N. Lightfoot, *Transport Phenomena*, 1960. John Wiley & Sons, 605 Third Ave., New York 10016, p. 502.

SAL 000057025