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The Use of MAG-1 Spectacles with Positive- and Negative-Pressure Respirators

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The Use of MAG-1 Spectacles with Positive- and Negative-Pressure Respirators

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THE USE OF MAG-1 SPECTACLES WITH POSITIVE- AND NEGATIVE-PRESSURE RESPIRATORS

by

Karen A. Reed and Tom O. Moore

ABSTRACT

Results of testing conducted at Los Alamos National Laboratory, Personnel Protection Studies Section, using MAG-1 spectacles in conjunction with positive- and negative-pressure full-facepiece respirators, are reported. The purpose of the three-phase study was to determine if the specially constructed strap of the MAG-1s affected the protection factors (PFs) of the respirators or the cylinder life of selected self-contained breathing apparatus (SCBA). The following respirators were tested with the MAG-1s: a) Phases I and II, positive-pressure full facepiece: Presur-Pak II SCBA (pressure-demand) Scottoramic facepiece, MSA 401 Air Mask Ultravue facepiece (medium), Survivair pressure-demand SCBA/silicone full facepiece, MSA powered air-purifying respirator/Ultravue facepiece (medium); b) Phase III, negative-pressure full facepiece: MSA Ultravue (small, medium, large), MSA Ultra-twin (small, medium, large), Norton Series 7600 (one size only).

Statistical analysis and review of the test data from Phases I and II indicated little, if any, variation with and without the MAG-1s with most protection factors greater than 10 000. Test data also indicated little, if any, difference in the cylinder life with and without the MAG-1s, except the Scott Presur-Pak II SCBA used with the Scottoramic facepiece.

Statistical analysis of the quantitative fit test data indicated no difference in PFs for the negative-pressure devices for the Ultravue negative-pressure respirator, but a significance at the 0.05 and 0.01 levels for the Ultra-twin and Norton full facepieces respectively.

I. INTRODUCTION

Workers and military personnel who must wear prescription glasses and full-facepiece respirators are presented with special problems associated with proper fit of the eyewear without interfering with the proper fit of the respirator. The practice most commonly used today for holding prescription lenses in their frames and in place inside the respirator involves a special apparatus (spectacle kit) that attaches to the inside of the facepiece. To date, spectacle kits of various designs have presented problems to those who must use them. They have a tendency to slip out of place, are sometimes uncomfortable, can get lost or broken when the respirators are sent to be cleaned, and may cause poor depth perception. Few other options for wearing prescription lenses with full-facepiece respirators have been available, and current standards prohibit the use of other types of spectacles that could possibly be worn with full-facepiece respirators.

One type of spectacle that is now prohibited from being worn in conjunction with full-facepiece respirators, because of existing Occupational Safety and Health Administration (OSHA) regulations[1] and American National Standards Institute (ANSI) Z88.2-1969[2] and Z88.2-1980[3] recommendations, is the Mask Adaptable Goggles (MAG-1) (Figs. 1 and 2). The MAG-1s were designed as military safety goggles to be worn with or without a full-facepiece respirator. The MAG-1s, marketed now with either the original-length bridles (unmodified) or shortened bridles (modified), are held in position on the wearer's head by neoprene straps that pass between the facepiece-to-face seal of the respirator. However, it has been thought that the design of the straps, which incorporates a thin area less than 1.5 mm thick at the facepiece-to-face sealing area, may create a minimal amount of interference with the facepiece-to-face seal. If this were true, then perhaps the MAG-1s would have some application in the workplace for those who must wear prescription lenses with full-facepiece positive-pressure respirators.

This study was conducted in three phases using the original unmodified MAG-1s (Figs. 1 and 2) in Phase I and modified MAG-1s (Fig. 3) in Phases II and III. In Phase I, test subjects were assisted with the donning of the MAG-1s (original design) and the respirator in order to provide a control as to proper fit and consistency of donning. This was done in order to be able to better evaluate any difference seen in the protection factors (PFs) or cylinder-life data acquired. A PF is defined as the ratio of the

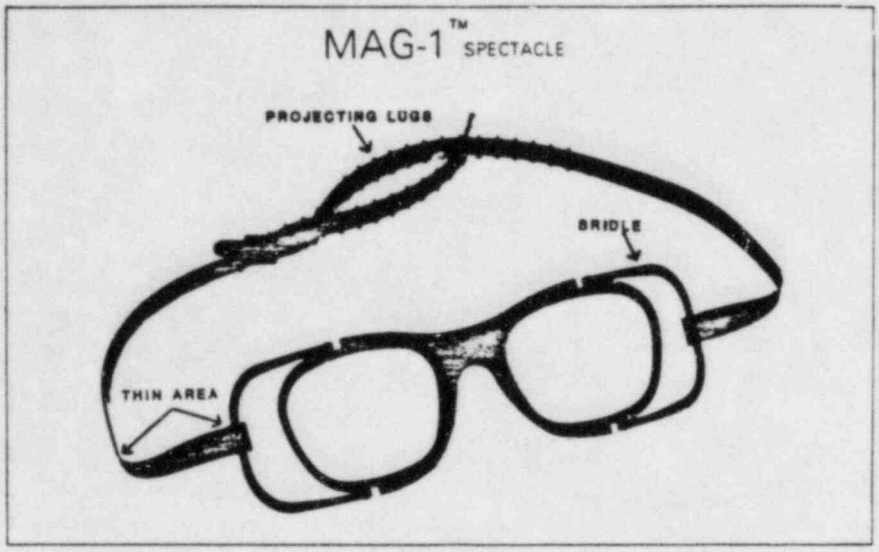

Fig. 1. MAG-1 spectacles (original-size bridles).

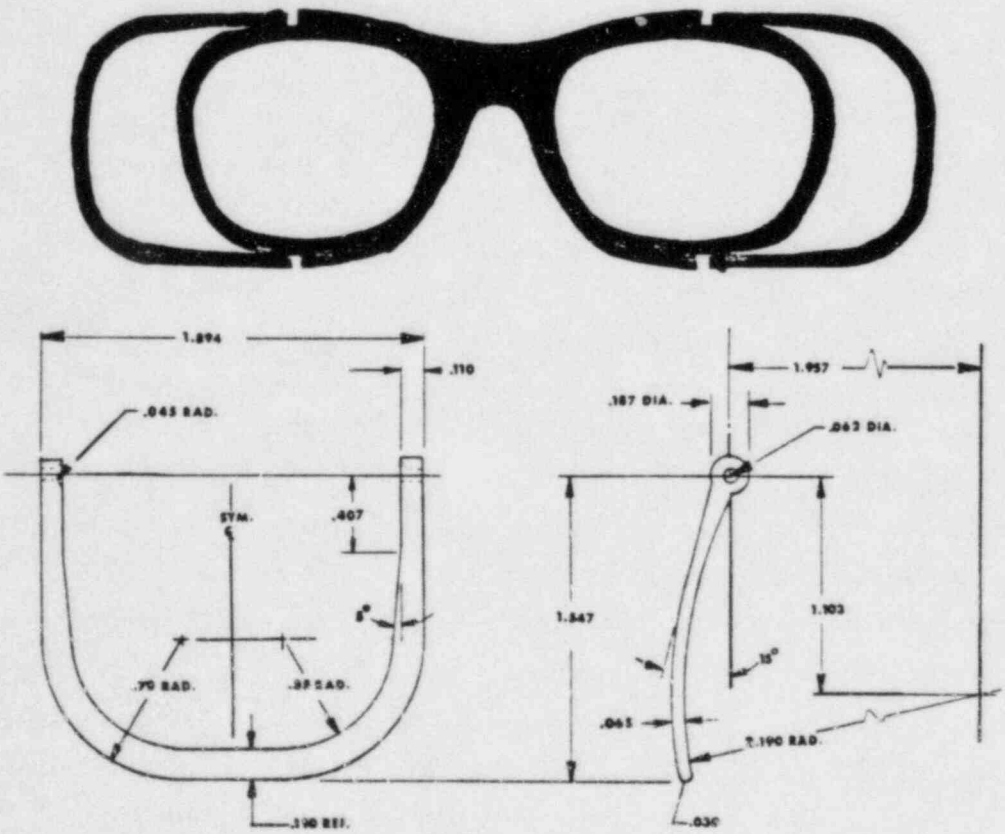

Fig. 2. MAG-1 spectacles with dimensions of the original-size bridles (unmodified) (Phase I tests).

