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**EVALUATION OF ONE-YEAR RESULTS OF THE FULL-FACE
RESPIRATOR QUANTITATIVE MAN-TEST FITTING
PROGRAM AT THE LAWRENCE LIVERMORE LABORATORY**

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University of California, Livermore

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MS. date: December 8, 1976

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EVALUATION OF ONE-YEAR RESULTS OF THE FULL-FACE RESPIRATOR QUANTITATIVE MAN-TEST FITTING PROGRAM AT THE LAWRENCE LIVERMORE LABORATORY

Abstract

In August 1975, Lawrence Livermore Laboratory began to quantitatively fit all employees who are or may be required to wear any type of full-face respirator. After one year, 306 employees have been fitted. A total of 1362 tests were made, using seven makes of full-face respirators. Of the 306 employees fitted, 284 were tested using more than one make of full-face mask.

All employees fitted could get a maximum use limit (MUL) of at least 100. 81 has a MUL of 100 to 499 on at least one of the makes of masks

tested, 11% had an MUL of 500 to 999, 13% had an MUL of 1000 to 1999, 24% had an MUL of 2000 to 4999, and 44% had an MUL greater than 5000. These numbers were derived using the average of the peak leakages occurring during each of six exercises performed while wearing each mask. If the overall average leakage occurring during the six exercises rather than the peak average is used in the calculations, 90% of the employees could obtain an MUL over 1000 on at least one make of mask.

Introduction

All personnel at Lawrence Livermore Laboratory who wear or might have occasion to wear any type of full-face respiratory protective device are annually screened by the Medical Department for such usage. After medical approval is granted, these employees are then given a quantitative man-test fitting to find out which makes of full-face respirators will give them a satisfactory facepiece-to-face seal.

The criterion for satisfactory seal at LLL has been that the integrated

average leakage does not exceed 0.5% while the test subject performs a series of six exercises, and that the peak leakage during any one or more of the six exercises does not exceed 1.0%. A maximum use limit (MUL)* of 100 is then used for the

* Maximum Use Limit (MUL) for a respirator is a number which is the multiple of the permissible time-weighted average or excursion limit for toxic materials or the MPC for radioactive materials, and is obtained by dividing 100 by the percent leakage: $(MUL = \frac{100}{\% \text{ Leakage}})$.

full-face respirator whenever the facepiece is under negative pressure. Further details on the fitting program can be found elsewhere.¹

This report is intended to evaluate

the quantitative man-test fitting program results, the different makes of facepieces used in the program in regard to their fitting characteristics, and the program itself.

Equipment and Procedures

The number of facepieces with which a person is fitted will depend on whether that person requires the use of air-purifying, supplied-air, self-contained breathing apparatus, or any two or all three types. For those people requiring the use of only air-purifying full-face respirators, the fitting tests are generally run with the MSA Clearvue, the MSA Ultravue, the Acme, and the Welsh masks. If the use is limited to self-contained breathing apparatus (SCBA), the fitting tests are generally conducted using the MSA Clearvue, the MSA Ultravue, the 6000 Series Scottoramic "old" style mask and the 9000 Series Scottoramic "new" style mask. Toward the end of the first year of fitting, the Survivair silicone mask was added to those being fitted with SCBA masks, for information only, although this

mask is not being used at Lawrence Livermore Laboratory (LLL). Figures 1 through 7 show the different masks used in the fitting program.

The fitting tests are conducted in a chamber containing air-generated polydisperse dioctylphthalate mist having a mass median aerodynamic diameter of between 0.6 to 0.7 micron. An Air Techniques Incorporated photometer, Model TDA-2C, connected to a recorder, is used for measuring the facepiece leakage (See Fig. 8). A complete description of the testing equipment is given elsewhere.²

For each mask being fitted, the test subject is asked to perform the following six exercises: (1) normal breathing, (2) deep breathing, (3) turning head slowly from side to side, (4) nodding head slowly up and down, (5) reciting the alphabet, and (6) alternately smiling and frowning.

Fig. 1. Acme full-face
respirator.

Fig. 2. MSA Clearvue
facepiece.

Fig. 3. MSA Ultravue
facepiece.

Fig. 4. Scottoramic
facepiece — new
type.

Fig. 5. Survivair
facepiece.

Fig. 6. Scottoramic
facepiece - old type.

Fig. 7. Welsh facepiece.

