

LABORATORY EVALUATION OF RESPIRATORS
DESIGNED FOR USE AGAINST PARTICULATES

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INTRODUCTION

The Australian practice in the evaluation of respiratory protective devices has been to require compliance with the Australian standard, the first edition of which in 1963 was derived from the British standard and used British specifications and test methods. Thus the Australian Standard AS Z18-1963 (Ref. 1) specified the methylene blue particulate cloud test for dust filters and gave limits for inlet and outlet air flow resistances but had no facial fit or performance test. Chemical cartridge and canister respirators, air supplied and self-contained breathing apparatus were required to be tested for facial fit using 5 test subjects with "normal facial size and contour" employing a "test gas" of 10 mg/m^3 of chloracetophenon (CN) in air for full facepiece, hood and helmet type respirators and 500 mg/m^3 of isoamyl acetate in air for half facepiece respirators. Thus a readily detectable agent for facial fit testing on a go/no-go basis was an early established method in this country.

In 1968 the revised Australian standard (Ref. 2) introduced four important changes:

1. facial fit testing using a panel of test subjects chosen on the basis of their facial length and width rather than a random choice of subject;
2. dust respirators were to be included in facial fit tests using isoamyl acetate, but substitution of organic vapour cartridges for the dust filters;
3. the test aerosol for full facepiece and hood and helmet respirators was established as o-chlorobenzylidene malononitrile, a "tear gas" of low toxicity but detectable at very low concentrations;
4. air supplied hoods and helmets were required to have a minimum positive pressure within the wearer's breathing zone at a 40 litre/minute volume breathing rate and to have a maximum noise not exceeding a specified level.

The requirement for facial testing on a selected panel was based on a limited anthropometric survey by Hughes and Lomaev (Ref. 3) published in 1972. Fifteen test subjects were required to be chosen comprising male persons between 18 and 65 years with facial dimensions which fitted into three groups as set out in Table 1. Ten of the panel were then used as test subjects with two members taken from groups A and C and six members from Group B. Hack et al of the Los Alamos Scientific Laboratory, in work sponsored by NIOSH in 1973 (Ref. 4) pointed out that the Australian test panel suffered from the serious limitation that only short length and width, medium length and width, and long length and width were specified, i.e. the various combinations of short and long were neglected. Hack recommended combined male and female test panels of 25 persons selected on the basis of face length and face width for full facepiece masks and face length and lip width for half-and quarter-mask testing. A later edition of the Australian standard AS 1716-1975 retained the 10 man test panel partially on the grounds of practicability and partially

because the system seemed adequate while only a qualitative go-no-go test was employed to determine satisfactory facial fit. Much of the current work reported here was undertaken to obtain information on how necessary it is to use quantitative measurements and protection factors to determine compliance with a standard specification taking into account the technical complexity and time factors involved in such measurements.

The principle of requiring air supplied hoods and helmets to maintain a measurable positive pressure in the wearer's breathing zone during medium to heavy work rates is now well established in Australian practice. Evidence is indicated below that it is maintenance of positive pressure which should be used as a design criterion rather than air flowrate. In the case of powered air filtering respirators high flowrates do not necessarily lead to a high standard of protection but may be conducive to lower protection factors, due to increased filter penetration.

TEST EQUIPMENT

The basic equipment used by the Division of Occupational Health and Radiation Control in the evaluation of respiratory protective devices is listed below with brief details of methods of calibration.

Dry Gas Meter, capacity 400 l/min manufactured by Gas Meters Pty. Ltd., calibrated against 300 litre spirometer by Australian Gas Light Company.

Resistance meter, comprising 280 l/min suction blower with 0-170 l/min Fischer & Porter flowmeter and $\pm$ 200 mm vertical manometer. Flowmeter calibrated against dry gas meter.

Anthropometric dummy head, 50 percentile size Caucasian male manufactured by Sierra Engineering Company, USA, fitted with tubular "mouth" and larynx. Dummy has soft vinyl plastic skin and firm foam filling.

Cartridge and canister gas absorption, apparatus comprising a refrigerated syringe feed which is used to inject test vapours in liquid phase into a temperature and humidity controlled air stream to give known test concentrations. Gas concentrations in exit gases from cartridge or canister under test is monitored by colour change in bubbler solutions or colour change on test papers. Some instrumental monitoring methods have been used but are not employed for routine testing.

