History of U.S. Respirator Approval (Continued) - Gas masks, Supplied-air respirators, and Chemical cartridge respirators

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ABSTRACT

This article is the third in a series of four articles on respirator history. This article continues to follow the history of respirator approval, use, and improvements in the US as discussed in our article entitled, *History of U.S. Respirator Approval*, published in the ISRP Journal, Vol. 35, No. 1, 2018 (Spelce. et. al. 2018). In addition, a 1957 respirator decision logic diagram illustrates the U.S. Bureau of Mines (USBM) rules to follow for respirator selection (USBM 1957).

Keywords: respirator approval, certification history, USBM respirator decision logic

Introduction

This is the third in our series of four articles on respirator history in the US. We continue our discussion of USBM respirator approval with the next promulgated schedule, gas masks, Schedule 14. Proceeding in chronological order, Schedule 19, Supplied-air respirators will be discussed next, followed by Schedule 23 for Organic Vapor, Chemical Cartridge Respirators. Our fourth and final article in this series will address air-purifying particulate respirators (Schedule 21 and 42 CFR 84).

Schedule 14, Gas Masks

Gas masks were designed to remove gaseous contaminants by sorption or by chemical reaction and basically consist of a facepiece and sorbent canister (USBM 1941). Other common components used included a harness to carry the canister and a breathing tube, if the canister was not attached to the facepiece. Gas masks were first created for military applications. From their expertise gained during World War I, the USBM developed approval standards for industrial use gas masks. Industrial gas mask canisters were divided into types based on the level of protection needed for the contaminants they were designed to protect against (Table 1) and color-coded.

To determine the chemical stability of the sorbents, except for carbon monoxide, canisters were tested at two flow rates against two concentrations of the gas for which approval was sought. Half were assessed for six hours at a relative humidity of 25% and the other half at 85% relative humidity. The next set of tests consisted of two or more test subjects wearing the gas masks while doing moderately heavy work at maximum test concentrations. If canister life during the tests met the minimum 30-minute requirement, they were approved for a maximum of 2% by volume of gas, except ammonia canisters, which were approved for 3%.

Table I. Types of Gas Mask Canisters and Contaminants

Type Canister	Contaminant Type
Type A	**Acid gases, such as chlorine, formic acid, hydrogen chloride, hydrogen cyanide, hydrogen sulfide, phosgene, and sulfur dioxide**
Type B	**Organic vapors, such as acetone, alcohol, aniline, benzene, carbon bisulfide, carbon tetrachloride, chloroform, ether, formaldehyde, gasoline petroleum distillates, and similar volatile compounds**
Type C	**Ammonia**
Type D	**Carbon monoxide**
Type E	**Dust, chemical smokes, fumes, and mists, such as tin tetrachloride, silicon tetrachloride, titanium tetrachloride, and sulfur trioxide**
Type F	**Special gases**
Types AB, ABC, etc.	**Combinations of the preceding types**
Type N	**Combinations to include all preceding types**

Laboratory testing for carbon monoxide was complex and will not be described. However, it is interesting to note that self-rescue devices called self-rescuers were used by mine workers for escape, and were tested by passing a 1% concentration of carbon monoxide through the canister at 32 liters per minute for 60 minutes. A second similar test was at 0°C (32°F) in 0.5 % carbon monoxide for 30 minutes. In both tests, maximum leakage could not exceed 640 milliliter (ml). The life of the canister and self-rescuer is dependent on the drying agent protecting the catalyst because moisture deceases the efficiency of the catalyst to oxidize carbon monoxide, thus requiring the canisters to have a moisture indicator. Carbon monoxide oxidation reaction is exothermic and 1 - 2% carbon monoxide generates enough heat to raise the canister temperature to an uncomfortable temperature, requiring the canisters to be insulated from the wearer. The filtered air got so hot that wearers were unable to tolerate wearing the mask longer than 20 – 30 minutes in 2 % carbon monoxide due to the hot dry air’s effect on their mucous membranes.

Since its' inception in 1919, Schedule 14 has been modified eight times, but the information below is from the 1941 version (Schedule 14E) concerning gas masks that are also approved for protection against particulate inhalation hazards. Figures 1, 2, and 3 are photos courtesy of MSA – The Safety Company illustrating early USBM approved gas masks.