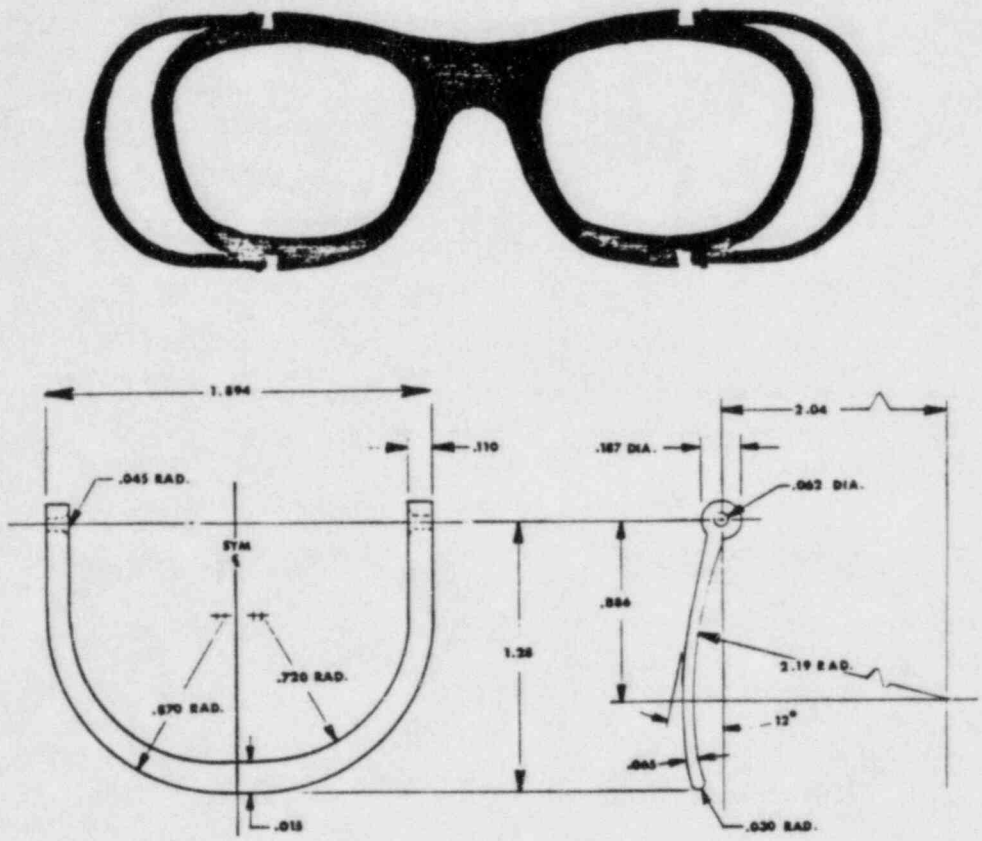

Fig. 3. MAG-1 spectacles with dimensions of the redesigned (modified) bridles (Phase II and III tests).

concentration of a test aerosol outside the facepiece to the concentration of aerosol inside the facepiece.[4] Phases II and III were conducted allowing self-donning of the MAG-1s (modified) and the respirator after careful instruction. Phases II and III were designed in this way in order to provide a more realistic, workplace-donning type of condition. Testing was conducted for Phases I, II, and III using 25-, 10-, and 25-person anthropometrically selected test panels respectively.[5] All members of the test panels wore each of the four positive-pressure and three negative-pressure respirators with and without the MAG-1s in place in order to obtain comparative data.

The objectives of the project were twofold:

1. To determine whether or not the wearing of the MAG-1s affected the quantitative fit of selected positive- and negative-pressure respirators.
2. To determine whether or not the wearing of MAG-1s affected the service life (amount of time a cylinder filled with compressed breathing air could be used) of selected self-contained breathing apparatus (SCBA).

Quantitative fit data were collected for all tests and evaluated as to comparative values with and without the MAG-1s in place for each test subject. Cylinder-life (service-life) data were also collected for the SCBA testing with and without the MAG-1s. The cylinder-life and quantitative fit data for the SCBAs were gathered concurrently in exactly timed trials.

The frame and bridles of the MAG-1s are made of nylon, and the spectacle straps are made of neoprene rubber. The MAG-1s are now marketed with the original bridles (unmodified) (Figs. 1 and 2) as well as the newly designed shortened bridles (modified) (Fig. 3). The unmodified and modified MAG-1s are sized according to the width of the lenses (46, 48, and 50 mm), corresponding to sizes small, medium, and large respectively, and the width of the contoured bridge area (22 and 25 mm). The frame front curves toward the face at 12° from horizontal. The bridles are designed to extend past the corner of the eye. The spectacle straps have projecting lugs that allow for adjustments in tension. The thickness of the strap is approximately 1.9 mm throughout except in the area where it interfaces with the facepiece-to-face seal. This area extends back from the bridle attachment approximately 45 mm and is less than 1.5-mm thick in this portion. The "modified" MAG-1s differ from the "unmodified" MAG-1s in two respects: The designer and manufacturer have shortened the bridles approximately 3 mm, and the radii of the bridles have been decreased, causing the bridles to be more flattened (Fig. 3). A major reason for these modifications was that the original bridles had a tendency to penetrate the facepiece-to-face seals of full-facepiece respirators.

II. RESPIRATORS TESTED

A. Positive-Pressure Respirators

1. Scott Presur-Pak II, Series 900 000, with a Scottoramic pressure-demand full facepiece (NIOSH approval No. TC-13F-41). The

regulator was operated for testing purposes in the pressure-demand mode. An aluminum cylinder pressurized to 1000 psi was used with the SCBA.

2. Mine Safety Appliances (MSA) Model 401 air-mask, pressure-demand SCBA with an Ultravue facepiece (size medium) (NIOSH approval No. TC-13F-30). The aluminum-fiberglass cylinder used with the SCBA was pressurized to 1000 psi before the start of each test.
3. Survivair pressure-demand SCBA with a silicone full facepiece (NIOSH approval No. TC-13F-45). The steel alloy cylinder used with this unit was pressurized to 1000 psi before the start of each test.
4. MSA-powered air-purifying respirator (PAPR) with an Ultravue full facepiece with twin exhalation valves (size medium) (NIOSH approval No. TC-21C-186).

B. Negative-Pressure Respirators

1. MSA Ultravue - small, medium, and large.
2. MSA Ultra-twin - small, medium, and large.
3. Norton full facepiece (Series 7600) - one size.

III. QUANTITATIVE FIT TEST METHODS

A 16-m^3 Los Alamos-constructed test chamber was used for all of the quantitative fit testing. Two Naval Research Laboratory (NRL) air-jet generators were used to produce a polydisperse aerosol using di-(2-ethylhexyl)sebacate (DEHS). The aerosol particle size was 0.22 μm ± 0.14-μm geometric mean diameter as measured with an active-scattering aerosol spectrometer (ASAS-XF) laser system. This aerosol was delivered to the test chamber at approximately 4 cfm. With a flow rate into the chamber of approximately 100 cfm, a concentration of aerosol within the test chamber was maintained at 25 mg/m^3 ± 5 mg/m^3.

An anthropometrically selected test panel[5] was utilized in the three phases of the study. The first and third phases were conducted using a full panel of 25 persons, and the second phase was conducted using 10 persons with each block of the chart (Fig. 4) represented. Because Phase II was a continuation of Phase I, a smaller test panel with all face sizes from the anthropometric chart represented (Fig. 4) provided an adequate amount of data for analysis. Phase III was conducted using the negative-pressure respirators; therefore, a 25-person test panel was used in order to provide a statistical base for the negative-pressure respirator/MAG-1 study.