Stability Tester, Cartridges and canisters are tested for mechanical stability by subjecting them to a horizontal reciprocating movement for either 10 or 30 minutes at a rate of 3 to 3.3 hz with a stroke amplitude of 85 mm and a free cartridge or canister movement of 5 mm.

Respiratory Pump, Single reciprocating piston pump activated by a sinusoidal cam with a nominal stroke volume of 2 litres, 20 strokes/minute, minute volume of 40 l/min, calibrated by dry gas meter.

Dummy head and torso of clothing dummy type (used for air supplied hoods and helmets only) with pressure tapping consisting of a 150 mm diameter perforated tube encircling the neck approximately 75 mm below mouth opening; connected to a sensitive manometer.

Manometer Greer Model M3 micromanometer with A10 differential pressure capsule transducer, ranged 0 to + 1 mm, 0 to + 3 mm, 0 to + 10 mm, manufactured by Mercury Electronics (Scotland) Ltd., calibrated against a Casella 0-200 mm vernier manometer.

Methylene blue particulate cloud apparatus to BS 2577

Sodium chloride aerosol apparatus to BS 4400-1969 with following modifications: (1) water cooling coil wound around cooling fins on photo multiplier entry tube to improve temperature stability of photo-multiplier; (2) hydrogen manometer replaced by Magnahelic gauge (0-150 mm W.G.); (3) galvanometer replaced by Hewlett and Packard digital multimeter, Model No. 3465A operated in the 0-200 microampere range. All compressed air used is from one source, with a manifold assembly after an initial filter.

Sodium chloride aerosol test hood - suspended cylinder of translucent PVC sheeting 600 mm diameter by 800 mm high with the top entry of NaCl aerosol into a plenum chamber connected to the top of the cylinder by a perforated partition to ensure even dispersion of aerosol into test chamber. An outer peripheral cylinder 750 mm diameter and 1100 mm high with vacuum offtake exhausts aerosol to reduce laboratory contamination. Test subjects stand in cylinder which extends to below hip level.

Sampling system - a probe consisting of a perforated metal tube with one closed end is connected via a flexible plastic tube to a battery operated pump sampling at 4.5 l/min which delivers the sample to the test tube and flame tube assembly of the detector system. The probe is introduced into the breathing zone of the subject under test, i.e. inside the hood or helmet or is used to sample chamber concentration.

Gas chamber - used for man tests employing isoamyl acetate vapour or o-chlorobenzylidene malononitrile (CS) aerosol as challenging agents. The unit consists of an inner chamber 1.6 m x 1.6 m x 2.1 m high with an outer chamber 1.6 m x 0.9 m x 2.1 m and is constructed in stainless steel with spring loaded gas-tight doors equipped with rubber seals. Both chambers have valved air inlets and outlets connected to a circulating blower and an exhaust blower connected to a chimney protruding approximately 4 meters above the building. Air can be introduced into either chamber and exhausted on a flow through system or by valving off one or other chamber, air can be continuously circulated through the chambers separately. The floor of the chambers are dished with sealed outlet drains to facilitate washing down and PVC coated steel grids over the dished floor provide a working platform. The inner chamber is equipped with a treadmill with a range of 3-10 km/hour walk rates and a set of 2 x 220 mm rise steps. On one wall of the chamber at a height of 1.8 meters is a shelf stacked with 1 kg wooden blocks used for a simple work

test routine. The vapour and aerosol dispersal system comprises an electric heating coil with an evaporating basin and oscillating fan. The test procedure is for one or two personnel fitted with the respirator under test to be shut into the inner chamber the door of which is fitted with a quick release "panic button" to enable quick exit. This facility is necessary when CS tear gas aerosol is employed as a test agent as facial seal leakage or filter penetration can rapidly be sufficiently unpleasant to warrant exit from the test chamber in some haste. To commence the test the test subjects pour the required quantity of isoamyl acetate or the CS crystals into the hot evaporating basin, the resulting vapour or aerosol smoke then being dispersed by the fan. Work routines used comprise shifting wooden blocks from the shelf to the floor one at a time and then returning them to the shelf, walking up the two steps and down 12 times a minute and a 6.5 km/hour walk on the horizontal tread mill.