According to (USBM 1941), the USBM "*Facepiece Tightness Test*" required two men to wear a facepiece, equipped with an ammonia canister and a harness, to enter an atmosphere of 1% (10,000 parts per million [ppm]) by volume of ammonia. They spent ten minutes on tasks designed to evaluate freedom of movement and comfort to determine if any detectable ammonia leakage occurred. Tasks included five minutes of walking, turning their head, and dipping their chin and another five minutes pumping air with a hand-operated tire pump into a 1-cubic-foot cylinder to a pressure of 25 pounds per square inch or equivalent work. In order to pass, ammonia could not be detected in the air breathed and the test subject could not experience any undue encumbrance or discomfort due to the fit or other features of the gas mask.

Additional Man Tests, which were similar to the "*Facepiece Tightness Test*", were performed as the final criterion for approval. These Man Tests required an average breathing rate of 25 liters per minute. To pass, all gas masks had to give complete respiratory protection to the wearers for 30 minutes except for Type N, which had to give complete protection against carbon monoxide for 30 minutes, organic vapors for 25 minutes, acid gases and ammonia for 15 minutes. Excessive eyepiece fogging or undue discomfort could not occur due to the fit or other physical or mechanical features of the gas mask.

Figure 1. MSA Burrell All Service Gas Mask.

Figure 2. MSA Tank Guager's Mask and Canister.

