A STUDY OF HOW SPEECH AFFECTS PEAK INSPIRATORY AIR FLOW VALUES, AT VARIOUS LEVELS OF WORK AND HOW THE TEST RESULTS SPREAD BETWEEN INDIVIDUALS IN A TEST GROUP.

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Abstract

This paper discusses the variation in Peak Inspiratory Air Flows observed while subjects were required, as part of their work, either to communicate loudly while wearing a half-face respirator or shout warning messages.

A group of 25 people in one company situated in Sydney, Australia, were asked in this study to talk or shout while wearing a half-face respirator during periods of light to heavy work. The Peak Inspiratory flows were measured continually during this period as was heart rate.

The measurement of Peak Inspiratory air flow was done with equipment specifically designed for this purpose. Subject work ranged from sedentary to heavy by standing in the one position while lifting light objects from ground level to bench level. The subjects then were asked to walk on a treadmill at 6.5 kph inclined at an angle of 7 degrees uphill. This report covers results up to 5 degrees uphill.

As this situation of speaking while wearing a respirator during light to heavy work occurs frequently in industrial practice, the implications for respirator wearers and designers are important.

Contents

Introduction

This paper discusses the findings from research carried out at the end of September, 1996 to show the variations in Peak Inspiratory air flows and patterns that resulted from subjects required to communicate or shout messages while wearing a half-face respirator. This situation occurs frequently in industrial practice, often in noisy type environments and sometimes the communication in critically important from a safety perspective.

Details are given in this paper of the equipment used, the wide physiological characteristics of the volunteer test group, and the type of work being performed at the time while measurements were being taken. Dramatic changes and large variations were observed.

Respirators are designed to seal against the face and for the inward air flow to be directed through a filter so as to trap and adsorb airborne particulate and gaseous contaminants. When subjects are shouting commands or even emergency messages, the pattern of breathing, Minute Air flows and Peak Inspiratory air flows are altered and increased well beyond normal levels. Since these can be expected to be regular occurrences, the implications are important to the users and designers of respiratory equipment when, for example, testing under standards requires a lower, constant flow value.

In this work, a treadmill was used to simulate work and increase the loads on individuals while wearing a respirator, as this provides standardised conditions and permits comparisons to be made. The general use of treadmills and exercise testing has been documented elsewhere and is not repeated here. Respirator performance has been evaluated for many years using treadmills (Silverman et [(3)] , De Roza [(4)] and others).

The development of the equipment at Safety Equipment Australia Pty Ltd to enable breathing characteristics to be collected every 0.020 seconds and downloaded to a P.C while the subject was working under controlled conditions, allowed an analysis of the breathing pattern to be made. If the subject shouted or talked during these exercises, the variation in the breathing pattern and the increased rate of air required to perform this function could be plotted. The heart rate of each volunteer was also continually observed and recorded during the trials. The variation was observed to be large and the rates much higher than initially anticipated. The deviation from normal breathing patterns could also be observed. All these are of critical importance in the design and normal functioning of respirators, particularly PAPR types.

A variety of respirator standards, either in draft form or in some aspect of the review stage, are considering the “calibration of the test subject” [(5)] [(6)] [(7)] by relating the heart rate values to the ventilation rate of each individual. Talking during the fit-testing procedure of a respirator on an individual is also a routine [8]. However, the breathing patterns are also significantly altered during these phases and the results from this work and more proposed may suggest that these variations need to be taken into account.

Experimental

Volunteer group

Twenty-five volunteer subjects took part in these trials set in Sydney, Australia towards the end of last year. The age and sex of the participants are given in table 1. Subjects ranged widely in age, fitness and physiological characteristics similar to that which could be expected in any industrial setting.

Subject	**Sex** Male	Female	**Age**
10	1		23
11	1		37
12	1		19
13	1		44
14	1		46
15	1		33
16	1		47
17	1		38
18		1	39
19		1	53
20	1		31
21	1		28
22	1		21
23	1		23
24	1		43
25	1		43
26	1		35
27		1	49
28		1	19
29	1		30
30		1	45
31	1		21
32	1		55
33	1		46
34	1		50
Sum	20	5	
Average			**36.7**

Age and sex of volunteers in the study

Table 1

Activities

Part 1: Subjects were asked to stand upright and still, looking directly ahead and speaking.

Part 2: Subjects were asked to simulate light work, i.e, picking up a set of articles from a box set at ground level and placing these on a table on a table directly in front. While carrying out this activity, they were asked to speak.

Part 3: Subjects were asked to walk on a treadmill set at 6.5 kph inclined at a zero degree incline. Volunteers were then asked to shout as if giving a warning message.

Part 4: Subjects were asked to walk on a treadmill set at 6.5 kph, but now inclined at a 7 degree slope uphill. This is a very strenuous activity. The volunteers were then asked to shout warning messages.

The results are given for each stage. Heart rates were continuously monitored as was the breathing pattern, Minute Flows and Peak Inspiratory Air Flows. Tests were discontinued if any signs of stress became evident.

Equipment

The equipment to conduct these trails were developed and calibrated at the facilities of Safety Equipment Australia Pty Ltd in Sydney. Details are given below:

Subjects: A total of 25 subjects from both sexes volunteered for this work, varying widely in age group and physical fitness. No preselection process was undertaken, although care was taken to ensure that subjects would be able to undertake the test. All subjects were also instructed to abandon the test in case of any discomfort being experienced.