QUALITATIVE VERSUS QUANTITATIVE FACIAL FIT

CS Test Aerosol

Details of Orthochlorobenzylidene malononitrile (CS) used as the challenging agent in the qualitative testing of dust respirators have been drawn from the Himsworth report (Ref. 6) and are as follows:

The material is a white crystalline solid which melts at 94-95°C and boils at 310-315°C. When heated it sublimes rapidly with slight decomposition and condenses to a cloud of solid or supercooled liquid of a mass median diameter lying between 1 and 2 micrometers. (Scanning electron microscope examinations at this laboratory of CS particles deposited on a slide reveal very few particles of less than 1 micrometer, the great majority being between 1 and 4 micrometers. During the observation the particles could be seen to be changing shape and subliming).

The smallest trace that a person can detect by slight irritation of the eyes and nose is about 0.004 mg/m³. A concentration of 0.5 mg/m³ will produce distinctly unpleasant symptoms of lacrymation and salivation and a concentration of 4 mg/m³ becomes intolerable to most people. However, from the toxicological point of view the dose of CS generated pyrotechnically which on one exposure, kills 50% of the most susceptible animal species tested, is some 3000-4000 times that required to deter even trained troops who can resist up to 10 mg/m³. For other species it is considerably higher. Evidence from healthy persons who have been repeatedly exposed to CS over a matter of years, although scanty, reveal no signs of ill-effects.

The Australian standard specified a concentration of 3 mg/m³ of CS as the test aerosol for evaluating facial fit. A successful test result would therefore infer that a protection factor as high as 2000 had been achieved (8.0/0.004). If, as it can safely be assumed, some people are less sensitive to the first detectable symptoms of nose and eye irritation than others, the actual protection factor could be considerably less than this figure. Experience with the method would indicate that failure to detect the CS aerosol can be taken, on a conservative estimate, as a protection factor of not less than several hundred to one and probably higher than this.

Test Method

For the gas chamber evaluation, one or two test subjects enter the chamber, taking with them the relevant quantity of CS weighed into a small bottle. After donning the hood or helmet under test and checking its normal operation, the CS is tipped into the heating evaporating basin. The test subjects stand still until the CS has sublimed and dispersed, this taking approximately 1 minute. If no aerosol penetration is detectable an exercise routine is carried out consisting of taking down wooden blocks one at a time from a shelf above the head of the subject and placing them on the floor a pace or two away and then returning them to the shelf. Although it is not specified in the Australian standard it is the practice of this test laboratory to encourage conversation by the test subjects during the 10 minute period of the test (particularly when half facepiece and full facepiece respirators are under evaluation). Discernible but slight irritation such as prickling of the eyes or throat due to CS aerosol filter penetration or facial seal leakage is reported but not necessarily taken as a "failure". Definite signs of penetration are smarting of the eyes causing rapid blinking and screwing up of the eyelids and/or a peppery irritation of the nose and throat usually with nose watering. These symptoms of failure usually build up in intensity if the first 1-2 minutes of the test and result in rapid withdrawal from the chamber to a fresher atmosphere. Recovery from the effects of the CS is rapid, 1 to 2 minutes in clear air sufficing to alleviate the symptoms. The chamber is ventilated between tests and a fresh concentration of aerosol generated for each pair of subjects. This is necessary due to the comparatively rapid fallout of the aerosol due to agglomeration and settling. It is reported (Ref. 6) that in a closed chamber with little or no air movement, aerosol concentrations in air fall to about 1/100 of the initial value in 30 minutes. As the chamber used by this laboratory has considerable air movement due to the use of an oscillating fan, the fallout would not be expected to be so rapid. Agglomeration of the smaller CS particles to larger ones could, however, be enhanced. As mentioned above scanning electron microscope examination of the CS aerosol has proved difficult due to the ephemeral nature of the deposited particles.

Powered Air Purifying Respirators

Test results are given in Table 2 for a range of tests on a number of powered air purifying respirators and several air supplied hoods.

Brief description of units tested;

Arbin hood Metal framed PVC coated fabric hood with integral vizor, no head harness or inner bib. Air supply via corrugated hose 3 metres long attached to cylindrical filter and blower unit for mounting on vehicle, e.g. tractor.

Power provided by vehicle battery (12V).

Hood modified in Australia by addition of towelling bib to provide positive pressure in head area.

MSA PAPR Catalogue No. 463354. Battery powered filter unit carried on waist belt with air led by corrugated hose to half facepiece respirator.

Martindale Mk IV with HEF filters. Powered filter unit and battery pack carried on waist belt with corrugated hose to full facepiece. Blower unit has 3 high efficiency cartridge filters.

Airwash hood Mk IV PVC coated nylon hood on head harness with bubble visor and shoulder cape elasticised around neck with velcro adjusting strap. Compressed air supplied via valve on waist belt.