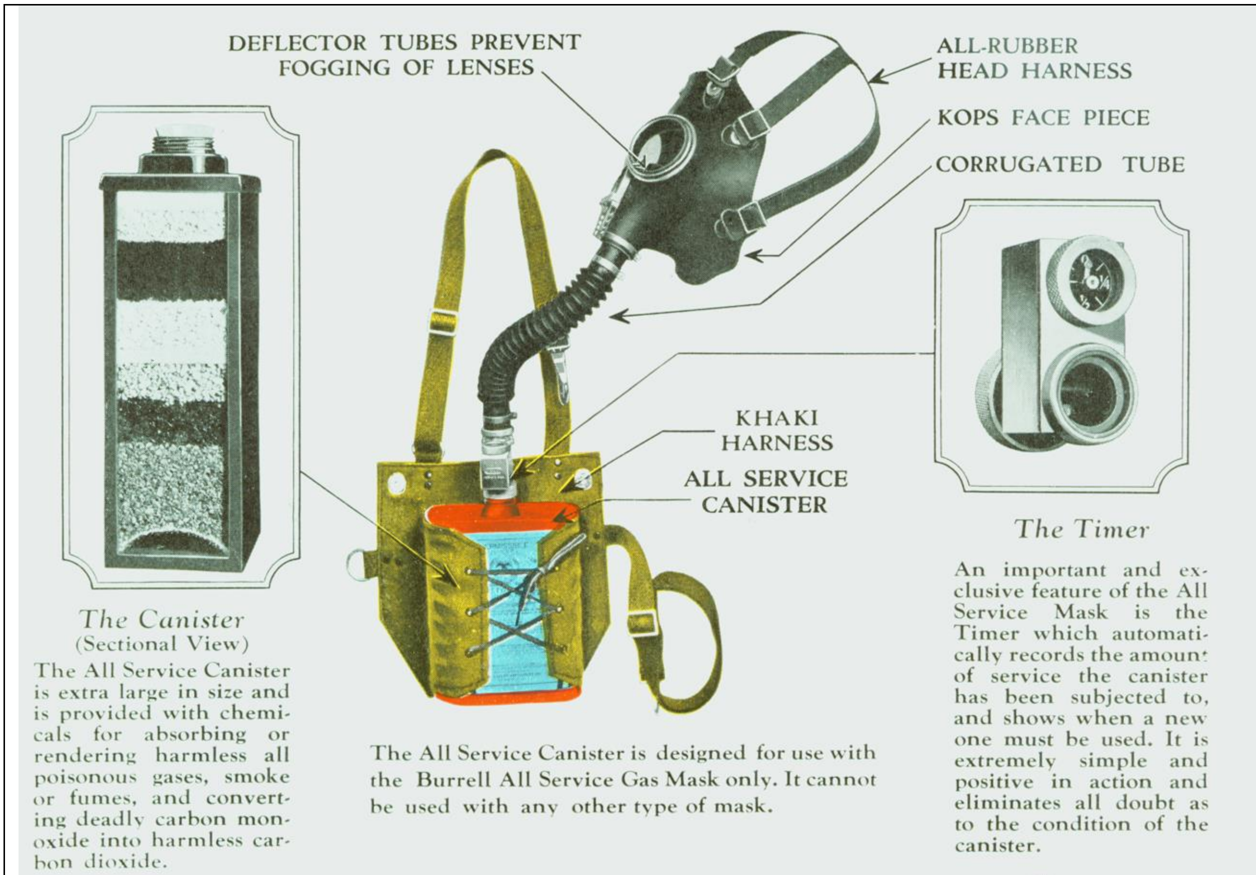

Figure 3. MSA Burrell All Purpose Gas Mask.

Besides being tested for gases and vapors, the respirators with particulate approvals had to meet the Schedule 21 requirements for Dusts, Fumes, and Mist. The canisters had to filter out "*specially prepared tobacco smoke*" while exposed to a simulated breathing rate of 85 liters per minute (lpm). Schedule 14 did not state how to prepare the tobacco smoke but a 1926 USBM Technical Paper referenced how to prepare tests against other particulate atmospheres (Katz, et. al. 1926).

Two separate particulate Man Tests had to be passed. In the first test, two men performed exercises in a 1,000 cubic foot room filled with smoke from one pound of cotton waste burning in a smudge pot. To pass the 10-minute test, no respiratory or eye discomfort or irritation could be experienced.

In the second test, which was a 20 minute test, two men had to perform exercises in a 500 ppm irritant smoke (stannous chloride) atmosphere without experiencing irritation of the eyes or respiratory system. Tin tetrachloride ($SnCl_4$) forms hydrogen chloride when combined with the moisture in the respiratory system, which is very irritating.

Protection of Railroad Engineers and Tunnel Workers

According to (Fieldner, et. al. 1922), USBM also conducted research to protect railroad engineers and tunnel workers in unventilated railroad tunnels (Figure 4). Locomotive smoke and sulfurous gases made breathing difficult for exposed trainmen, especially those on the locomotive. Temperatures in locomotive cabs passing through tunnels were as high as 162° F. High humidity from exhaust steam augmented the discomfort and difficulty to breathe due to the smoke and sulphur dioxide. Track workers were subjected to the same affects. Pocket canisters (Figure 5) were more convenient to carry than gas masks, but had less capacity to filter gases. However, they were found to last a minimum of two months in rather severe conditions in the Schenley Tunnel of the Baltimore & Ohio Railroad at Pittsburgh, PA.

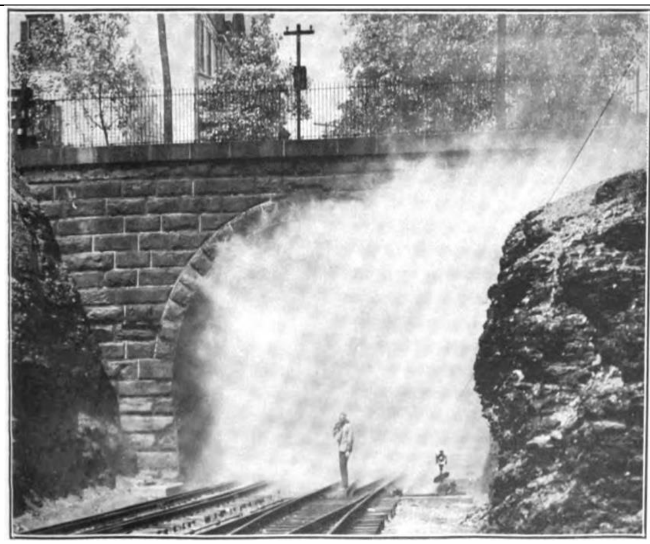

Figure 4. Unventilated Railroad Tunnel after Train Passage.

Figure 5. Railroad Pocket Canister.

The small pocket canisters were also convenient for protection against many poisonous gases and vapors found in industry, especially for infrequent use in low concentrations of acid gases and organic vapors in air.