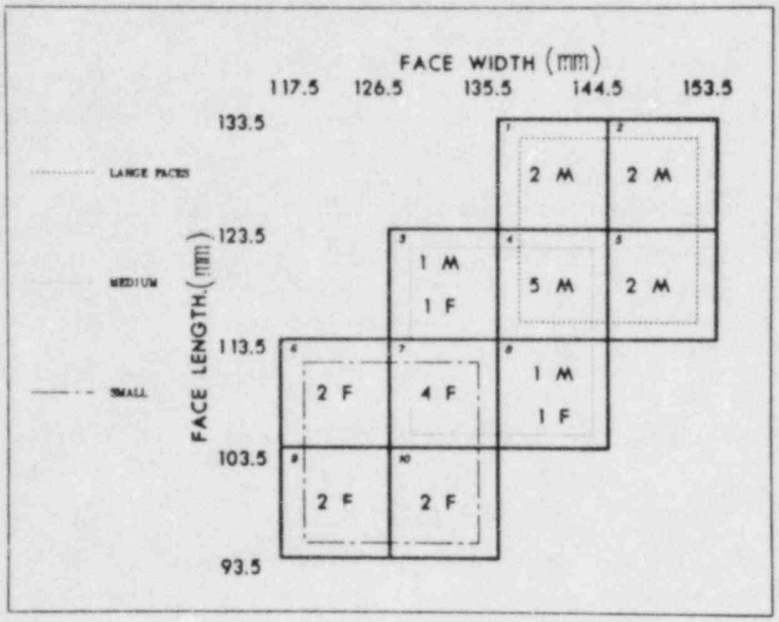

Fig. 4. Anthropometric test panel.

The test chamber exercises performed in all three phases, selected to simulate a slow-to-moderate work rate, were normal breathing; deep breathing; frowning with normal breathing; turning the head side to side with deep breathing; nodding the head with normal breathing; talking from a prepared text with a pause and deep breath at the end of each sentence; moving wooden blocks from a shelf approximately 1 ft from the floor to a shelf 7 ft from the floor; moving small brass discs from one rack to another simulating side-to-side head movements; slow jogging utilizing a metronome to keep a steady, constant pace; and resting with normal breathing. The exercises ranged in performance time from 0.5-2 min (see Table I).

A Los Alamos Model 691 photometer provided a direct reading of the penetration of the challenge aerosol particles into the respirators worn by the test subjects. A latex sample line was attached to a probe that was located in the breathing-zone area of each respirator. This sample line was attached to the photometer; therefore, at the end of each test, a PF could be determined. This was done by dividing the average concentration of aerosol outside the facepiece by the average concentration of aerosol inside as determined by the peak averaging method.

TABLE I

EXERCISES PERFORMED BY TEST SUBJECTS

Phases I and II

Exercises	Duration (min)
Normal breathing (n.b.)	1.0
Deep breathing (d.b.)	0.5
Frown with n.b.	0.5
Turn head side to side with d.b.	1.0
Nod head up and down with n.b.	1.0
Talk from a prepared text--pausing at the end of each sentence to take a deep breath	1.0
Place small wooden blocks on a shelf 7 ft from the floor	2.0
Move brass discs from one rack to another	2.0
Slow jog--using a metronome to keep a steady, consistent pace	2.0
Rest with n.b.	1.0
Total exercise time	12.0

All testing obtained paired data for comparison with and without the MAG-1s. The order of the wearing of the MAG-1s for each pair was determined by the flip of a coin in order to achieve randomness. The tests conducted with the SCBAs for acquiring comparative cylinder-life data were conducted in exactly timed 15-min trials. Exceptions to this timing are discussed in the "Results" section.

A. Fitting of MAG-1s

As recommended by the designer and manufacturer of the MAG-1s, the following procedures were used to determine the correct MAG-1s were worn by each test subject:

1. Determination that the frame front with the proper 12° curve was made. This was done by placing the MAG-1s face up on a flat, sturdy surface and checking that four points on the back side of the MAG-1s touched the surface. These four points were the top outer edge of each frame and the two projections at the bridge area. If these points did not touch, the frame was either replaced or heated and manipulated until it had a satisfactory curve. In this study one

frame was heated and adjusted, and another frame was replaced before the study started. Periodic evaluations of the MAG-1s through all phases of the study did not reveal any changes in the curvature.

2. Selection of the proper-size MAG-1s was made starting with the smallest size and increasing the size until the proper size was determined for that particular subject. This selection was based on centering (geometric center) of the subject's pupils in the lens of the MAG-1s.

3. The subject was then instructed on strap adjustment procedures. Proper tension was described as not causing an indentation at the temples, undue pressure on the bridge of the nose, or curling of the thin area of the strap.

B. Testing Procedures

1. Tests Using SCBAs (Phases I and II). A cylinder was put into its appropriate SCBA backpack, and the high-pressure breathing hose from the regulator was attached to the cylinder. In order to maintain randomness in the testing, a coin was tossed to determine whether or not the test subject would be wearing the spectacles during the first test. If spectacles were to be worn, the researcher determined the proper size for the test subject based on criteria provided by the manufacturer as well as instructions made by the designer of the MAG-1s. Next, the subject was instructed in strap-adjustment procedures. Once the MAG-1s were in place, proper strap tension was evaluated, and adjustments were made in the tension at that time if the researcher deemed it necessary (Phase I). In Phase II, adjustments were not made by the researcher, but rather notes were taken as to any indentation made by the straps. However, adjustments to the straps were made in Phase II if the straps were twisted. Next, the respirator was donned with the following differences noted between Phases I and II:

Phase I: The respirator donning was an assisted procedure because testing was being conducted to detect the degree of spectacle interference with the fit of the respirator, not to test subject knowledge on the proper donning procedure. Proper placement of the head harness of the respirator was made before the straps were tightened. Initial tightening of the head straps, in most cases, was made by the researcher. From this point, the test subject was instructed to finish tightening the straps for comfort.

Phase II: The respirator donning and adjusting were unassisted procedures. The test subject was given specific instructions as to the proper donning, but no further assistance was given. This was done in order to simulate a workplace situation. Using a penlight, observation was made by the researcher as to whether or not the MAG-1 bridles or strap attachments were penetrating into the facepiece seal.

Phase I: If the bridle(s) or strap attachment(s) were penetrating the facepiece-to-face seal, manipulations were made to bring the bridle(s) and/or strap attachment(s) inside the seal. If this could not be done by redonning the respirator, the MAG-1s were pushed forward into the facepiece until these areas were inside the seal, if possible (two times in Phase I with two test subjects, face size 2), or a smaller size MAG-1 was selected, if available (one time in Phase I with test subject, face size 2). This selection did not jeopardize the optometric fit, but it should be kept in mind that in field applications, a pair of MAG-1s would be issued to the wearer based on good optometric fit.

Phase II: No adjustments were made to the positions of the MAG-1s with respect to the interface with the facepiece-to-face seal. Notes were made as to any interferences with the seal evidenced upon penlight inspection.

The test subject then donned the SCBA harness containing the cylinder and regulator. The cylinder valve was turned on to supply air to the regulator. The test subject was instructed to take a deep breath, and the breathing hose from the respirator was attached to the regulator. The select lever on the Scott or Survivair regulator was then switched to the pressure-demand mode immediately. (It should be noted that the MSA regulator was always in the pressure-demand mode so no switch was necessary.) As soon as air was started from the regulator to the facepiece in the pressure-demand mode, a stopwatch was started to monitor the exact time of the test. The test subject then proceeded to the test chamber, and the following protocol, which was developed before the experiment, was followed:

1. Thirty seconds were allowed for the test subjects to walk into the test chamber.

2. After 30 s, the person at the photometer counted over the chamber microphone, in 5 seconds, "one, uncap (meaning to remove the plastic cap from the sample line connected to the facepiece); three, four, plug in (meaning to connect the sample line from the facepiece to the sample line going to the photometer)." The assistant inside the test chamber with the test subject was responsible for connecting the sample line from the facepiece into the photometer sample line inside the chamber at the instruction, "plug in."
3. The Los Alamos Model 691 photometer was immediately switched to "sample." Fifty-five seconds elapsed. During this period the test subject was asked if any outward leakage could be felt around the facepiece, and this reply was recorded by the operator. Also, it was at this time that any adjustments of the facepiece straps were made to obtain a tighter fit if the test subject felt that there was an inordinate amount of outward leakage.
4. At the end of 1.5 min, the test subject was instructed through exercises (Table I) simulating a slow-to-moderate work rate.
5. At the end of the exercises, the person operating the photometer instructed the test subject to breathe normally while the 0.1 per cent and 100 per cent readings on the photometer were rechecked. One minute was allowed for this procedure.
6. At the end of that 1 min, the test director again counted in seconds, "one, unplug (meaning unplug the sample line of the respirator from the sample line leading to the photmeter); three, four, cap (meaning to place a plastic cap over the sample line to eliminate any air that might be lost from the facepiece through the sample line).
7. At the end of that 5 s, the test subject was instructed to leave the test chamber--25 s were allowed.
8. At 14 min 55 s, a countdown was begun. One second before 15 min, the test subject drew a deep breath, and air to the facepiece was stopped by stopping the flow from the regulator to the facepiece.
9. The total designed test time was 15 min. At the end of each test, the SCBA was removed from the test subject, who was then given a 10- to 15-min break before the next test was begun.