Fig. 8. Quantitative man-test fitting chamber and instrumentation.

Evaluation of Results

Table 1 shows the results of 1362 quantitative fit tests with seven makes of full-face respirators. The maximum use limits (MUL's) were obtained by taking the integrated average of all six exercises. The tests were made on 306 test subjects, 284 of whom were tested on more than one make of facepiece. Four of the test subjects were female, but no difficulty was experienced in their obtaining a satisfactory fit on at least one make of mask. Often, the generally smaller shape of the female face will make it more difficult to fit a full-face respirator as the facepieces are usually sized for

fitting the average-sized male face.

Table 2 is similar to Table 1, but shows, instead, the MUL obtained when the peak leakages from all exercises are averaged, rather than the integrated average leakage from all exercises.

The current method of arriving at a "pass/fail" limit for a respirator is that the average percent leakage for a full-facepiece must be $<0.5\%$, and that no peak for any exercise shall exceed 1.0% . An MUL of 100 is then assigned to the full-facepiece. An analysis of the data shows that the "pass/fail" criteria could be

Table 1. Results of 1362 quantitative fit tests with seven makes of full-face respirators using integrated average maximum use limit.

Make of respirator	Number of people tested on each make of respirator	% of people tested obtaining the MUL as indicated using integrated averages for six exercises						
		<10	10-100	100-500	500-1000	1000-2000	2000-5000	5000 or greater
Acme	253	4	15	30	11	8	9	23
MSA Clearvue	306	1	7	17	15	18	18	24
MSA Ultravue	222	4	4	20	17	18	18	19
Scottoramie-New	139	2	29	22	11	5	10	21
Scottoramie-Old	185	7	14	21	15	16	18	9
Survivair	19	0	11	5	26	11	21	26
Welsh	<u>238</u>	6	14	28	8	13	11	30
1362 (total)								

Table 2. Results of 1362 quantitative fit tests with seven makes of full-face respirators using peak average maximum use limit.

Make of respirator	Number of people tested on each make of respirator	% of people tested obtaining the MUL as indicated using peak averages for six exercises						
		<10	10-100	100-500	500-1000	1000-2000	2000-5000	5000 or greater
Acme	253	4	23	32	9	8	12	12
MSA Clearvue	306	1	9	25	21	12	16	16
MSA Ultravue	222	4	5	30	18	18	16	9
Scottoramie-New	139	3	34	27	5	8	11	12
Scottoramie-Old	185	8	17	29	15	17	11	3
Survivair	19	0	16	16	16	21	5	26
Welsh	<u>238</u>	5	16	23	12	13	10	21
1362 (total)								

changed to using just the average of the peak leakages for all exercises if it does not exceed 1% (MUL $\geq$ 100). Since a user's average exposure is the integrated average of all exercises, the average of the peaks obtained in all exercises is still conservative. One number for the "pass/fail" criterion would be easier to use than the current system of two numbers.

The analysis also shows that if a user is not permitted to wear any full facepiece that does not give him a MUL of at least 100, he could wear those devices, within the capabilities of the cartridges or canisters, up to the maximum MUL he had obtained on those facepieces. Since only the peak averages are used to determine

the user's MUL, a safety factor is still built in to account for not donning the facepiece in an identical manner each time.

Table 3 shows the highest MUL obtainable on 284 people who were fitted with two or more full-facepieces. In most cases, at least four different full-facepieces were tested. Every person tested could get at least one make of facepiece which gave him or her a MUL over 100. Using the peak averages for all six exercises, 81% of those fitted obtained a MUL of 1000 or greater, of which 44% were over 5000.

Table 4 gives the percent of times in which different makes of full-face respirators were the best and the

Table 3. Highest maximum use limit obtained on 284 people who were fitted with two or more full-face respirators.

Best MUL obtained	Total number of people		% of people	
	Peak ave. for six exercises	Integrated ave. for six exercises	Peak ave. for six exercises	Integrated ave. for six exercises
<100	0	0	0	0
100-500	22	5	8%	2%
500-1000	32	22	11%	8%
1000-2000	36	29	13%	10%
2000-5000	70	52	24%	18%
5000 & greater	124	176	44%	62%

Table 4. Percent of times in which different makes of full-face respirators were the best or poorest fitting on people who were fitted with two or more masks.

