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EVALUATION OF A MINIATURE CONDENSATION NUCLEUS COUNTER FOR QUANTITATIVE FIT TESTING (U)

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DEFENCE RESEARCH ESTABLISHMENT OTTAWA

TECHNICAL NOTE 90-23

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ABSTRACT

A miniature Condensation Nucleus Counter (CNC) was evaluated as a possible tool to measure respirator fit factors under field conditions. The factors which make this instrument a good candidate for fit testing under field conditions are that it uses ambient aerosol as the test agent and is portable. The mini CNC was compared to and correlated with an existing fit testing instrument in a controlled aerosol atmosphere. It was also used outdoors in an uncontrolled aerosol atmosphere and the results were compared to those obtained in a controlled atmosphere. The results indicated good correlation of the mini CNC with current equipment in a controlled atmosphere (for fit factors up to 5,000) whereas very poor correlation results were obtained outdoors. The discrepancies in the results were accounted for by a lack of control of the mini CNC's sampling time, and the fact that it was not possible to monitor aerosol concentrations inside and outside the mask for the duration of a test because the CNC only has one photometer. It was concluded that, although the mini CNC has some shortcomings in its present "as purchased" configuration, there is a good chance that they could be overcome. Further development of a system using the mini CNC for field fit testing is recommended.

RÉSUMÉ

Un détecteur miniature visant à compter le nombre de particules contenues dans l'air ambiant, fut évalué pour déterminer sa capacité de mesurer le facteur de protection de masques à gaz dans le champs. Les facteurs qui font de cet instrument un bon candidat pour ce genre de mesure, sont qu'il est très petit, léger et qu'aucun autre agent traçeur n'est requis autre que l'air ambiant. Il fut comparé et correlé avec un autre instrument plus conventionel dans des conditions ambiantes controllées d'aérosol. Il fut également utilisé dehors, dans des conditions ambiantes non-controllées, et ces résultats furent comparés avec ceux obtenus dans des conditions controllées. Les résultats indiquent une bonne corrélation du détecteur miniature avec sa contrepartie dans des conditions ambiantes controllées, pour des facteurs de protection allant jusqu'à 5,000. Par contre, la corrélation des résultats obtenus dehors ne fut que très médiocre. Les différences entre les résultats furent expliqués, en majeure partie, par le manque de contrôlle des paramètres de mesure du détecteur miniature, et le fait qu'il n'y ait qu'un seul photomètre pour mesurer la concentration d'aérosol ambiante et celle du masque de façon ininterrompue durant les essais. Le rapport conclut qu'il devrait être possible, malgré ces problèmes, d'obtenir des résults significatifs dans des conditions ambiantes non-controllées, moyennant quelques modifications.

EXECUTIVE SUMMARY

The current methods of measuring the protection afforded by a gas mask use aerosol generating and measuring equipment in fixed installations. The entire apparatus usually includes a chamber to contain and control the aerosol concentration, pumps and fans and to generate the aerosol, detection instruments and ancillary equipment. Test subjects enter the chamber and perform standard exercises while the aerosol concentration is measured outside and inside the mask; the ratio of these concentrations is called the fit factor. While these standard exercises are chosen, in principle, to reproduce the movements that individuals are likely to perform in the field, laboratory test conditions generally fall short of this objective.

Since protection factors in the field are what is ultimately of interest to commanders, there is a need to obtain fit factor measurements under actual field conditions. The purpose of this study was to determine whether a commercially-available miniature condensation nucleus counter (CNC), which uses the aerosol present in ambient air to measure the protection afforded by the mask, could be used for that purpose. The objective of the study was twofold:

i) to compare/correlate the mini-CNC with current fit testing equipment in controlled aerosol atmosphere, and,

ii) to compare/correlate fit test results obtained outdoors in an uncontrolled aerosol atmosphere with those obtained in a controlled atmosphere.

The results indicate good correlation of the mini-CNC with current equipment in a controlled atmosphere (for fit factors up to 5,000) whereas very poor correlation results were obtained outdoors. The discrepancies in the results were accounted for by a lack of control of the mini CNC's sampling time, and the fact that it is not possible to monitor aerosol concentrations inside and outside the mask for the duration of a test because only one photometer is available. It was concluded that although the mini CNC has some shortcomings in its present "as purchased" configuration, there is a good chance that they could be overcome. Further development of a system using the mini CNC for field fit testing is recommended.

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1.0 INTRODUCTION

One of the problems facing developers and users of NBC respirators is getting a true measure of the performance of the respirators against a gaseous or aerosol challenge. The current way of evaluating a respirator is by using a laboratory method of evaluation as opposed to a field method. In this method, the subjects are tested in fairly ideal conditions: they are clean shaven, they are not under stress to don their mask, they do not have to perform demanding tasks with it and they do not have to wear it for very long. Although they are put through a series of exercises which try to simulate the movements in their work place, the end result may or may not relate to the real life situation. Because of the difficulty of measuring fit factors in the field with any degree of certainty, it is not known exactly how the laboratory fit evaluation relates to actual field conditions.