Tests for each subject using the SCBAs with and without the MAG-1s were conducted on the same day during the same scheduled testing period. This was

done in order to maintain as much human physiological uniformity for the cylinder-life testing as possible. This uniformity was important in reducing the difference in breathing rates between the first and second tests.

Cylinder-life data were collected at the conclusion of each test by attaching the SCBA cylinder to the Heise gauge and bleeding the remaining air through the AL-1000 Singer dry-gas meter. The volume remaining in the cylinder at the end of the test was subtracted from the volume at 1000 psig. (Before the start of the testing, all cylinders used in the study were checked to determine what volumes of breathing air each contained at 1000 psig.) Thus, the quantity of breathing air consumed during the test was determined.

2. Tests Using the PAPR (Phases I and II). A coin was tossed to determine whether the test subject would wear the MAG-1s during the first trial. The same donning procedures as used in Phases I and II respectively with the SCBAs and MAG-1s were used with the donning of the MAG-1s and Ultravue PAPR facepiece. Once the facepiece was in place, the test subject was assisted with placing the belt holding the PAPR around the waist, attaching the breathing hose from the facepiece to the PAPR unit, and turning on the blower. Once inside the test chamber, the technical assistant connected the sampling line from the facepiece to the photometer sampling line within the chamber. The exercises used were the same as those used in the SCBA testing (Table I). At the end of each test, the PAPR was removed from the test subject, and the flow rate was quantitated using the calibrated pneumotachograph. If, at any point, the flow rate was less than 4 cfm, the battery was recharged and that test was repeated. Any flow rate greater than 4 cfm was considered to be acceptable.[6]

3. Tests Using the Negative-Pressure Full-Facepiece Respirators (Phase III). A 25-person anthropometrically selected test panel (Fig. 4) was used for Phase III. Because the MSA Ultravue and Ultra-twin full facepieces were available in the sizes of small, medium, and large, the best respirator fit for each test subject had to be determined. Protocol was developed in which a minimum of two sizes were evaluated on each person (the Norton Series 7600 was available in one size only). After careful instruction as to proper donning, the test subject was assisted with the donning of the respirator for the preliminary acceptable fit determination. Once it was determined that the respirator was properly in place, the test subject then proceeded into the

test chamber, where a series of standard shortened exercises were performed in order to determine how well the respirator fit. Measurement of aerosol penetration into the respirator was done using the Los Alamos Model 691 photometer. At the end of the shortened test, the test subject left the chamber, rested, and then was assisted, if necessary, with the donning of the alternate-size respirator. Again, a standard shortened quantitative fit test (QNFT) was performed. The results of the shortened tests were compared, and the proper-size MSA Ultravue and Ultra-twin were chosen according to acceptable fit and comfort criteria. Even though the Norton Series 7600 respirator was only available in one size, it was still necessary to determine whether or not an acceptable fit (defined as a DEHS aerosol penetration of <20 per cent) could be obtained for each test subject utilizing an assisted donning procedure.

If there was more than a 20 per cent breakthrough of aerosol in the preliminary testing, this was considered a failed test, and no further testing was conducted with that size respirator. In the case of the Norton respirator, a breakthrough of test aerosol >20 per cent during the preliminary testing meant the respirator was disqualified from any further testing with that test subject. At the end of the test subject's use of the respirator, the respirator was washed and air dried. Then, the respirator and filters were quality assurance (QA) tested using a Q-127 testing bench.

Once the proper-sized respirator was selected for the test subject, the study of the fit of that respirator with and without the MAG-1s began. In this part of Phase III, the subject was not assisted with the donning of the MAG-1s or the respirators. If the MAG-1 straps were twisted, the test subject was told this and asked to untwist them because test protocol required data to be collected with the MAG-1 straps lying flat across the temples. The test subject was asked to proceed to the test chamber where he/she performed exercises (Table II) simulating a slow-to-moderate work rate.

IV. RESULTS AND DISCUSSION

A. Hypotheses Tested

The hypotheses tested were as follows:

1. The wearing of MAG-1 spectacles did not significantly affect the quantitative fit of selected positive- and negative-pressure respirators.

TABLE II

EXERCISES PERFORMED BY TEST SUBJECTS

Phase III

Exercises	Duration (min)
Normal breathing (n.b.)	1.0
Deep breathing (d.b.)	0.5
Frown with n.b.	0.5
Turn head side to side with d.b.	1.0
Nod head up and down with n.b.	1.0
Talk from a prepared text--pausing at the end of each sentence to take a deep breath	1.0
Place small wooden blocks on a shelf 7 ft from the floor	1.0
Move brass discs from one rack to another	1.0
Slow jog--using a metronome to keep a steady, consistent pace	1.0
Rest with n.b.	1.0
Total exercise time	9.0

2. The wearing of MAG-1 spectacles did not significantly affect the cylinder life of selected SCBAs.

B. Statistical Tests Used

A nonparametric test was needed to evaluate the data from Phases I and II because there was not a normal distribution of the data. The Wilcoxon Signed Rank Test, a nonparametric test, was selected because it could be used to compare data in these paired tests. A p-value of 0.05 was used to determine whether to reject the null hypotheses.

In Phase III the entire experiment was replicated. Each subject was tested twice both with and without MAG-1 spectacles. This repetition of the experiment necessitated the use of a nonstandard statistical analysis.

The data were grouped into one of five classes: those people who obtained a lower protection factor wearing the MAG-1 spectacles in both replications (-,-), those who had a higher protection factor in one replicate using the MAG-1 spectacles but a lower protection factor in the other replicate (-,+),

and those subjects who had a higher protection factor with the MAG-1 spectacles in both replicates (+,+). In addition, for those cases where the protection factors were the same in one replicate, the data from the other replicate were collapsed into those whose protection factors were greater without the MAG-1 spectacles (-) and those whose were worse (+). If there is no effect of wearing the MAG-1 spectacle then for those subjects where both replicates are classified, one expects 1/4 of the observations to be classified (-,-), 1/2 classified (-,+), and 1/4 to be classified as (+,+). In those cases where one replicate is the same, 1/2 of these observations are expected to be (+) while 1/2 are expected to be (-).

The expected number of observations in each classification was estimated using the data and the above-expected proportion. A chi-square statistic was computed by summing the difference of the data and its expected number squared, divided by its expected number. Under the hypothesis of no effect of the MAG-1 spectacles, this chi-square statistic has a chi-square distribution with 3 degrees of freedom (2 degrees of freedom for those data sets where there are little or no data in the (+), (-) classification).

For example, the data for the MSA Ultra-twin were classified as 7, 5, and 0 observations in the classes (-,-), (-,+), and (+,+) with expected values of 3, 6, 3, and 4, and 2 observations in the (-), (+) classes with expected values of 3. The chi-square statistic is $(7-3)^2/3 + (5-6)^2/6 + (0-3)^2/3 + (2-3)^2/3 + (4-3)^2/3 = 9.1667$ with 3 degrees of freedom.