Make of respirator	No. of people fitted with this make (two or more different masks used)	% of time when this make gave best fit	% of time when this make gave poorest fit
Acme	253	19	26
MSA Clearvue	284	29	11
MSA Ultravue	222	23	7
Scottoramie "New"	139	11	53
Scottoramie "Old"	185	14	28
Survivair	19	26	11
Welsh	238	24	19

poorest fitting on the 284 employees who were fitted with two or more masks. Again, in most cases, each person was fitted with at least four different makes of masks. The MSA Clearvue, the MSA Ultravue, the new Scottoramie, the old Scottoramie, and the Survivair masks were fitted on those people who use or may have occasion to use self-contained breathing apparatus (SCBA). The Survivair facepiece was only fitted on 19 people as this mask was just obtained in June 1976.* The Acme, MSA Clearvue, MSA Ultravue, and the Welsh facepieces were fitted on people who use or may have occasion to use air-purifying full-facepieces.

For SCBA facepieces, the two MSA facepieces not only gave the best fit to the greatest number of people,

but also gave the poorest fit to the fewest number of people. The Survivair facepiece performed well, based on the low number of people on which it has been tested.

A special internal report has been prepared on the SCBA program at LLL. Portions of this report are included in the Appendix for additional information. The differences in the fitting of the four air-purifying facepieces were not as dramatic as with the SCBAs.

Table 5 shows the first and second choices of facepieces from 196 employees who were fitted with four or more different makes of full-facepieces. The choices were made on comfort only without the test subject knowing whether or not the mask gave a good fit. As far as the Laboratory employees were concerned, the two MSA and the Welsh facepieces were by far the most popular. For those tested, the Survivair facepiece was also well received.

* Thirty firefighters have since been fitted with the Survivair facepiece, and the results are shown in the Appendix.

Table 5. First and second choices of 196 test subjects who were fitted with four or more full-face respirators.^a

Make of respirator	First choice	Second choice	Total
Acme	14	20	34
MSA Clearvue	66	39	105
MSA Ultravue	50	43	93
Scottoramic-New	5	5	10
Scottoramic-Old	16	16	32
Survivair ^b	8	4	12
Welsh	37	36	73

^a Choices were made by test subject on comfort only without subject knowing whether that respirator gave a good fit or a poor fit.

^b Only 19 test subjects were fitted with the Survivair and given this respirator from which to choose.

Conclusions

It is concluded that the "pass/fail" criteria for full facepieces can be based just on the peak leakages for all exercises. A user should not be permitted to use a respirator that does not give him

a MUL of at least 100, but should be permitted to wear a device, within the capabilities of the cartridges or canisters, up to the maximum MUL he has obtained on that device.

References

1. "Respiratory Protection Manual, Supplement 10.05," *Health and Safety Manual*, Lawrence Livermore Laboratory, University of California (Feb. 1977).
2. *Hazards Control Progress Report No. 51, July through December, 1975*, Lawrence Livermore Laboratory, University of California (1976).

Appendix A
A Study of Lawrence Livermore Laboratory Self-Contained
Breathing Apparatus Program

Bruce J. Held and Charles P. Richards

QUANTITATIVE FITTING RESULTS

Table A-1 lists the results of the quantitative fitting tests on the firefighters in groups, according to the percent of leakage occurring. Table A-2 shows the results for each firefighter with the actual amount of leakage occurring with each facepiece tested.

The Scott 6000 series mask that had been altered to accommodate the Metrotech Communications Unit gave a very poor fit to most of the firefighters. This was as expected, since the Metrotech has to be mounted on the right or left side of the facepiece. The Metrotech itself is quite heavy, and this additional weight on only one side of the mask distorts the shape of the facepiece, causing it to leak.

Table A-1. Results of quantitative fitting tests on LLL firefighters with five makes of full-face respirators and a Scott 6000 series mask fitted with a Metrotech Communications Unit using the peak average percent leakage on six exercises.

Type of facepiece	No. of firefighters with < 1% facepiece leakage	No. of firefighters with 1-5% facepiece leakage	No. of firefighters with > 5% facepiece leakage
MSA Clearvue	28	2	0
MSA Ultravue	29	1	0
Scott 6000 facepiece	18	9	3
Scott 9000 facepiece	9	18	2
Survivair	24	5	1
Scott 6000 facepiece with Metrotech Unit	10	16	4

Table A-2. Fitting results of the LLL firefighters by individual SCBA facepieces.