Whereas the conventional measuring equipment to measure fit factors is relatively bulky, complex and delicate, a miniature Condensation Nucleus Counter (CNC) was developed by TSI for the US Army Chemical Research, Development and Engineering Center (CRDEC). This instrument seemed to offer the portability and accuracy required for use in quantitative fit testing in the field. The purpose of this study was to investigate the possibility of using the miniature CNC for fit testing in the field. In the first part of this study, the miniature CNC was used with test subjects in a controlled aerosol environment and compared with a forward light scattering photometer. In the second part, the miniature CNC was used in an uncontrolled environment, i.e. outdoors.

2.0 EXPERIMENTAL

2.1 MEASURING INSTRUMENTS

2.2.1 The Corn Oil Aerosol Chamber

The corn oil Quantitative Fit Testing (QnFT) instrument used in this experiment was a Dynatech Frontier model 260BC system, purchased in 1985. The aerosol generated by the instrument has a mean mass aerodynamic diameter between 0.5 μm and 0.7 μm. This instrument uses a forward light scattering photometer which gives a measure of the aerosol mass concentration (mg/m^3). This system is fully automated, and has been successfully correlated with fit factors determined using the gas SF_6 for Fit Factors of up to 10,000 [1].

2.2.2 The Miniature Condensation Nucleus Counter

The instrument used in this experiment was a Portacount™ respirator fit tester made by TSI Inc. The Portacount is based on the technology of condensation nucleus counting, in which particles as small as 0.02 μm are grown to an easily detectable size (around 12 μm) by condensing alcohol vapor on them. This kind of instrument uses a laser diode and gives a measure of the aerosol number concentration (number of particles/cm^3), as opposed to mass concentration. This system is automated, and switching sampling lines from the respirator to the chamber concentration is done automatically. It can detect a single particle.

2.2 TEST PROTOCOL

A total of five subjects were used in these tests. Each subject was fitted with a respirator in which two sampling ports were installed next to each other in the lower half of the right eyepiece. Each subject was checked for fit prior to the experiment to ensure that they had a properly adjusted mask. After this initial check, the subjects were placed two at a time in the corn oil aerosol chamber. One of the mask's ports was connected to the chamber's sampling line and the other to the miniature condensation nucleus counter's (CNC's) sampling line. Two miniature CNCs were used. Since the sampling ports were very close to each other, it was expected that the two sampling lines would measure the same aerosol concentration values. The CNCs were started prior to the test and allowed to stabilize for 3 minutes. The test subjects then carried out the following six exercises:

1. NB - Normal Breathing
2. DB - Deep Breathing
3. SS - Side to Side head motion
4. UD - Up and Down head motion
5. RP - Reading the Rainbow Passage (Annex B)
6. FE - Facial Expressions (smile, yawn and frown)

The beginning of the sampling of both the CNC and forward light scattering photometer was synchronized as well as possible. The duration of each exercise was 45 seconds, and both the CNC and Portacount fit factors were recorded for that exercise. After the series of exercises, the subjects disconnected from the Dynatech chamber sampling lines and walked outside without removing their mask. The same exercises were repeated outdoors, with the CNC only, using the ambient aerosol as the tracing agent. At the completion of the test, the subjects removed their masks, and were allowed to rest for 30 minutes. Each subject repeated the test three times.

3.0 RESULTS & DISCUSSION

During the experiments, two sets of data were obtained: one for the indoor phase, which compared the miniature CNC to the forward light scattering photometer, and one in the outdoor phase, which is simply a measure of the fit of the mask using ambient aerosol. Both data sets are listed in Annex A as they were obtained, i.e. on a per subject basis. For the sake of clarity, the discussion of the results has been separated into the indoor and outdoor phases.

3.1 THE INDOOR PHASE

The fit factors for all of the exercises for each test subjects of the indoor phase were plotted on a log-log scale so as to obtain a global view of the relationship between the Portacount and the Dynatech test chamber fit factors (see Figure 1). It is obvious that a fairly good relationship exists between the