C. Quantitative Fit Testing - Phase I (Unmodified MAG-1s)

Of the 166 QNFTs conducted with the SCBAs in Phase I, three test subjects failed to achieve a PF of greater than 10 000 (Table III). Of these three tests, two tests were with the spectacles in place and one was without the spectacles in place. A PF of approximately 1000 was attained with the Scottoramic facepiece with the spectacles in place. A PF of approximately 5000 was attained for the same facepiece without the spectacles in place and on a different subject. With the MSA 401 pressure-demand air mask using an Ultravue facepiece, a PF of approximately 5000 was attained with the spectacles in place.

The person (size 2 from the panel) (Fig. 4) who obtained a PF of 1000 (Scottoramic facepiece) with the MAG-1s in place compared with >10 000 without the MAG-1s had an obvious penetration of the facepiece-to-face seal by the bridle on one side. Testing of this same test subject with the bridles not

TABLE III

QUANTITATIVE FIT TESTING RESULTS

Phase I

Unit/Facepiece	No. of Tests WITHOUT Spectacles	No. of Tests WITH MAG-1s	PF WITHOUT MAG-1s	PF WITH MAG-1s
Scott Presur-Pak II SCBA/Scottoramic	30	30	29 > 10 000 1 < 10 000	29 > 10 000 1 < 10 000
MSA 401 Pressure-Demand Air Mask/ Ultravue	28	26	28 > 10 000	25 > 10 000 1 < 10 000
Survivair Pressure-Demand SCBA/Silicone	25	27	25 > 10 000	27 > 10 000
MSA PAPR/Ultravue	27	27	27 > 10 000	25 > 10 000 2 < 10 000 27 > 3 000

penetrating the facepiece-to-face seal resulted in PFs of >10 000 for both tests.

The person (size 8 from the panel) who obtained a decreased PF of 5000 (Ultravue facepiece) with the MAG-1s also may have had penetration by the bridle on one side under the seal of the facepiece. It was difficult to make this determination upon penlight inspection of the area.

The test subject (size 3 from the panel) who obtained a PF of 5000 (Scottoramic facepiece) without the MAG-1s had this occur with the first test of the entire testing series. It was evident, on post inspection of the respirator on the face, that there was an area along the forehead where there was a slight anatomical indentation that could have caused the facepiece to not seal adequately. On the second test, in which the MAG-1s were worn, the facepiece was tightened more by the test subject, which could have accounted for the increase in PF (>10 000).

Of the 54 tests conducted with the MSA PAPR with the Ultravue facepiece, all PFs were greater than the ANSI Z88.2-1980[3] recommendation of 3000 for units used with HEPA filters. All tests, in fact, were greater than 10 000 with the exception of two tests on two different test subjects. One test subject (size 2 from the panel) obtained a PF of 4000 with the MAG-1s in place. At the end of the testing, it was noted that the bridle on the right

side was between the facepiece seal and the face. The other test subject (size 4 from the panel) obtained a PF of 8000 while wearing the MAG-1s. Again, it was determined that the bridle and strap attachment area were under the seal on one side. The confounding factor introduced with this size 4 panel member was the fact that the flow rate of the PAPR was less than 4 cfm when checked with the pneumotachograph at the end of this test. This also could have accounted for a decreased PF due to a possible increase of negative pressure inside the facepiece during the exercises.

The P values given by the Wilcoxon Signed Rank Test, using a two-tail normal approximation for the Scott SCBA, MSA SCBA, Survivair SCBA, and MSA PAPR, were 0.517, 0.530, 0.214, and 0.192 respectively. Thus, the null hypothesis of no difference in the PFs with or without the MAG-1s could not be rejected at an alpha of 0.05.

Table IV, showing the mean values of the raw paired test data, quantitatively supports the conclusions of the statistical analysis that there was very little difference in the PFs with or without the MAG-1s because the averages are all very close in value. Thus, QNFT data acquired in Phase I indicated that there was very little difference in PFs with and without the MAG-1s in place.

TABLE IV

MEAN VALUES OF QUANTITATIVE FIT TESTING RESULTS

Phase I

Unit/Facepiece	No. of Paired Tests	Average PF WITHOUT MAG-1s	Average PF WITH MAG-1s
Scott Presur-Pak II SCBA/Scottoramic	30	18 900 (Range: 5000-20 000)	18 500 (Range: 1000-20 000)
MSA 401 Pressure-Demand Air Mask/Ultravue	26	19 700 (Range: 15 900-20 000)	19 400 (Range: 5000-20 000)
Survivair Pressure-Demand SCBA/Silicone	25	19 900 (Range: 19 500-20 000)	19 990 (Range: 19 800-20 000)
MSA PAPR/Ultravue	26	19 500 (Range: 17 900-19 900)	18 900 (Range: 4000-19 900)

D. Quantitative Fit Testing - Phase II (Modified MAG-1s)

Of 71 (35-paired) QNFTs conducted with the SCBAs and 20 (10-paired) QNFTs with the PAPR in Phase II, all test subjects achieved a PF of greater than 10 000 (Table V). At no time did the bridles or strap attachments of the modified MAG-1s penetrate the facepiece-to-face seal of the respirator.

The P values given by the Wilcoxon Signed Rank Test, using a two-tail normal approximation for the Scott SCBA, MSA SCBA, Survivair SCBA, and MSA PAPR, were 0.249, 0.839, 0.080, and 0.097 respectively. Thus, the null hypothesis could not be rejected at an alpha of 0.05.

Table VI, showing the mean values of the raw-paired data quantitatively, supports the conclusion of the statistical analysis, indicating very little difference in the means of the PFs with and without the MAG-1s.

Additional QNFTs were conducted that included three members of the Personnel Protection Studies Section. This increased the number of tests performed with the SCBAs to 79 (39 paired) and with the PAPR to 24 (12 paired). All test subjects achieved a PF of >10 000 (Table VII).

TABLE V

QUANTITATIVE FIT TESTING RESULTS

Phase II[a]

Unit/Facepiece	No. of Tests WITHOUT Spectacles	No. of Tests WITH MAG-1s	PF WITHOUT MAG-1s	PF WITH MAG-1s
Scott Presur-Pak II SCBA/Scottoramic	11	11	11 > 10 000	11 > 10 000
MSA 401 Pressure-Demand Air Mask/ Ultravue	13	12	13 > 10 000	12 > 10 000
Survivair Pressure-Demand SCBA/Silicone	12	12	12 > 10 000	12 > 10 000
MSA PAPR/Ultravue	10	10	10 > 10 000	10 > 10 000

[a]Test results do not include data using Personnel Protection Studies Section personnel as test subjects.

TABLE VI

MEAN VALUES OF QUANTITATIVE FIT TESTING RESULTS

Phase II[a]

Unit/Facepiece	No. of Paired Tests	Average PF WITHOUT MAG-1s	Average PF WITH MAG-1s
Scott Presur-Pak II SCBA/Scottoramic	11	19 700 (Range: 17 000-20 000)	19 400 (Range: 15 400-20 000)
MSA 401 Pressure-Demand Air Mask/Ultravue	12	18 000 (Range: 11 700-20 000)	18 100 (Range: 12 200-20 000)
Survivair Pressure-Demand SCBA/Silicone	12	20 000 (Range: 19 600-20 000)	19 200 (Range: 12 700-20 000)
MSA PAPR/Ultravue	10	19 400 (Range: 18 500-19 700	19 700 (Range: 19 500-20 000)

[a]Without Personnel Protection Studies Section personnel data.

TABLE VII

QUANTITATIVE FIT TESTING RESULTS

Phase II[a]

Unit/Facepiece	No. of Tests WITHOUT Spectacles	No. of Tests WITH MAG-1s	PF WITHOUT MAG-1s	PF WITH MAG-1s
Scott Presur-Pak II SCBA/Scottoramic	12	12	12 > 10 000	12 > 10 000
MSA 401 Pressure-Demand Air Mask/ Ultravue	14	13	14 > 10 000	13 > 10 000
Survivair Pressure-Demand SCBA/Silicone	14	14	14 > 10 000	14 > 10 000
MSA PAPR/Ultravue	12	12	12 > 10 000	12 > 10 000

[a]Test results do include data using Personnel Protection Studies Section personnel as test subjects.