Z facepiece leakage -- peak averages for all exercises

Firefighter test subject no.	Scott 6000	Scott with Metrotech 6000	Scott 9000	MSA Ultravue	MSA Clearvue	Survivair
1	0.25	0.33	3.2	0.1	0.03	0.04
2	0.27	4.4	2.0	0.09	0.04	0.44
3	0.1	0.12	9.0	0.33	0.12	0.07
4	3.3	4.7	4.2	1.5	0.50	2.1
5	0.62	20.0	3.0	0.30	0.20	0.34
6	29.0	24.0	0.23	0.65	0.05	0.13
7	0.6	3.3	3.1	0.3	0.10	0.09
8	3.5	5.0	3.4	0.2	0.36	0.18
9	0.3	0.2	0.6	0.45	0.01	0.17
10	0.7	0.60	0.3	0.05	0.04	0.01
11	4.4	4.8	3.7	0.18	0.1	0.12
12	1.0	0.4	3.2	0.2	0.15	0.02
13	4.4	2.4	0.5	0.06	0.02	0.01
14	1.4	4.6	0.2	0.1	0.14	0.01
15	0.2	1.2	4.5	0.7	0.3	0.24
16	0.01	0.56	0.12	0.2	0.01	0.33
17	0.1	1.28	6.9	0.2	0.2	0.04
18	0.1	0.9	0.3	0.03	0.8	3.2
19	3.2	2.5	1.7	0.3	0.3	1.1
20	0.13	0.92	1.2	0.55	0.02	0.07
21	2.1	3.4	1.9	0.42	1.4	1.2
22	8.4	2.2	1.6	0.6	0.5	1.3
23	0.4	1.0	0.8	0.4	0.1	0.23
24	0.1	1.6	0.1	0.01	0.06	0.08
25	7.0	0.36	—	0.23	1.7	0.57
26	0.07	1.9	1.9	0.37	0.01	0.48
27	0.7	6.9	3.8	0.50	0.09	0.30
28	0.7	0.8	4.4	0.6	0.04	0.20
29	1.7	4.2	4.5	0.3	0.3	8.3
30	0.1	4.0	4.4	0.1	0.03	0.21

Table A-3 shows the percent of time each type of mask was the best fitting and the poorest fitting on the firefighters. Based on fitting alone, the MSA Clearvue is by far the best fitting mask with the LIL Fire Department personnel. Of an added advantage is the fact that the MSA Ultravue can be used on the same 401 SCBA unit, thus giving an option of using two types of masks on the same unit. No other SCBA unit has this option. It should be further noted that the two firefighters who had a leakage between 1-2% on the MSA Clearvue got their best fit on the MSA Ultravue.

COMFORT

Each firefighter being fitted was asked at the end of the session which type of facepiece he preferred, particularly in regard to comfort. Twenty-seven of them gave a first and some a second choice; the remainder either found none of them comfortable or had no preference. Table A-4 lists the preferences of the firefighters who had an option. While there was no overwhelming favorite, the Survivair mask received the greatest number of first and second choices. The other four masks all scored about equally.

Table A-3. Percent of times in which the five makes of masks were the best or the poorest fitting.

Type of facepiece	% of time when this type of facepiece gave the best fit of the five types tested ^a	% of time when this type of facepiece gave the poorest fit of the five types tested ^a
MSA Clearvue	58%	0
MSA Ultravue	15%	0
Scott 6000 facepiece	3%	35%
Scott 9000 facepiece	0	55%
Survivair	24%	10%

^a The results were counted in favor of both types of masks.

Table A-4. Preference of twenty-seven firefighters on which of five facepieces they felt most comfortable.^a

Type of facepiece	First choice	Second choice
MSA Clearvue	6	2
MSA Ultravue	3	6
Scottoramie "Old"	6	2
Scottoramie "New"	5	5
Survivair	7	6

^a These preferences were stated without the firefighters being tested knowing which facepiece gave him a satisfactory fit.

ANTHROPOMETRIC SURVEY

To see if our fitting results were influenced at all by having Fire Department personnel with different facial sizes than would normally be expected with an adult male population, face length and face width measurements were made on nineteen of the firefighters. In general, the LLL Fire Department personnel were very slightly skewed toward having, overall, longer faces than the average adult male population in the Air Force and LASL studies. However, the differences were not great enough to have any effect on the overall fitting characteristics of the individuals tested.