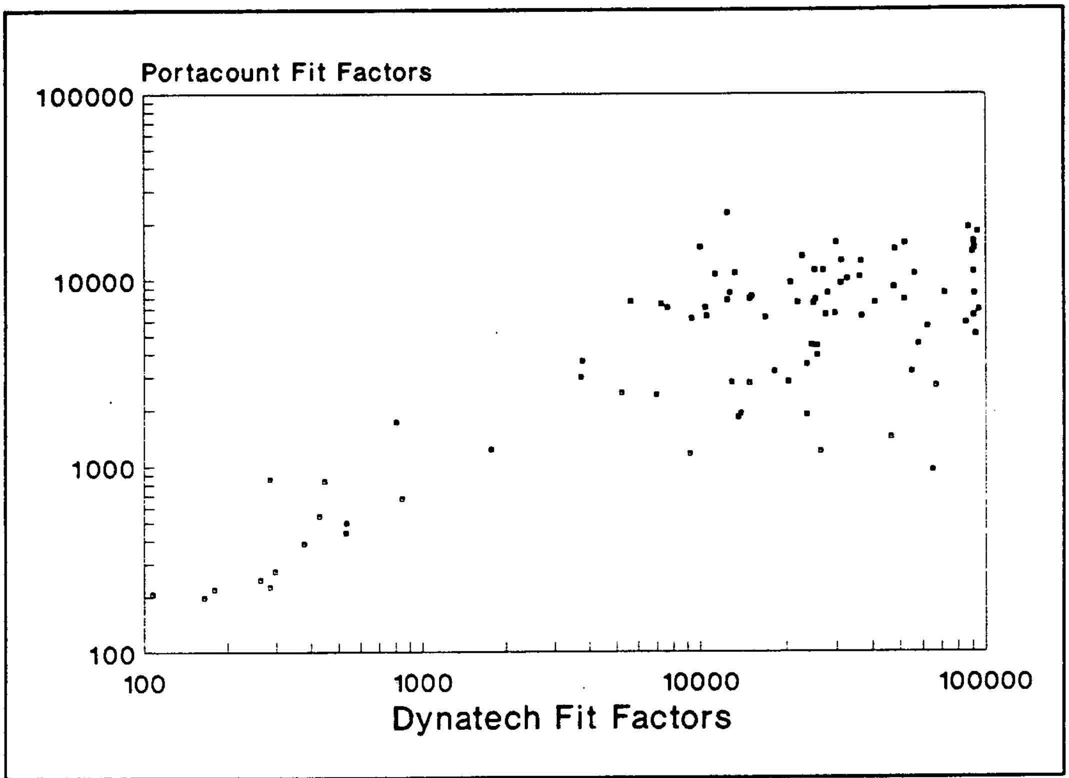

Figure 1 (U) Dynatech vs Portacount fit factors

Portacount and the Dynatech, at least for fit factors up to about 50,000.

It is apparent that the scatter increases significantly as the fit factor increases. Hence, the correlation is quite dependent on the range of fit factors considered. For this reason, it is best to consider the correlation in portions. In this case, a portion comprising fit factors from 0 to 5,000 was analyzed, another comprising fit factors from 0 to 10,000 and a third for the overall data. A summary of the statistics computed for each portion is listed in Table 1.

TABLE I. Summary correlation statistics of the Dynatech vs Portacount fit testing instruments in a controlled aerosol atmosphere.

	Dynatech Fit Factors < 5,000	<10,000	All
Correlation Coefficient, R	0.98	0.85	0.77
Slope	0.90	0.82	0.15
t statistic	15.2	8.1	11.2

The high correlation coefficient (0.98) obtained for the first portion of the graph (i.e. fit factors less than 5,000) confirms the similarity of results obtained with the test instruments. The slope of the least squares fit (0.90) however, indicates that the Portacount has a tendency to yield slightly lower fit factors. A possible explanation, which warrants further investigation, could be that the aerosol particle size distribution within the mask differs from the ambient aerosol's. Going back to the basic differences between the detection instruments in 2.2.1 and 2.2.2, for a given number of particles inside the mask, the mass concentration of the aerosol would vary in accordance with the particle size distribution. Ten large particles, for instance, weigh more than ten small ones. Yet the Portacount would not differentiate between these two conditions. Conversely, a group of twenty particles or a group of ten particles adding up to the same weight would read the same on the Dynatech but not on the Portacount.

As in any filter, it is logical to assume that there will be a specific size of particle which will penetrate through a leak in the faceseal better than another. Particles bigger or smaller than that size would be removed by either impaction for large particles or Brownian motion for smaller particles. It is also logical that the large particles are less penetrating than the smaller ones through the narrow passages of a leak. This means that a larger proportion of small particles would be present inside the mask. Therefore, the number of particles would be high but the total mass would be low.

As expected, the scatter in the results increased with the fit factors and thus the correlation decreased. The second portion of the graph analyzed, which included fit factors from 0 to 10,000, still shows a reasonable correlation coefficient, although the scatter, as evidenced by Figure 2, is quite large from 5,000 on. The fit factors in the 5,000 to 10,000 range do not seem to correlate very well. No attempt was made to correlate fit factors beyond 10,000. The poor correlation above 10,000 is similar to the poor correlation of the fit factors obtained with the Dynatech and a method using SF_6 gas [1].