The P values for the three Personnel Protection Studies Section persons included for the Scott, MSA, and Survivair SCBAs, and the MSA PAPR were 0.249, 0.839, 0.116, and 0.045 respectively. Note that this statistical evaluation indicates that the difference of means with the MSA PAPR is significant at the 0.05 level, indicating a lower PF without the MAG-1s compared with the MAG-1s. However, practically speaking, there was no meaningful difference

with or without the MAG-1s because all of the PFs were greater than 10 000, and the accuracy of measured PFs greater than 10 000 is questionable.

Table VIII, showing the mean values of the PFs for the data including test results of Personnel Protection Studies Section personnel, indicated very little difference in the means with and without the MAG-1s. Because the chamber aerosol became diluted by 1-5 per cent because of the filtered air from the PAPR being blown into the test chamber, most reported PFs for the PAPR were slightly lower than if the chamber concentration of aerosol had remained stable.

E. Quantitative Fit Testing - Phase III (Modified MAG-1s)

Using the three previously described negative-pressure air-purifying respirators, 276 QNFTs were conducted (Table IX). Of the 276 QNFTs, 268 were paired tests that could be evaluated using the comparative data obtained. It should be noted that two test subjects (face sizes 2 and 10) could not obtain an acceptable fit with the MSA Ultra-twin, and seven test subjects (face sizes 2, 2, 4, 6, 7, 10, 10) (Fig. 4) could not obtain an acceptable fit with the Norton Series 7600. With the size 2 faces, which represent the biggest faces on the panel, either the respirators could not be donned because of interference by the MAG-1s, or the MAG-1s were too uncomfortable when the respirator was in place. In either case, the testing could not proceed.

A chi-square test was used to evaluate the unrounded data from Phase III. The chi-square values for the Ultravue, Ultra-twin, and Norton, using a PF of 20 000 as the upper bound, were 2.971 (3 d.f.), 8.070 (3 d.f.), and 14.294 (2 d.f.). The chi-square value for the Ultravue was not significant at the 0.05 level ($\rho \geq 0.05$); therefore, the null hypothesis of no effect on the PFs with the MAG-1s in place could not be rejected. Significance did occur at the 0.05 and 0.01 levels for the Ultra-twin and Norton respirators respectively, indicating that there was an effect on the PF of these respirators, lowering the PF when the MAG-1s were in place.

Table X shows that the raw data of the unrounded PFs were evaluated using the arithmetic means of obtained PFs with each respirator with and without the MAG-1s. The averages were consistently higher without the MAG-1s compared with the MAG-1s, with very large ranges in PFs noted. Although the differences are evident, these averages are very high, with the lowest average being 3500. This indicates that although some obtained PFs were <50 (with 28

TABLE VIII

MEAN VALUES OF QUANTITATIVE FIT TESTING RESULTS

Phase II[a]

Unit/Facepiece	No. of Paired Tests	Average PF WITHOUT MAG-1s	Average PF WITH MAG-1s
Scott Presur-Pak II SCBA/Scottoramic	12	19 700 (Range: 17 000-20 000)	19 400 (Range: 15 400-20 000)
MSA 401 Pressure-Demand Air Mask/Ultravue	13	18 300 (Range: 11 700-20 000)	18 100 (Range: 12 200-20 000)
Survivair Pressure-Demand SCBA/Silicone	14	19 900 (Range: 19 600-20 000)	19 400 (Range: 12 700-20 000)
MSA PAPR/Ultravue	12	19 400 (Range: 18 500-19 700	19 700 (Range: 19 500-20 000)

[a]With Personnel Protection Studies Section personnel data.

TABLE IX

QUANTITATIVE FIT TEST RESULTS
(NEGATIVE-PRESSURE FULL-FACEPIECE RESPIRATORS/MODIFIED MAG-1s)

Phase III

Respirator	No. Tests WITHOUT MAG-1s	No. Tests WITH MAG-1s	No. Test Subj. Disqualified	PF WITHOUT MAG-1s		PF WITH MAG-1s	
				No. Subj.	PF	No. Subj.	PF
MSA Ultravue	52	51	0	35	>10 000	29	>10 000
				45	> 1 000	48	> 1 000
				51	>100	50	>100
				51	>50	51	>50
				1	<50	0	<50
MSA Ultra-twin	51	47	2 (Sizes 2 and 10) (Fig. 4)	25	>10 000	19	>10 000
				43	> 1 000	39	> 1 000
				49	>100	46	>100
				51	>50	46	>50
				0	<50	1	<50
Norton (Series 7600)	37	38	7 (Sizes 2, 2, 4, 6, 7, 10, 10) (Fig. 4)	16	>10 000	4	>10 000
				27	> 1 000	18	> 1 000
				34	>100	31	>100
				36	>50	37	>50
				1	<50	1	<50

TABLE X

MEAN VALUES OF QUANTITATIVE FIT TESTING RESULTS

Phase III

Respirator	No. Paired Tests	No. Disqualified	Average PF WITHOUT MAG-1s	Average PF WITH MAG-1s
Ultravue	50	0	12 900 (Range: 30–20 000)	11 300 (Range: 60–20 000)
Ultra-twin	48	2 (Sizes 2 and 10) (Fig. 4)	10 300 (Range: 50–20 000)	8 500 (Range: 70–20 000)
Norton Series 7600	36	7 (Sizes 2,2,4,6. 7,10,10) (Fig. 4)	9 100 (Range: 40–20 000)	3 500 (Range: 30–20 000)

being the lowest) and considered not acceptable, most PFs were actually very high (>1000). This becomes more evident when Table IX is examined. In 128 tests, subjects achieved a PF of >10 000; in 261 tests, subjects achieved a PF of $\geq$100. Four different test subjects failed to achieve a PF of 50. Two of these tests were with the MAG-1s in place and two were without the MAG-1s in place.

In summary it is evident, from evaluation of the raw data from Phase III, that although the MAG-1s did decrease the PF of the respirators on the average, 80 per cent of the tests with or without the MAG-1s showed PFs greater than or equal to 1000, 95 per cent of the test subjects had a PF >100 and 98 per cent of the test subjects had a PF >50. These results do not account for the possibility of a reduced PF under actual field use conditions.

F. Cylinder-Life Testing - Phase I (Unmodified MAG-1s)

Using the Wilcoxon Signed Rank Test to evaluate the data of the 79-paired cylinder-life tests, the P values for the Scott, MSA, and Survivair SCBAs were 0.270, 0.700, and 0.681 respectively. The null hypothesis could not be rejected at the 0.05 level of significance for this data. The indication was that there was little, if any, difference in cylinder life with or without the MAG-1s.

Included in the 79 tests were two paired tests in which one of the pairs in each set had to be discontinued before 15 min. This was due to low pressure in the cylinder because of a large amount of outward leakage of the cylinder air from the facepiece. Both of these test subjects were from the smallest size on the panel (size 10), and both shortened tests were with the MAG-1s in place with a Scottoramic facepiece. One test subject consumed 24.1 ft^3 of cylinder air in a 14.25-min test with the MAG-1s in place compared with 10.2 ft^3 without the MAG-1s in place. The other test subject consumed 17.6 ft^3 of cylinder air in 14 min with the MAG-1s in place compared with 12.3 ft^3 without the MAG-1s. Both of these test subjects obtained a PF greater than 10 000 during the time cylinder air was available.

Table XI shows that for each unit the average volume of breathing air consumed with and without the spectacles in place was approximately the same. The wide ranges were generally indicative of breathing-air consumption differing from person to person, except as previously described.

The raw data for Phase I cylinder-life tests were further evaluated in Table XII. The face sizes of small, medium, and large from the anthropometric chart (Fig. 4), with overlaps in sizes 4 and 7 (Fig. 4), were grouped to determine if there was a tendency for the cylinder life to be affected by the subject's face size used with the respirators. The ranges, in percentage, denoted the percentage difference between the tests with and without the MAG-1s. For instance, using the Scott SCBA, 10 test subjects who were defined as having large faces had a decreased cylinder life without the MAG-1s compared with their individual test with the MAG-1s. The percentage of those paired differences ranged from 1 per cent to 9 per cent. To determine the approximate effect on the cylinder life, it was necessary to multiply the per cent by the amount of time a fully pressurized cylinder should provide air given the person who was working at a slow-to-moderate work rate (30 min for a cylinder pressurized to 2216 psi). For example, a 9 per cent difference would indicate that without the MAG-1s in place, the cylinder life was decreased by approximately 3 min more on a 30-min cylinder life compared with the test with the MAG-1s.