Plysu hood Clear PVC hood with shoulder cape attached to body by tapes under armpits, no head harness, inner bib or control valve. Air supplied by hose from compressed air source.

Racal "Airstream" helmet The basic unit combines head, face and respiratory protection by means of a helmet with a vizor provided with flexible plastic facial flaps which contact the sides of the face. Air is drawn via a coarse filter by an axial fan located in the rear of the helmet and expelled through a fine filter into the head space, exhausting to atmosphere in the chin area. Power is provided by a rechargeable battery carried at the waist. Several alternate fine filters and 2 models of fan motors are available.

Martindale Clear Air Helmet, HPA-QQ1 A motorcycle style helmet with integral visor and neck bib with drawstring. Air is drawn via two cartridge filters near rear of helmet through fan unit into head space and exhausts through bib to atmosphere. Power provided by rechargeable battery pack on waist belt.

AP/10 helmet Hood type unit supported on head by harness with integral vizor and nylon shoulder cape fastening under armpits. Air is supplied from a battery powered fan unit with replaceable filter cartridge attached to a waist belt.

Discussion

All the PAPR's failed the CS aerosol test except for two with high efficiency filters, i.e., the MSA PAPR and the Martindale full facepiece with HEF filters. Unfortunately, protection factors were not measured for these two devices but comparative figures between the other PAPR's and two air-supplied hoods indicate that a protection factor of at least 1000 is required to pass the CS aerosol test. For those filters shown in Table 2, filter efficiency tests at two flowrates, and for both methylene blue and NaCl aerosols, show that the filter efficiencies fell with increasing flowrate. It was not possible to measure the filter efficiencies at the air flows provided by the PAPR's but if it is assumed that the fall in filter efficiencies continued to increase with these higher flows, the failure in the CS chamber tests of units with nominally highly efficient filters is simple to explain. As the filter efficiencies at the operating flowrates are not known, it is not possible to calculate the contribution of filter penetration to the overall protection factor and the contribution due to hood design or facial fit factors. However, the large change in protection factor for the Martindale HPA-001 when the inner bib was loosened, and the fall in measured positive pressure within the helmet to a negligible figure, indicate that hood design can play an important part in obtaining high protection factors.

Table 3 gives protection factor results on two models of the Racal Airstream helmet, the AH4/G11 having a more powerful motor and higher flowrate than the AH1/G11. The helmets were tested on small (A) and medium (B) size faces chosen in accordance with AS 1716-1975 (see Table 1), some of the subjects being bearded (+) and some clean shaven (0). Subjects were tested wearing the helmets with small and large facial flaps, the small being designed for larger faces. The results show a significantly lower protection factor for bearded subjects compared to clean shaven and some indication that the choice of facial flap size is also of importance. A larger sample with the inclusion of subjects in size (C), i.e. with large faces would be necessary to confirm these indications.

A comparison between the two Racal units tested, on the basis of flowrate gives a lower protection factor probably due to increased filter penetration.

Single-use disposable respirators

Test results (Table 4) on given single use disposable respirators using standard test panels of 10 people with facial sizes in accordance with AS 1716-1975 gave completely anomalous results to those obtained with powered air filtering respirators. Several people complained of slight nasal irritation during the CS tests while the remainder indicated no effect due to the test aerosol. (Gas-tight goggles were worn during the tests.) These test results indicated a protection factor in excess of 1000 despite the fact the methylene blue penetration figures ranged up to 24%. The explanation would seem to be in the particle size range of the CS aerosol (mostly 1-4 micrometers) compared to the methylene blue particulate, said to have a mass median size of 0.5 micrometer but by count to be almost all below 1 micrometer in size (Ref. 7). A further factor could be the unknown increase in filter penetration at the high flowrates of the PAPR units. However, from the facial fit point of view, which should not be affected by the particle size of the test cloud, all five respirators would seem to have given an excellent fit on all of the Australian test panel.

The few NaCl protection factor tests carried out also showed highly anomalous results compared to those obtained by other laboratories. Protection factors reported by Lowry (Ref. 8) in 1977 on similar types of respirators gave factors ranging from 2 to 1000 with most of the figures on 10 person test panels between 5 and 20 compared to the 60-5000 found here.