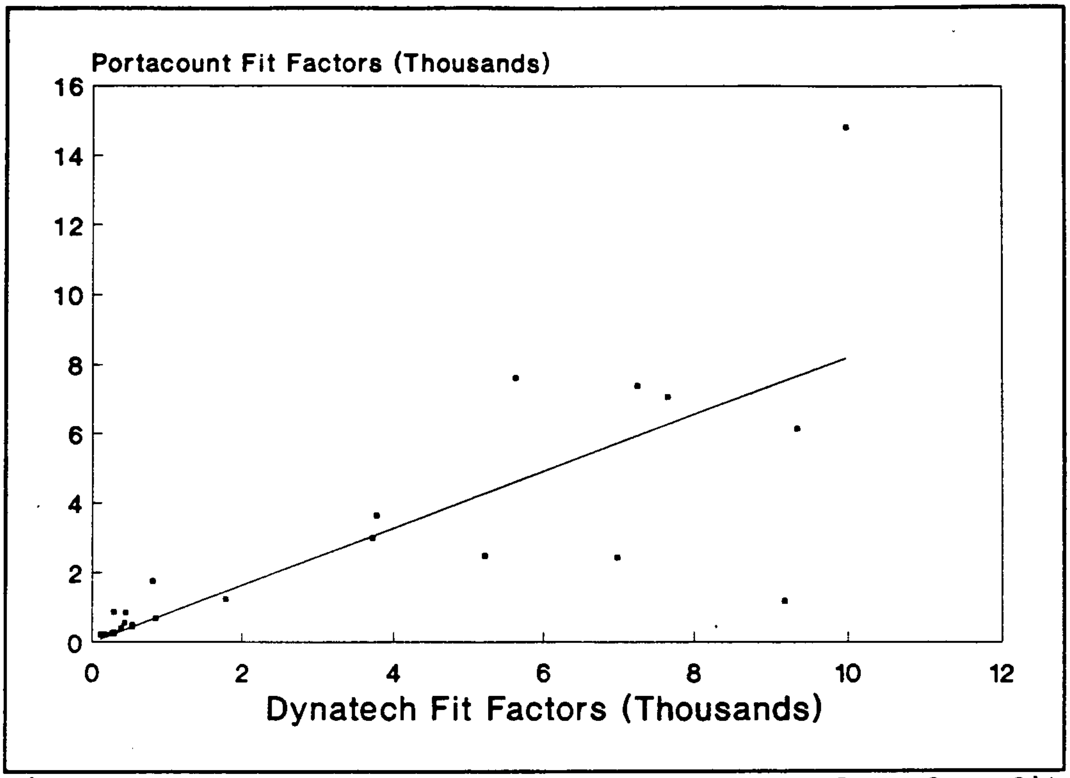

Figure 2 (U) Dynatech vs Portacount results for fit factors less than 10,000.

Several factors affected the correlation of the Dynatech and Portacount fit factors. One of the biggest difficulties was the coordination of the instruments' sampling. When the Portacount is activated, it purges itself with clean air for 4 seconds. It then measures the ambient aerosol concentration for 5 seconds and purges itself again for 11 seconds. It samples the respirator for 10 seconds, purges for 4 before sampling the ambient aerosol for another 5 seconds. Thus, in the 40 seconds it takes the Portacount to carry out one test, only 10 are spent sampling inside the facepiece. This is the consequence of having a single photometer doing internal and external sampling: it must do both sequentially. The Dynatech has three photometers: one for the ambient concentration and two for test subjects and therefore is capable of sampling the mask over the entire 45 seconds.

In cases where the fit factor is stable over the duration of the exercise, this difference would not be noticeable. However, in cases where there is a large fluctuation in the fit factor within the first 20 seconds of the exercise, before the Portacount switches to mask sampling, the difference could be quite significant. One such case, shown in Figure 3, was chosen to illustrate this. At the start of exercise 3 (side to side head motion) there is a distinct dip in the fit factor curve. It is practically over at the 20 second mark, which means it was measured by the Dynatech but not the Portacount. The average fit factor of 5,629 was measured for that exercise by the Dynatech. Omission of

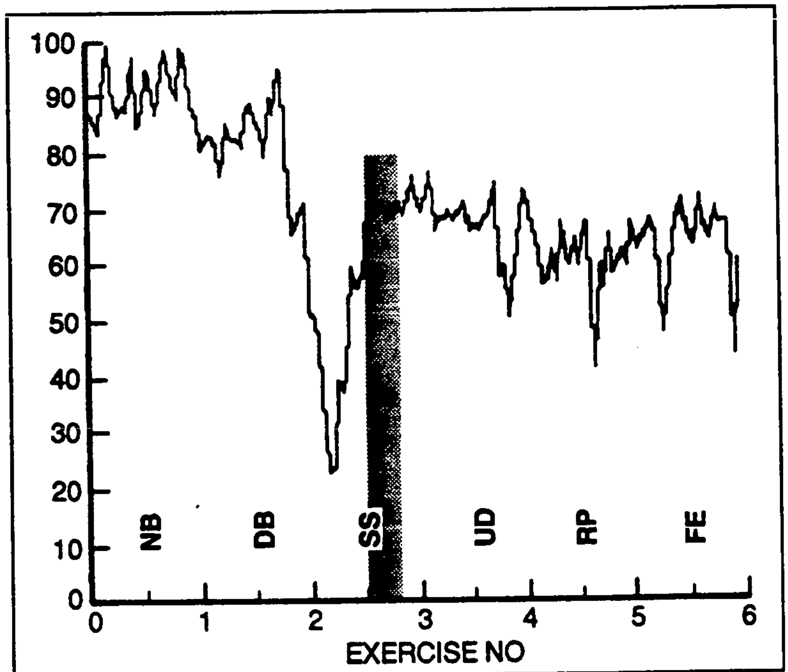

Figure 3 (U) Dynatech fit factor versus exercise (subject 5, test 3).

the dip would bring the average up to approximately 8,000, which is about what the Portacount measured (7,610), and the correlation would be almost perfect. Because of cases like this one, several points on the graph would realign more closely than they do now.