Schedule 19, Supplied-Air Respirators

Schrenk (1939) describes types of supplied-air respirators (SAR[1]) approved under the revised Schedule 19A (August 9, 1937 first established in 1927) as types A, B, C, AE, BE, and CE. The letter “E” designation was for abrasive approval. Types A and AE and Types B and BE SAR are no longer approved, but are still encountered in industrial workplaces. Type A SAR has a tight-fitting facepiece with a large diameter hose (7/8” ID), and a blower that can be operated either electrically or hand cranked. The blower allows free entrance of air to the hose when the blower is not in operation which enables the wearer to breathe on their own without the benefit of the blower. The blower takes in fresh air from a

[1] The authors use the convention that “SAR” is both singular and pleural abbreviations for “supplied-air respirators.”

source outside the contaminated atmosphere and delivers it to the user's facepiece in hose lengths limited to 150 feet. According to (USBM 1955), Type A SAR was the only SAR approved for use in atmospheres considered "immediately harmful atmospheres" [now referred to as, "immediately dangerous to life or health" (IDLH)] or those from which the wearer could not escape without the aid of the respirator. Per (Federal Register Vol 42, No. 251 of 1977), the Type A respirator lost approval for entry into IDLH atmospheres in 1977. Figure 6 (photo courtesy of MSA – The Safety Company) illustrates a Type A SAR approved for entry into a confined space. Notice that the blower accommodated two workers wearing the Type A SAR.