As reported above, the tests were performed using an NaCl aerosol apparatus to BS 4400 with some minor modifications, none of which should have affected the test results. Test sampling was done by attaching a 5 mm I.D. plastic tube to the respirator in the vicinity of the mouth and drawing a 4.5 l/min sample continually from the facepiece. Flame photometer readings were taken by digital micro-ampere meter at 2-3 second intervals, after the reading became relatively steady, for a 2 minute sampling period and the mean of the readings was calculated. Test hood concentrations were taken both before and after the test on the subject using the same sampling tube as for the man tests. Highly significant differences were found in some cases between the "before" and "after" test hood readings, the quantity of NaCl detected at the end of the

man test with the disposable respirators sometimes being as low as 10% of the "before" result. In these cases the protection factor, if calculated using the "before" hood concentration as the basis, was up to 5000, showing that deposition on condensed exhaled breath (sometimes visible) in the tube was probably the cause of the anomalous results. Further work to improve our sampling technique is obviously necessary.

That deposition of NaCl particles on surfaces is a significant factor was also apparent when erratic and fluctuating readings were obtained whenever the hood or connecting tubing was knocked or agitated during measurement of the test hood concentration. It is noteworthy that the British Standard (Ref. 9) using this method instructs the test subjects to sit "perfectly still" during the test.

CONCLUSIONS

The comparison reported herein between qualitative testing of dust respirators using a CS aerosol and a quantitative NaCl particulate cloud system shown that the two methods can both give useful results. The qualitative method is easy to carry out, requires very little equipment (a shed or pvc sheeting tent in the open air would suffice), and can show up a poorly fitting respirator or one with a less than highly efficient filter. It cannot, however, distinguish between a poor filter and one with filtering ability quite suitable for many industrial applications. Its use could also be argued as ethically unacceptable as it uses a biologically active agent on human subjects albeit one of extremely low toxicity (Ref. 6). It also suffers from the disadvantage that its effect on the human subject can be unpleasant, even if only transient, making volunteers as test subjects sometimes difficult to obtain.

The NaCl quantitative evaluation on the PAPR's indicate that this method of assessment is excellent and should be included in the Australian standard. However, it was apparent from the small amount of work carried out on disposable respirators that considerable expertise is required for its use which this laboratory to date has not acquired.

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Bibliography

1. Australian Standard AS Z18-1963, "Specification for Respiratory Protective Devices" (Standards Association of Australia, Sydney).
2. Australian Standard AS Z18-1968, "Specification for Respiratory Protective Devices" (Standards Association of Australia, Sydney).
3. J.G. Hughs, O. Lomaev, "An Anthropometric Survey of Male Facial Sizes", Am. Ind. Hyg. Assoc. J., 33 71-78 (February 1972).
4. A. L. Hack, E.C. Hyatt, B.J. Held, T.O. Moore, C.P. Richards, and J.T. McConville, "Selection of Respirator Test Panels Representative of U.S. Adult Facial Sizes", Los Alamos Scientific Laboratory Report LA-5488, Los Alamos, New Mexico (1973).
5. Australian Standard AS 1716-1975, "Specification for Respiratory Protective Devices", (Standards Association of Australia, Sydney).
6. H. Himsworth (Chairman), "Report of the Enquiry into the Medical and Toxicological Aspects of CS (Orthochlorobenzylidene Malononitrile)", Pt. 2 (1971), Home Office, U.K.
7. British Standard BS 2577:1955, "Methylene Blue Particulate Test for Respirator Canisters", (British Standards Institution, London).
8. P.L. Lowry, P.R. Hesch, and W.H. Revoir, "Performance of single-use respirators", Am. Ind. Hyg. Assoc. J., 38, 462-467 (September 1977).
9. British Standard BS 2091:1969, "Specification for Respirators for Protection Against Harmful Dusts and Gases" (BSI, London).

TABLE 1--Facial Dimensions of Test Panel - AS 1716-1975

Group	No. in Each Group	Facial Dimensions (mm)	
		Bizygomatic diameter	Menton-nasal root depression lengths
A	3	128 - 136	100 - 111
B	9	137 - 146	112 - 123
C	3	147 - 154	124 - 133

(From Australian Standard AS 1716-1975, with permission)