A second factor which could have had an effect on the difference in fit factors between the instruments, is the fact that the sampling lines were not coincidental. They were approximately 5 mm apart. In view of the closeness of their position and the turbulence inside the respirator, this would be expected to be a second order effect, not sufficient to explain the large discrepancies.

3.2 THE OUTDOOR PHASE

Although all precautions were taken not to disturb the fit of the mask during a series of tests, the subjects had to disconnect from the Dynatech sampling line and walk outside. In this process, the fit of the mask could have improved slightly, as perspiration starts forming a better faceseal. Likewise, it could also have been inadvertently displaced, and this could either have improved or worsened the fit. Unfortunately, there is no way of making sure that there was no change in the fit of the mask during transit.

This is one external variable affecting the correlation which cannot be controlled.

The correlation depends not only on maintaining the same faceseal but also on the ability of the test subject to repeat the exercises in the exact same manner outside as he did inside. For instance, he must repeat deep breathing and facial expressions with the same intensity and rhythm as inside. Certainly, it would be difficult to obtain the same fit factor values twice in a row performing a random set of facial expressions. The exact values were rarely obtained, but the pattern of fit factors observed from the effect of exercises however can still be observed in the outdoor fit factor test results. For instance, the effect of speech (the Rainbow Passage) on the fit of the mask is well known, and almost invariably decreases the fit factor. This effect was noted in 13 out of 15 cases of the Portacount inside, and 15 out of 15 cases of the Portacount outdoors. This indicates that the Portacount is responding to the leakage of the mask in the same relative fashion as the Dynatech did inside.

Since the particle size distribution was not measured outdoors, it is not possible to ascertain the mechanism theorized in Section 3.1, i.e. the change in distribution from outside to inside the mask. In this case, however, it is possible that larger particles are present in the ambient air (outdoors), which have not been generated by the corn oil machine, which stand very little chance of passing through the narrow-passages of the faceseal leak. This point could partially explain the higher fit factor values observed.

Also, it should be noted that the ambient aerosol concentration measured outdoors is usually one order of magnitude <u>smaller</u> than the concentration measured in the Dynatech chamber. In the same vein, it should be noted that the fit factor values outdoors tend to be one order of magnitude <u>larger</u> than those obtained indoors. This observation leads to the hypothesis that there is a relationship between the ambient aerosol concentration and the fit factor observed. Let us take for example a mask fit factor of 25,000. For an ambient aerosol concentration of 25,000 particles per cm^3 (as in Appendix A, subject 1), the concentration inside the mask would be 1 particle per cm^3. Given a sampling rate of 1.67 cm^3 per second (0.1 liter per minute), the Portacount would measure, on average, only 17 particles during a complete test. Clearly, large fluctuations can accrue from this condition and it would be quite easy to imagine that, over a 10 second sampling time, fewer particles are actually sampled. Because of this very short sampling time, a difference of a few particles can quickly result in fluctuations of 25 to 35 percent.

It is not surprising therefore to see a large scatter of results in Figure 4. The overall correlation coefficient was calculated to be 0.59, the slope of the regression line 3.94 and a t statistic of 6.97. While the correlation numbers obtained are not very good (in any range of fit factors), they do, however, indicate a relationship between the two variables, i.e. it is not a random distribution of points. The poor correlation numbers point to the process used in this experiment, rather than to the instrument itself, because the relative effect of the exercises on the fit factor was clearly observed (see Annex A). Although an absolute correlation of the Portacount outdoors may not be possible, it is felt that a significant improvement of the fit factor correlation can be achieved by mitigating the effects of some of the external variables. For instance, the actual facepiece sampling time should be controlled as a function of ambient aerosol concentration. Also, since simultaneous sampling of the Portacount with the Dynatech is not possible, the less repeatable exercises, such as facial expressions, should be left out in favour of more repeatable ones. Ideally, an accurate method of measuring fit factors outdoors should be developed so it could be used simultaneously with the Portacount. This would circumvent some of the problems encountered.

Although not as successful as hoped, the outdoor correlation experiments did reveal some of the weaknesses of the Portacount. As in the indoor experiment, the fact that this instrument only has one photometer (to measure both the inside and outside concentrations) proved, indirectly, to be a shortcoming. Because of the low outdoor aerosol concentration, a 10 second facepiece sampling time was clearly insufficient to collect enough particles for an accurate fit factor calculation. Indoor, the correlation was strongly dependent on how representative the 10 second facepiece sampling was of the total exercise.