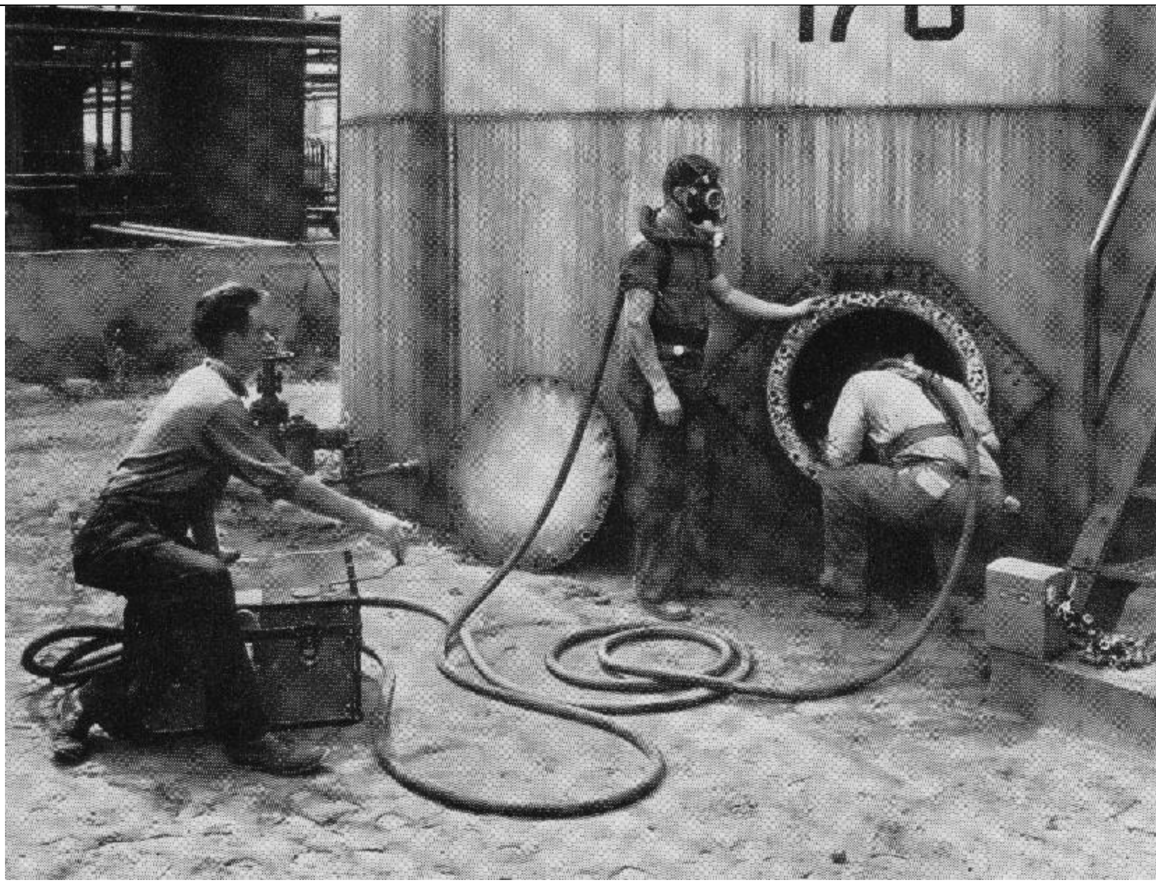

Figure 6. MSA Type A Hose Mask with Double Outlet Blower.

Per (USBM 1955), "*No multiple system, whereby one man is supplied by one blower, will be approved unless each hose line is connected directly to a manifold at the blower.*" In other words, no "*buddy-breathing*" connections were allowed – both respirators had to be connected to the blower manifold and respirators used in tandem was not permitted.

In contrast to the powered Type A SAR, Type B hose mask respirators had large diameter hoses, but no blower. Type B operated by the wearer's lung power to draw air through the hose and into the facepiece. The hose length was limited to 75 feet because inhalation was the mode of operation. Type B respirators required a tight-fitting facepiece in order to create negative pressure to help with drawing air through the hose. A metal spike was required to anchor the air inlet funnel in an area with respirable atmosphere. A 100-mesh, U.S. standard sieve of corrosion resisting material mesh covered the air inlet funnel to prevent large particles and insects from entering the hose.

Per (USBM 1955), testing for hose mask approval included evaluating the air-supply line, harness, breathing tubes, and respiratory-inlet covering. The authors find it interesting that this was the first mention we found in the literature referring to respiratory-inlet covering, which (USBM April 19, 1955) defined as:

> "*The term "respiratory-inlet covering is used for the covering worn over the face or head by the wearer of the respirator, when otherwise it would be necessary to use an expression such as "facepiece, half facepiece, helmet", or "hood.*"

In contrast, today's respirator vocabulary generally refers to respiratory-inlet coverings as all respirator components connecting the wearer's respiratory tract to an air-purifying or an atmosphere-supplying respirator.

As a final test according to (USBM 1955), the complete device was worn for 10 minutes in 1% ammonia (10,000 ppm). To pass, ammonia could not be detected in the air breathed by the wearer and could not cause the wearer undue encumbrance or discomfort due to the fit, air delivery, or other respirator features. The complete respirator was worn in an atmosphere of 50 ± 10 milligrams (mg) per cubic meter of ground flint for 30 minutes at flow rate of 32 liters per minute withdrawn from the respiratory-inlet covering and hose. The dust collected from the respiratory-inlet covering could not exceed that collected from the air withdrawn simultaneously from the source of air supplied to the respirator by more than 0.5 mg for the 30-minute test period. During this test, the wearer would perform the following actions:

5 minutes	Walking, turning head, and dipping chin.
5 minutes	Pumping air with a tire pump into a 1-cublc-root cylinder to a pressure of 26 pounds per square inch or equivalent work.
5 minutes	Resting.
5 minutes	Walking, turning bead, and dipping chin.
5 minutes	Pumping air with a tire pump into a 1-cublc-root cylinder to a pressure of 26 pounds per square inch or equivalent work.
5 minutes	Resting.

A similar test against particulates was performed using a test suspension consisting of 50 ± 10 mg per cubic meter of ground flint (99+ percent through 325 standard mesh sieve), and consisting of 99 + percent free silica (SiO_2).

It is interesting that all types of SAR must be equipped with a safety harness which facilitates the rescue of a wearer from contaminated atmospheres if required. However, the primary purpose of the harness was to prevent the air hose from exerting pull on the face or head covering. Harnesses of SAR having rigid or semi-rigid head coverings were used to assist in holding the respiratory-inlet covering in place.