TABLE 2 TEST RESULTS ON RESPIRATORS DESIGNED FOR USE AGAINST PARTICULATES

Respirator	Filter Cat. No.	Country or origin	Type of unit	Flowrate to wearer (L/min)	Positive Pressure (mm W.G.)	Chamber test with CS aerosol	Protection Factor with NaCl aerosol	Filter % NaCl penetration (@ 35 lpm)	Filter % NaCl penetration (@ 85 lpm)	%Methylene Blue penetration (@ 30 lpm) for filter	%Methylene Blue** penetration (@ 120 lpm) for filter
Racal Helmet Model AH1	AS23	U.K.	Battery operated	130	0.01 to 0.40	Failed	60-150 (4)	6.1 $\pm$ 3.4	13.5 $\pm$ 1.8	1.0 $\pm$ 0.3	10.2 $\pm$ 2.1
Model AH3	AS23-3	U.K. (for USA)	"	130	0.01 to 0.35	"	Not tested	16 (1)	Not tested	7.5 $\pm$ 0.9	17.1 $\pm$ 2.4
Model AH1/G11	G1150	U.K.	"	125	0.01 to 0.35	"	120 - 670 (11)*	0.31 $\pm$ 0.1	0.73 $\pm$ 0.5	0.06 $\pm$ 0.02	0.3 $\pm$ 0.1
Model AH4/G11	G1150	U.K.	"	180	0.02 to 0.40	"	60 - 260 (12)*	0.31 $\pm$ 0.1	0.73 $\pm$ 0.5	0.06 $\pm$ 0.02	0.3 $\pm$ 0.1
Martindale Clear Air Helmet HPA-001	RP18012/SF	U.K.	"	140	Bib tight: 0.35 to 1.0 Bib loose: negligible (less than 0.01)	" 60 - 80 (4)	Bib tight: 740-910 (4) Bib loose:	0.17 $\pm$ 0.07	0.41 $\pm$ 0.15	0.02 $\pm$ 0.005	-
AP/10 Helmet	CA-304SE	Japan	"	180	1.0 to 5.2	"	20-100 (3)	-	0.88 (1)	0.8	-
Arbin Hood	-	Holland (modified in Australia)	"	225	With bib: 0.7 to 2.6 Without bib Negligible (less than 0.01)	With bib: Failed Without bib Failed badly	50 (1) 50 (1) during exercise	-	-	3.5 $\pm$ 0.5	-
MSA 463354 Powered Air Purifying Respirator with Comfo facepiece	463284 Type P1	U.S.A	"	185	-	Pass (10)	-	-	-	Less than 0.01	-
Martindale MK IV with full facepiece	H.E.F. filters	U.K.	"	140	1.0 to 10.0	Pass (10)	-	-	-	Less than 0.01	-
Airsearch MK IV hood	N.A.	Australia	Airline hood	At 124 kPa (minimum operating pressure): 120 (valve closed) 170 (valve opened)	0.4 to 10.0	Pass (2)	1000-1400 (2)	N.A.	N.A.	N.A.	N.A.

Notes:

(-) indicates number of persons tested with NaCl aerosol in determining protection factors

N.A. indicates test not applicable

* See also Table 3

** Filter size reduced to give equivalent of 120 l/min through filter

TABLE 3 Protection Factors Obtained for Racal Airstream
Helmets Using NaCl Aerosol

Facial size (No. of subjects Tested		Bearded (+) or Cleanshaven (0)	Protection Factors Small Flaps		Large Flaps
<u>AH1/G11</u>					
A	(1)	+	-	620	
A	(1)	0	160	130	
B	(2)	+		80 - 280	
B	(4)	0	170 - 590	80 - 280	
<u>AH4/G11</u>					
A	(1)	+	120	260	
B	(2)	+		60	
B	(3)	0	110	100 - 250	

TABLE 3A Summary of Protection Factors Obtained for
Racal Airstream Helmets using NaCl Aerosol

	Mean Protection Factor	
	Small Flaps	Large Flaps
Bearded	140	100
Clean Shaven	220	210

TABLE 4 CS Aerosol Test versus Protection Factors (PF)
for Disposable Dust Respirators

Respirator Cat. No.	No. of subjects in CS Aerosol Size A	Size B	Size C	No. passing CS test	Approximate PF obtained with NaCl aerosol	No. tested with NaCl	Methylene blue penetration at 30 l/min %
3M 8710	2	6	2	10	60 - 5000	4	10 - 24
3M 8800	2	6	2	10	-	0	0.8 - 4.0
3M 9900	2	6	2	10	-	0	0.2 - 0.6
3M 9920	2	6	2	10	420 - 3000	4	0.1 - 0.4
Glendale "Dustbuster"	2	6	2	10	-	0	3.0 - 6.0