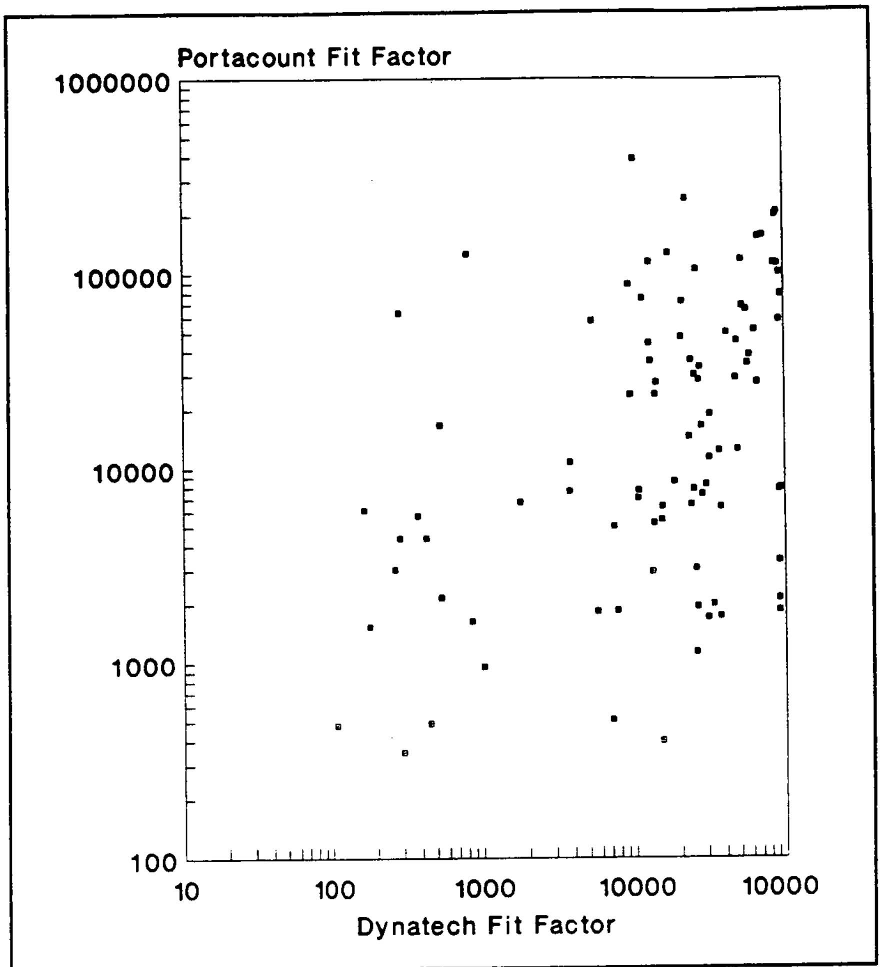

Figure 4 (U) Dynatech fit factor vs Portacount used outdoors. (U)

4.0 CONCLUSIONS

4.1 INDOOR CORRELATION.

(1) In the indoor correlation study, the results indicated a good correlation for fit factors up to 5,000.

(2) The correlation was strongly affected by the shape of the fit factor curve and whether the 10 second facepiece sampling of the Portacount coincided with a representative portion of the 45 second exercise/test.

(3) In the range of fit factors up to 5,000, the slope of the regression line (0.90) indicates that the Portacount results are consistently less than those obtained by the Dynatech.

This could be attributed to the different detection methods used by the Portacount and Dynatech instruments: i.e. a ratio of particle quantities as opposed to a ratio of aerosol mass concentrations. In that regard it was postulated, but not proven, that a difference in particle size distribution from the ambient aerosol to the mask sampled aerosol could be sufficient to cause an illusion of lower fit factors.

(4) As expected, a larger scatter in the results was observed in fit factors greater than 5,000. This could be partly explained by the greater susceptibility of the Portacount to sample a non representative 10 second portion of the 45 second fit test.

4.2 OUTDOOR CORRELATION

(1) Because of the low outdoor aerosol concentration, a 10 second facepiece sampling time is clearly insufficient to measure fit factors accurately.

(2) The methodology used in the experiment contributed to the poor correlation observed. In order to minimize the variability of results, for correlation purposes, it is important to ensure repeatability of the exercises. This would mean omitting difficult to reproduce exercises such as facial expressions.

5.0 RECOMMENDATIONS

(i) More experimentation is required to find a Portacount arrangement which would yield accurate results for outdoor fit testing.

(ii) Modification of the Portacount sampling time may be required, or alternatively greater use should be made of two photometric detectors to continuously sample the facepiece and ambient aerosol concentrations.

(iii) The test protocol used in these experiments must be revised to exclude exercises which are unpredictable or difficult to reproduce.

6.0 REFERENCES

(1) P.P. Meunier, Correlation Study of SF_6 and Corn Oil Aerosol in Respirator Quantitative Fit Testing (U). DREO Report 1035, 1990.