Per (30 CFR Part 11 1972) Type C SAR are a positive-pressure air-supply system that provides air at a maximum pressure of 125 psi with a maximum hose length of 250 feet. It is interesting to note that Type A respirators, which had no flow requirements, were allowed for entry into IDLH atmospheres, but Type C respirators, which required 115 liters (4 cubic feet) for tight-fitting, respiratory-inlet coverings, and 170 liters (6 cubic feet) for loose-fitting respiratory-inlet coverings were prohibited for IDLH entry. In 1955, Schedule 19B recognized only two Type C classes, which were continuous flow and demand. Demand SAR provided respirable air to the respiratory-inlet covering only when the wearer inhales.

Approval criteria for SAR operating in pressure-demand mode was included in the 1972, 30 CFR Part 11 (30 CFR Part 11 1972). The pressure-demand Type C regulator maintains positive-pressure inside the facepiece at all times. There is usually a spring located between the diaphragm and the regulator case, which holds the admission valve slightly open, allowing for continual airflow into the facepiece. When this positive-pressure is reduced by inhalation, breathing air is admitted to the facepiece at a higher pressure. A spring located in the facepiece exhalation valve maintains positive-pressure in the facepiece at all times and also releases excess pressure in the facepiece.

A Type CE SAR is approved for abrasive blasting and is equipped to protect the wearer against the impact of rebounding abrasive material. In this abrasive blasting test, the respirator wearer placed their head inside a common iron kettle[2] of approximately hemispherical shape, about 30 inches in diameter and 30-gallon capacity. The wearer would blast the entire inner kettle surface, with the blast at all times directed approximately at right angles to the surface, with the nozzle of the gun about 6 inches from the surface, and with their head approximately 18 inches from the blast nozzle. They would move their head forward, backward, and sideways during the blasting operation. Further conditions of the test were:

Air pressure was 40 to 70 pounds per square inch.
Composition of abrasive to be used: 99+ percent free silica (SiO_2).
Size properties of abrasive: The sand shall be a mixture of 90 percent by weight of essentially No. 1 sand-blast and 10 percent air-floated fines.
Length of test period: 30 minutes continuously or in 5 -, 10 -, or 15 -minute Intervals with 5-minute periods between the work periods.

Air sampling at 32 liters per minute was performed near the wearers' nostrils. Simultaneously air was drawn at the same rate from the source of intake air to the respirator. Particulate matter was collected from these air streams by electrical precipitation and the collected material was determined by weight. The amount of particulate matter in the air withdrawn from the respiratory-inlet covering could not exceed that from the respirator intake air by more than 0.5 mg for the 30-minute test period.

Per (30 CFR Part 11 1972) "*To be able to Identify the approved respiratory inlet coverings, hose, harness, couplings, and other parts of approved respirators the Bureau requires a symbol as "B. M. 1900" stamped or stenciled on each part in bold, waterproof letters and figures at least one-eighth Inch high, placed in a position plainly visible.*" What a great help this must have been to field industrial hygienists during workplace inspections to determine if the respirator was used in an approved configuration.

30 CFR 14A, Schedule 23 of 1944 - Non-emergency Gas Respirators

Per (USBM 1944), on 13 November 1944, the Bureau of Mines published Schedule 23 for organic vapor, chemical cartridge respirators for use in non-IDLH atmospheres of organic vapors up to concentrations of 1,000 ppm or 0.1%. As implied above, the 1944 version of this standard was limited in scope to only organic vapor respirators. However, particulate filters were used in combination with many organic vapor respirators. These combination cartridge respirators had to pass some interesting tests.

[2] It is interesting to note that the kettle test was run only once because of a mishap during the test. This test was run in the silica dust chamber of the Air Purifying and Aerosol Laboratory (APAL) in Morgantown, WV (Personal Communication 2018). It occurred that the test subject inside the kettle became startled when someone tapped on the dust chamber's observation glass and began sandblasting the observation glass. The kettle test was not performed again because of concern that the observation glass could shatter releasing large amounts of silica into the APAL lab. Today the level of protection provided by abrasive blast Type CE supplied air respirators is determined using sodium chloride or corn oil (standard test procedure No. RCT-ASR-STP-0112, (NIOSH 2005).

This schedule approved two types of respirators: Type B and Type BE. Type B respirators were approved for protection against organic vapors only and were color-coded black, as were gas mask canisters. Cartridges were tested for their efficacy against a challenge concentration of 1,000 ppm carbon tetrachloride using both high flow (64 lpm) and low flow (32 lpm) machine testing.