The percentage of differences in the paired tests (Table XII) was small. The highest percentage difference was 18 per cent with a small face (size 6) wearing the Survivair SCBA and MAG-1s. This equated to an approximate 6 min decrease (based on a 30 min cylinder life) when wearing the MAG-1s compared to

TABLE XI

CYLINDER-LIFE TEST TESULTS

Phase I

Unit/Facepiece	Number of Paired Tests	Average Vol. (ft^3) Consumed WITHOUT MAG-1s	Average Vol. (ft^3) Consumed WITH MAG-1s
Scott Presur-Pak II SCBA/Scottoramic	30	12.2 (Range: 7.8-17.7)	12.6 (Range: 7.8-24.1)
MSA 401 Pressure-Demand Air Mask/Ultravue	26	10.1 (Range: 6.9-17.9)	10.2 (Range: 7.6-17.3)
Survivair Pressure-Demand SCBA/Silicone	23	13.3 (Range: 8.5-19.0)	13.5 (Range: 8.4-19.5)

TABLE XII

DECREASED CYLINDER-LIFE DATA CATEGORIZED BY FACE SIZE WITH RANGES OF PERCENTAGE DIFFERENCE FROM PAIRED TEST

Phase I

Unit/Facepiece	Large Face Size (Sizes 1,2,4,5)[a]		Medium Face Size (Sizes 3,4,7,8)		Small Face Size (Sizes 6,7,9,10)	
	No. of Test Subj. w/Decreased C.L.[b] WITHOUT MAG-1s	No. of Test Subj. w/Decreased C.L. WITH MAG-1s	No. of Test Subj. w/Decreased C.L. WITHOUT MAG-1s	No. of Test Subj. w/Decreased C.L. WITH MAG-1s	No. of Test Subj. w/Decreased C.L. WITHOUT MAG-1s	No. of Test Subj. w/Decreased C.L. WITH MAG-1s
Scott Presur-Pak II SCBA/Scottoramic	10 (Range: 1-9%)	2 (Range: 4-16%)	12 (Range: 1-9%) 1 pr = same vol.	2 (Range: 7-14%)	5 (Range: 1-11%)	6 (Range: 1-11%)[c]
MSA 401 Pressure-Demand Air Mask/ Ultravue	5 (Range: 3-11%)	6 (Range: 1-5%)	3 (Range: 2-7%) 2 pr = same vol.	8 (Range: 1-11%)	5 (Range: 2-6%)	5 (Range: 7-12%)
Survivair Pressure-Demand SCBA/ Silicone	7 (Range: 1-8%)	4 (Range: 2-6%)	3 (Range: 1-2%)	8 (Range: 1-4%)	4 (Range: 4-11%)	5 (Range: 4-28%)

[a]Underlined numbers denote overlap in categories.
[b]C.L. = Cylinder Life.
[c]Data do not include two tests that had to be discontinued before the 15 min. These are discussed in the text.

not wearing the MAG-1s. Note that Table XII does not include the data from the two tests using the Scottoramic facepiece that had to be discontinued before the 15 min. These tests cannot be considered as paired data but are interesting because in both shortened tests the subjects were wearing the MAG-1.

Although it is interesting from the standpoint of the decreased cylinder-life data for the various SCBAs among the categories of face sizes, it must be pointed out that these values, when compared as paired data not associated with face sizes, were not statistically significant at the 0.05 level.

G. Cylinder-Life Testing - Phase II (Modified MAG-1s)

Using the Wilcoxon Signed Rank Test, the data of the 30-paired cylinder-life tests were evaluated (Table XIII). The P values given by the Wilcoxon Signed Rank Test for Phase II (without Personnel Protection Studies Section personnel) for the Scott SCBA, MSA SCBA, and Survivair SCBA were 0.042, 0.308, and 0.508 respectively. The null hypothesis could not be rejected at the 0.05 level of significance for the MSA and Survivair SCBAs. It could be rejected at this level for the Scott SCBA because the value obtained indicated that there was a statistical difference between the means with the Scott SCBA at an alpha level of 0.05. This means that at the 0.05 level of significance, statistical analysis of the data indicates more air was consumed with the MAG-1s in place compared with the paired tests without the MAG-1s.

As shown in Table XIII, which does not include data from tests with Personnel Protection Studies Section personnel, the average volumes consumed with and without the MAG-1s in place were practically the same. The ranges again illustrated the differences in air consumption among persons. All test subjects were able to complete the 15-min paired tests.

Data from testing conducted, utilizing members of the Personnel Protection Studies Section, are shown in Table XIV. There was no difference with or without the MAG-1s for the cylinder-life data with the MSA or Survivair SCBA units, with the P values being 0.450 and 0.694 respectively. No Personnel Protection Studies Section personnel were tested with the Scott unit. The results indicated that the null hypothesis could not be rejected at an alpha level of 0.05, meaning that there was little difference in means in tests conducted with and without the MAG-1s. As in the data for Phase II cylinder-life test results (Table XIII) without the Personnel Protection

TABLE XIII

CYLINDER-LIFE TEST RESULTS

Phase II[a]

Unit/Facepiece	Number of Paired Tests	Average Vol. (ft^3) Consumed WITHOUT MAG-1s	Average Vol. (ft^3) Consumed WITH MAG-1s
Scott Presur-Pak II SCBA/Scottoramic	10	12.1 (Range: 8.3-18.5)	12.6 (Range: 9.8-18.2)
MSA 401 Pressure-Demand Air Mask/Ultravue	10	10.8 (Range: 7.5-14.7)	10.4 (Range: 7.7-15.5)
Survivair Pressure-Demand SCBA/Silicone	10	13.3 (Range: 10.3-17.5)	14.0 (Range: 11.1-19.9)

[a]Data do not include Personnel Protection Studies Section personnel.

TABLE XIV

CYLINDER-LIFE TEST RESULTS

Phase II[a]

Unit/Facepiece	Number of Paired Tests	Average Vol. (ft^3) Consumed WITHOUT MAG-1s	Average Vol. (ft^3) Consumed WITH MAG-1s
Scott Presur-Pak II SCBA/Scottoramic	10	12.1 (Range: 8.3-18.5)	12.6 (Range: 9.8-18.2)
MSA 401 Pressure-Demand Air Mask/Ultravue	11	10.8 (Range: 7.5-14.7)	10.5 (Range: 7.7-15.5)
Survivair Pressure-Demand SCBA/Silicone	12	13.6 (Range: 10.3-17.5)	14.1 (Range: 11.1-19.9)

[a]Data do include tests using Personnel Protection Studies Section personnel.

Studies Section personnel, there was very little difference in the mean values for the volumes consumed with and without the MAG-1s when the extra data were added. All test subjects were able to complete the 15-min paired tests. Further comparison of average test volumes for each unit tested was made with the Phase I data from Table XI. It was interesting to note that the average volumes consumed in both phases were very similar with and without the MAG-1s in place.

Further evaluation of the raw data was done again comparing the face sizes with increased consumption of air as was done in the Phase I cylinder-life results discussed previously. These data are presented in Table XV. The percentage of differences in most cases was rather small, with the highest percentage difference being 29 per cent with a small face (size 6) with the Survivair SCBA and MAG-1s. (Note: this size 6 did not participate in Phase I tests.) This equated to an approximately 9-min decrease (based on a 30-min cylinder life) when wearing the MAG-1s compared with not wearing the MAG-1s. This type of decrease in an atmosphere, immediately dangerous to life and health or with a firefighter's SCBA, could be highly significant.

H. MAG-1 Sizes Used in Testing

In Table XVI, the distribution is shown of MAG-1 sizes used in Phases I, II, and III. A majority of the test subjects wore the smallest size MAG-1 (46-22 or 46-25).