ANNEX A

OVERALL RESULTS

SUBJECT (Date)	TEST	FIT FACTORS IN CHAMBER Dynatech	FIT FACTORS IN CHAMBER Portacount	FIT FACTORS IN CHAMBER Ambient*	FF OUTDOORS Portacount	FF OUTDOORS Ambient*	CNC SERIAL
1 (day 1)	1 NB	12,480	22,700	386,000	114,000	26,900	224
	DB	9,178	11,600	384,000	87,600	26,500	
	SS	9,973	14,800	386,000	109,000	26,000	
	UD	11,246	10,600	390,000	74,300	27,200	
	RP	3,721	2,990	387,000	7,530	26,900	
	FE	285	850	390,000	62,500	26,200	
	2 NB	31,029	9,490	399,000	11,200	25,800	
	DB	21,831	7,520	397,000	241,000	30,800	
	SS	806	1,730	397,000	109,000	30,400	
	UD	56,188	10,700	393,000	74,300	31,000	
	RP	3,774	3,640	394,000	7,530	39,900	
	FE	27,491	6,440	397,000	16,300	37,800	
	3 NB	89,884	14,000	365,000	111,000	25,000	
	DB	91,275	14,700	NA	57,200	27,800	
	SS	89,669	74,000	NA	205,000	28,900	
	UD	87,126	19,000	NA	198,000	28,200	
	RP	18,174	3,200	NA	8,440	24,400	
	FE	93,403	18,000	NA	7,800	31,900	
2 (day 1)	1 NB	20,664	9,600	67,900	71,500	8,310	219
	DB	13,872	1,910	63,800	27,300	8,260	
	SS	16,885	6,240	66,800	127,000	7,360	
	UD	12,468	7,770	64,500	43,500	7,700	
	RP	13,625	1,830	60,400	23,700	8,670	
	FE	20,311	2,830	60,900	46,600	8,450	
	2 NB	71,533	8,420	57,000	155,000	8,120	
	DB	66,838	2,700	55,200	153,000	9,180	
	SS	94,739	6,870	50,700	77,700	9,440	
	UD	62,478	5,580	49,000	50,600	9,060	
	RP	26,334	1,200	46,400	28,200	11,200	
	FE	58,084	4,510	47,800	37,800	10,400	
	3 NB	92,119	5,080	37,100	100,000	5,460	
	DB	65,222	953	38,500	27,300	5,800	
	SS	85,001	5,850	39,100	112,000	5,880	
	UD	54,981	3,210	38,600	64,600	5,930	
	RP	46,376	1,430	31,300	28,700	5,160	
	FE	1,774	1,230	24,000	6,620	9,160	

		FIT FACTORS IN CHAMBER			FF OUTDOORS		
SUBJECT (Date)	TEST	Dynatech	Portacount	Ambient*	Portacount	Ambient*	CNC SERIAL
3 (day 2)	1 NB	51,764	15,600	72,000	67,500	23,500	219
	DB	47,471	9,110	69,700	44,700	3,600	
	SS	90,896	15,900	70,300	3,300	822	
	UD	90,896	11,000	67,300	7,730	12,100	
	RP	90,896	6,410	66,400	2,110	956	
	FE	90,896	8,360	64,200	1,830	967	
	2 NB	32,639	10,100	92,300	1,970	1,190	
	DB	36,691	6,330	93,800	6,220	1,120	
	SS	29,902	15,700	96,200	1,680	1,120	
	UD	36,403	12,500	91,900	1,710	1,130	
	RP	25,660	4,390	92,200	1,920	1,130	
	FE	29,521	6,530	94,000	8,150	1,470	
	3 NB	40,628	7,490	69,800	49,200	2,960	
	DB	25,590	3,910	69,100	104,000	9,490	
	SS	31,133	12,600	71,000	18,700	3,390	
	UD	13,286	10,800	72,800	5,150	4,580	
	RP	23,520	1,880	69,700	35,500	4,980	
	FE	23,525	3,490	69,000	6,430	7,700	
4 (day 2)	1 NB	179	219	393,000	1,520	98,500	224
	DB	428	539	386,000	4,330	18,300	
	SS	107	207	380,000	475	16,200	
	UD	165	197	378,000	6,060	37,700	
	RP	447	830	373,000	486	17,600	
	FE	298	272	371,000	346	16,800	
	2 NB	14,903	7,880	377,000	5,360	1,800	
	DB	27,829	8,450	372,000	7,240	1,700	
	SS	1,009	5,430	366,000	945	1,680	
	UD	25,071	11,130	366,000	1,120	1,680	
	RP	14,860	2,780	366,000	392	1,680	
	FE	25,217	7,780	364,000	3,010	1,640	
						1,960	
	3 NB	377	384	385,000	5,660	5,350	
	DB	530	440	379,000	16,500	14,200	
	SS	264	246	377,000	3,000	6,170	
	UD	285	226	373,000	4,340	8,040	
	RP	535	495	370,000	2,140	10,500	
	FE	845	671	365,000	1,620	14,300	