Type BE respirators were approved for protection against organic vapors and dusts, fumes, and mists. If the cartridge was designed with built-in particulate protection, a white stripe is placed on the black cartridge to indicate particulate approval.

The BE respirators had to pass the Type A, B, C, or D tests under schedule 21 for Dust, Fume and Mist.

In addition, two Man Tests were conducted for the organic vapors. The first was a "*tightness test*" where two men exercised while wearing the respirators in 100 ppm isoamyl acetate, which is similar to the current qualitative banana oil fit test.

In the second test, the respirators were tested against a 5,000 ppm carbon tetrachloride atmosphere in which two men wore the respirators until the odor of carbon tetrachloride was detected. A series of exercises were performed including the one shown in Figure 7, from (Held 1978), in which the test subjects pumped air with a hand operated tire pump into a one cubic foot cylinder to a pressure of 25 psi. The chemical cartridges had to last at least 30 minutes to pass the test. Although this picture shows testing with gas masks, Type B and Type BE cartridge respirators only had a mouthpiece with nose clip or half-mask facepieces. Inhalation valve(s) were required to prevent exhaled air from contacting the sorbent material and an exhalation valve was also required. In addition, adjustable, replaceable headbands were a requirement. ·

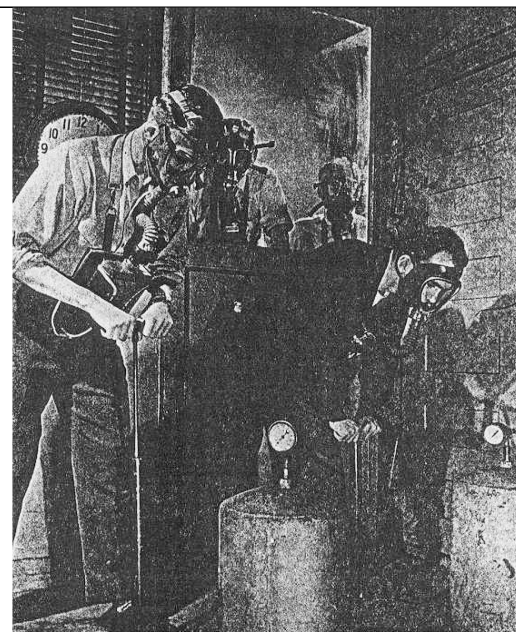

Figure 7. Man Test - Pumping Air Cylinder.

Even though the test was performed under high concentrations, approval was still granted only for organic vapor concentrations not exceeding 1,000 ppm. To speed up the test by about five times, 5,000 ppm of carbon tetrachloride was used instead of 1,000 ppm. NIOSH now considers 200 ppm carbon tetrachloride as IDLH. Carbon tetrachloride has an odor threshold of approximately 10 ppm. These Man Tests were conducted at 25 times the current IDLH concentration for carbon tetrachloride! Thirty minutes of protection was required to pass this test.

Approval labels were reproduced on the packaging and included cautions and limitations of the respirator. Approval labels were required to state, "*Approved for respiratory protection in atmospheres not immediately dangerous to life and containing not more than 0.1 percent by volume of organic vapors.*"

Facepieces and cartridges labels had to be marked with the USBM approval number and cartridges stated, "*Permissible cartridge for organic vapor only. Approved for respiratory protection in atmospheres not immediately dangerous to life and containing not more than 0.1 percent by volume of organic vapors.*"

Minor changes were added in Schedule 23A published on April 23, 1955 (USBM 1955).

USBM Respirator Selection Logic

Per (Pearce 1957), on 13 November 1944, the Bureau of Mines published Schedule 23 for organic vapor, chemical cartridge respirators for use in non-IDLH atmospheres of organic vapors up to concentrations of 1,000 ppm or 0.1%. As implied above, the 1944 version of this standard was limited in scope to only organic vapor respirators. However, particulate filters were used in combination with many organic vapor respirators. These combination cartridge respirators had to pass some interesting tests.

Figure 8 illustrates the respirator selection logic for USBM approved respirators in 1957 from (Pearce 1957).