I. Limitations

As with most studies, certain limitations of the information must be noted.

1. The information presented directly pertains to the use of the MAG-1s with the four positive-pressure and three negative-pressure devices tested only.
2. The data from this project cannot be directly applied to other positive-pressure or negative-pressure respirators. Each respirator type should be evaluated separately with the MAG-1s. This would require an experimental evaluation using QNFT procedures.
3. Whenever MAG-1s are to be worn with respirators, each user/respirator/MAG-1 combination must be evaluated for satisfactory performance.
4. Test data were obtained under controlled laboratory conditions with exercises approximating a slow-to-moderate work rate. The effects of poor donning practices, twisted straps beneath the sealing surface of the respirator, hard work practices, extreme body movements, etc., were not tested, but these would be expected to decrease the PF.

J. Discussion

A factor that could not be controlled in this project was the amount of training or experience that an individual had before the testing. This could

TABLE XV

DECREASED CYLINDER-LIFE DATA CATEGORIZED BY FACE SIZE WITH RANGES OF PERCENTAGE DIFFERENCE FROM PAIRED TEST

Phase II

Unit/Facepiece	Large Face Size (Sizes 1,2,4,5)[a]		Medium Face Size (Sizes 3,4,7,8)		Small Face Size (Sizes 6,7,9,10)	
	No. of Test Subj. w/Decreased C.L.[b] WITHOUT MAG-1s	No. of Test Subj. w/Decreased C.L. WITH MAG-1s	No. of Test Subj. w/Decreased C.L. WITHOUT MAG-1s	No. of Test Subj. w/Decreased C.L. WITH MAG-1s	No. of Test Subj. w/Decreased C.L. WITHOUT MAG-1s	No. of Test Subj. w/Decreased C.L. WITH MAG-1s
Scott Presur-Pak II SCBA/Scottoramic	2 (Range: 1-2%)	2 (Range: 1-8%).	0	4 (Range: 1-6%)	0	4 (Range: 2-15%)
MSA 401 Pressure-Demand Air Mask/ Ultravue	1 (9%)	3 (Range: 1-5%)	2 (Range: 13-15%)	2 (Range: 1-4%)	2 (Range: 8-13%)	2 (2% = both)
Survivair Pressure-Demand SCBA/ Silicone	2 (Range: 6-9%)	2 (Range: 1-6%)	2 (Range: 5-6%)	3 (Range: 2-13%)	2 (Range: 3-7%)	2 (Range: 13-29%)

[a]Underlined numbers denote overlap in categories.
[b]C.L. = Cylinder Life.
(All data included.)

TABLE XVI

MAG-1 SIZES USED WITH THE TEST PANELS

Size	(Phase I) Number of Subjects	(Phase II) Number of Subjects	(Phase III) Number of Subjects
46-22 Small	17	8	11
46-25 Small	4	1	5
48-22 Medium	3	2	5
48-25 Medium	4	2	4
50-22 Large	0	1	0
50-25 Large	0	0	1

have affected how well the respirator was finally adjusted as well as how much anxiety the wearing of the apparatus produced. An increase in the anxiety level in either of the paired tests with each of the SCBAs could have accounted for an increase in cylinder air consumption.

Another factor that was difficult, if not impossible, to control was the variability of donning and tightening of the straps for each test. Although an attempt was made in Phase I to control this, it was always somewhat suspect as to whether or not the respirator could be donned consecutively the same way

even with expert assistance. These factors must be considered when presenting the entire picture of the experiment. It is judged that these factors did not have significant effect on the overall results; therefore, comparative analysis of the data is considered appropriate. Paired tests and randomization of test order should have accounted for these factors.

Although the limitations noted in Section IV-G relative to extrapolation of the results to typical field situations are a concern, much of the existing respirator PF data is based on laboratory testing, and it seems appropriate to consider the data in this report to have similar validity.

V. SUMMARY

In this three-phase study, using anthropometrically selected test panels of 25, 10, and 25 persons for Phases I, II, and III respectively, paired data were acquired for PFs and cylinder-life values for tests with and without MAG-1s with 4 positive-pressure and 3 negative-pressure respirators.

The Wilcoxon Signed Rank Test was used to determine any statistical difference in the paired data acquired from Phases I and II. Statistical evaluation of the data indicated the following:

1. In Phases I and II (positive pressure), there were no significant differences at the 0.05 level in the PFs with and without the MAG-1s.
2. In Phase I there was no statistical difference at the 0.05 level in the cylinder-life of the selected SCBAs with or without the MAG-1s.
3. In Phase II, there was no statistical difference at the 0.05 level in the cylinder life data of the MSA and Survivair SCBAs.
4. In Phase II, there was a statistical difference at the 0.05 level for the cylinder-life data associated with the Scott Presur-Pak II SCBA used with the Scottoramic pressure-demand facepiece, indicating more air was used with the MAG-1s in place than without the MAG-1s in place. This was not significant at the 0.01 level.

A chi-square test addressing the observed and expected values was used to evaluate the data in Phase III (negative-pressure respirators). Following are the results:

1. No statistical differences in PFs were noted with or without the MAG-1s with the MSA Ultravue respirator ($\alpha = 0.05$).
2. There was a statistical difference in PFs at an $\alpha = 0.05$ level for the MSA Ultra-twin respirator, indicating a lower PF with the MAG-1s than without the MAG-1s.

3. There was not a statistical difference in PFs at an $\alpha = 0.05$ level for the Norton Series 7600 respirator, but a statistical difference in PFs at an $\alpha = 0.01$ level, indicating a statistically significant lower PF with the MAG-1s than without the MAG-1s at this level.

VI. CONCLUSIONS

At a 0.05 level of significance, statistical evaluations of the test results for PF and cylinder-life data indicate that, with one exception, the MAG-1s could be worn by the test subjects with the four types of positive-pressure respirators tested. The exception was the Scott SCBA in the Phase II cylinder-life tests where a $\rho = 0.042$ indicated a significant decrease in cylinder life for the test subjects wearing the MAG-1s.

The statistical analyses of the data for the three types of negative-pressure full-facepiece respirators tested indicate a PF decrease for the MSA Ultra-twin (at $\alpha = 0.05$) and Norton Series 7600 (at $\alpha = 0.01$) when used with the MAG-1s. Ninety-five per cent of the test population wearing the negative-pressure respirators achieved a PF of >100 with and without the MAG-1s. A majority of wearers experienced a PF decrease with the MAG-1s in place compared with the paired test without the MAG-1s.

The results of this three-phase study do not account for the possibility of reduced PFs in actual field conditions.

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13. ABSTRACT (200 words or less)

Results of testing conducted at Los Alamos National Laboratory, Personnel Protection Studies Section, using MAG-1 spectacles in conjunction with positive- and negative-pressure full-facepiece respirators, are reported. The purpose of the three-phase study was to determine if the specially constructed strap of the MAG-1s affected the protection factors (PFs) of the respirators or the cylinder life of selected self-contained breathing apparatus (SCBA). The following respirators were tested with the MAG-1s: a) Phases I and II, positive-pressure full facepiece: Presur-Pak II SCBA (pressure-demand) Scottoramic facepiece, MSA 401 Air Mask Ultravue facepiece (medium), Survivair pressure-demand SCBA/silicone full facepiece, MSA powered air-purifying respirator/Ultravue facepiece (medium); b) Phase III, negative-pressure full facepiece: MSA Ultravue (small, medium, large), MSA Ultra-twin (small, medium, large), Norton Series 7600 (one size only).

Statistical analysis and review of the test data from Phases I and II indicated little, if any, variation with and without the MAG-1s with most protection factors greater than 10 000. Test data also indicated little, if any, difference in the cylinder life with and without the MAG-1s, except the Scott Presur-Pak II SCBA used with the Scottoramic facepiece.

Statistical analysis of the quantitative fit test data indicated no difference in PFs for the negative-pressure devices for the Ultravue negative-pressure respirator, but a significance at the 0.05 and 0.01 levels for the Ultra-twin and Norton full facepieces, respectively.

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