		FIT FACTORS IN CHAMBER			FF OUTDOORS		
SUBJECT (Date)	TEST	Dynatech	Portacount	Ambient*	Portacount	Ambient*	CNC SERIAL
5 (day 3)	1 NB	26,869	11,200	403,000	32,800	7,030	224
	DB	51,489	7,830	409,000	117,000	7,150	
	SS	10,531	6,340	408,000	7,560	8,450	
	UD	47,968	14,500	404,000	12,300	7,340	
	RP	24,378	4,450	403,000	7,680	11,800	
	FE	24,761	7,420	401,000	29,900	12,500	
	2 NB	12,712	8,480	415,000	35,400	10,100	
	DB	5,221	2,470	408,000	56,800	10,500	
	SS	36,169	10,300	401,000	12,100	60,000	
	UD	22,721	13,300	401,000	14,300	9,040	
	RP	12,945	2,810	399,000	2,890	10,300	
	FE	15,120	8,120	397,000	6,260	8,190	
	3 NB	10,381	7,060	344,000	6,930	3,960	
	DB	9,341	6,140	346,000	23,600	4,180	
	SS	5,629	7,610	343,000	1,820	4,120	
	UD	7,643	7,060	337,000	1,830	3,320	
	RP	6,983	2,410	332,000	503	3,800	
	FE	7,237	7,360	330,000	4,980	4,510	

* Ambient refers to the number of particles present per cubic centimeter in the ambient air (as sampled by the Portacount).

NB = Normal Breathing
DB = Deep Breathing
SS = Side to Side head movement
UD = Up and Down head movement
RP = reading the Rainbow Passage
FE = Facial Expressions

ANNEX B

RAINBOW PASSAGE

WHEN THE SUNLIGHT STRIKES RAINDROPS IN THE AIR, THEY ACT LIKE A PRISM AND FORM A RAINBOW. THE RAINBOW IS A DIVISION OF WHITE LIGHT INTO MANY BEAUTIFUL COLOURS. THESE TAKE THE SHAPE OF A LONG ROUND ARCH, WITH ITS PATH HIGH ABOVE, AND ITS TWO ENDS APPARENTLY BEYOND THE HORIZON. THERE IS ACCORDING TO LEGEND, A BOILING POT OF GOLD AT ONE END. PEOPLE LOOK BUT NO ONE EVER FINDS IT. WHEN MAN LOOKS FOR SOMETHING BEYOND HIS REACH, HIS FRIENDS SAY HE IS LOOKING FOR THE POT OF GOLD AT THE END OF THE RAINBOW.

DOCUMENT CONTROL DATA

(Security classification of title, body of abstract and indexing annotation must be entered when the overall document is classified)

1. ORIGINATOR (the name and address of the organization preparing the document. Organizations for whom the document was prepared, e.g. Establishment sponsoring a contractor's report, or tasking agency, are entered in section 8.) Defence Research Establishment Ottawa National Defence Ottawa, Ontario K1A 0Z4	2. SECURITY CLASSIFICATION (overall security classification of the document, including special warning terms if applicable) UNCLASSIFIED

3. TITLE (the complete document title as indicated on the title page. Its classification should be indicated by the appropriate abbreviation (S,C or U) in parentheses after the title.)

EVALUATION OF A MINIATURE CONDENSATION NUCLEUS COUNTER FOR QUANTITATIVE FIT TESTING (U)

4. AUTHORS (Last name, first name, middle initial)

MEUNIER, Pierre P. and CONSTANTINE, Larry R.

5. DATE OF PUBLICATION (month and year of publication of document) JULY 1990	6a. NO. OF PAGES (total containing information. Include Annexes, Appendices, etc.) 18	6b. NO. OF REFS (total cited in document) 1

7. DESCRIPTIVE NOTES (the category of the document, e.g. technical report, technical note or memorandum. If appropriate, enter the type of report, e.g. interim, progress, summary, annual or final. Give the inclusive dates when a specific reporting period is covered.)

TECHNICAL NOTE

8. SPONSORING ACTIVITY (the name of the department project office or laboratory sponsoring the research and development. Include the address.) Defence Research Establishment Ottawa
National Defence
Ottawa, Ontario K1A 0Z4

9a. PROJECT OR GRANT NO. (if appropriate, the applicable research and development project or grant number under which the document was written. Please specify whether project or grant) 051LD	9b. CONTRACT NO. (if appropriate, the applicable number under which the document was written)
10a. ORIGINATOR'S DOCUMENT NUMBER (the official document number by which the document is identified by the originating activity. This number must be unique to this document.) DREO TECH NOTE NO. 90-23	10b. OTHER DOCUMENT NOS. (Any other numbers which may be assigned this document either by the originator or by the sponsor)

11. DOCUMENT AVAILABILITY (any limitations on further dissemination of the document, other than those imposed by security classification)

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