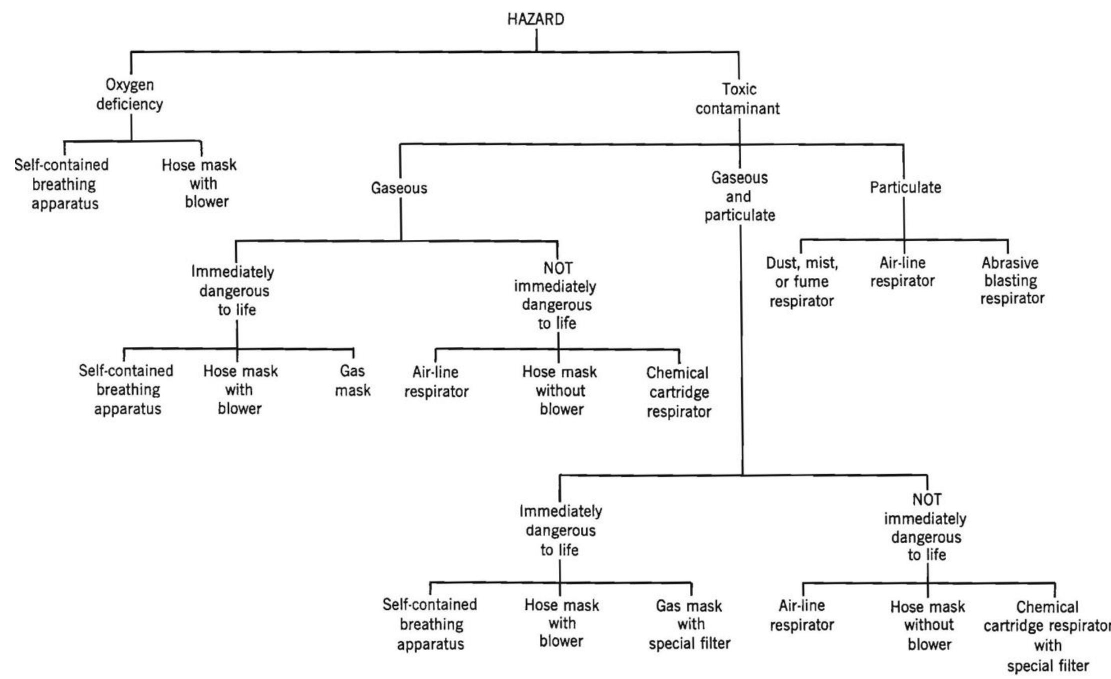

Figure 1. - Outline for selecting respiratory protective devices.

Figure 8. 1957 USBM Respirator Selection Logic.

Summary

In March 1972, all individual respirator approval schedules were codified into Title 30 Code of Federal Regulations (CFR) Part 11, 30CFR11 (30 CFR – PART 11 1972). With the Coal Mine Safety and Health Act of 1969 (United States Public Law 91-173 1969), the National Institute for Occupational Safety and Health (NIOSH) in the Health, Education and Welfare Department started jointly approving respirators with the Bureau of Mines. Later the Department of Interior transferred this USBM responsibility to its Mining Enforcement and Safety Administration (MESA) (MESA 1974), and then subsequently transferred its responsibility to the Mine Safety and Health Administration (MSHA) of the Department of Labor (MSHA 1977). Since 1977, NIOSH and MSHA have jointly approved respirators. Beginning in 1995 with the promulgation of Title 42 Code of Federal Regulations Part 84, and a memorandum of understanding between NIOSH and MSHA, together the agencies jointly approve respirators for mine rescue and other mine emergencies (42 CFR Part 84 1995). NIOSH continues to solely approve respiratory protective devices for other occupational uses.

Acknowledgements

The authors thank NIOSH for providing many photographs of mining and respirators. Portions of this article were written by David Spelce while in an official capacity as a Department of the Navy employee.

Disclaimer

Mention of any company or product or photograph of product does not constitute endorsement by the authors. Instances of their use are to provide historical content and perspectives only.

The findings and conclusions in this report are those of the author(s) and do not necessarily represent the official position of the Centers for Disease Control and Prevention and National Institute for Occupational Safety and Health.

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