All subjects had the purpose and the experimental procedure explained and care was taken to ensure that the subjects had experienced the use of a treadmill prior to any testing.

Respirator used A Sundstrom SR-90 respirator (in two sizes) were used for the work, fitted with a flow meter designed, built and calibrated by SEA Pty Ltd in Sydney. Calibration was capable of being traced to a Reference Standard.

Flow meter The flow meter utilises the pressure drop over a standard Sundstrom P3 particle filter to measure the air flow. The pressure drop is measured by a Honeywell Differential Pressure Transducer

Treadmill A treadmill (Spectra Mattan) was set at a steady speed of 6.5 Kph
A lower speed had to be used for some individuals.

Calibration equipment

IPZ test bench at SEA Pty Ltd with Flow meter 0 to 600 L/min and X/Y chart recorder. Flow meter used to calibrate the IPZ test bench was a ROTA YOKOGAWA type RHN.01 950215.0701.

Calibration The unit was calibrated using the IPZ test bench a SEA Pty Ltd. Calibration is a two-point calibration: High Limit flow value and Low Limit flow value. The equipment response has been measured and verified to be linear. The calibration procedure is automated in the software. The software will request a High Limit flow value. It will then average 1500 samples over 30 seconds. The numerical value is then entered via the keyboard. The process is repeated for the Low Limit flow value. Gain and offset factors are calculated and stored in separate files as calibration constants.

Calibration of the system was repeated a second time towards the end of the test series to check for change of flow resistance of the filter due to airborne contamination. The difference was negligible.

Measuring accuracy

Accuracy of the system is affected by errors in the equipment as well as the inaccuracies of the calibration equipment. The ROTA YOKOGAWA reference flow meter has an error of +/-5%. The estimated error of the IPZ will be 6.7% according to the principle of Gaussian distribution and using a 3sd limit for maximum error.

The precision of the AD converter is specified to be 2 bits. Two bits over a 12 bit range equals an error of 0.1%.

Unlinearity of the particle filter response introduces errors also. The filter was measured for linerity response on the IPZ test bench using the Spirograph XY chart recorder. Maximum linearity erroe is 3% located at 150 L/min flow.

The resultant maximum error of the SEA Flow Meter is 10%.

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Results

Part 1

Standing upright, looking directly ahead and not talking (i.e, no physical work performed)

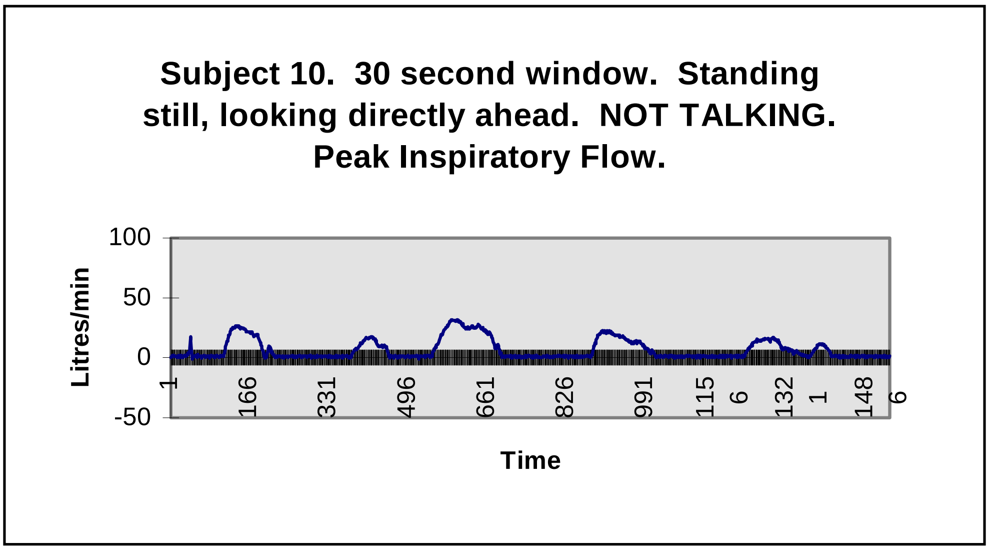
Identification	NO TALKING			WITH TALKING		
	Average heart rate (bpm)	*Average Minute Flows (litre/min)*	*Peak Inspiratory Air Flow (litre/min)*	*Average heart rate (bpm)*	*Average Minute Flows (litre/min)*	*Peak Inspiratory Air Flow (litre/min)*
10	65	7.5	31.5	76	8.4	92
11	84	10.4	-	79	11.1	115
12	90	8.1	35.0	93	7.6	126
13	58	11.3	25.0	68	10.9	170
14	80	7.0	44.0	94	10.6	127
15						
16	62	9.2	30.0	66	12.0	148
17	84	12.0	53.0	88	12.2	123
18	101	12.9	37.0	101	9.7	111
19						
20						
21	98	8.6	39.0	99	9.2	122
22						
23	75	9.5	108	96	11.6	160
24	73	10.3	51.0	78	8.4	107
25	60	8.7	37.0	74	10.8	172
26	86	10.1	54.5	95	11.5	100
27	76	8.2	32.0	76	8.4	117
28	79	6.5	27.0	90	6.1	82.5
29	67	7.5	25.0	82	10.5	133
30						
31						
32						
33	81	6.2	22	78	8.1	60.5
34						
35						

Heart rate, Minute Flows and Peak Inspiratory Air Flows for subjects standing stationary and standing stationary, talking. (i.e, no external work being done).

Table 2

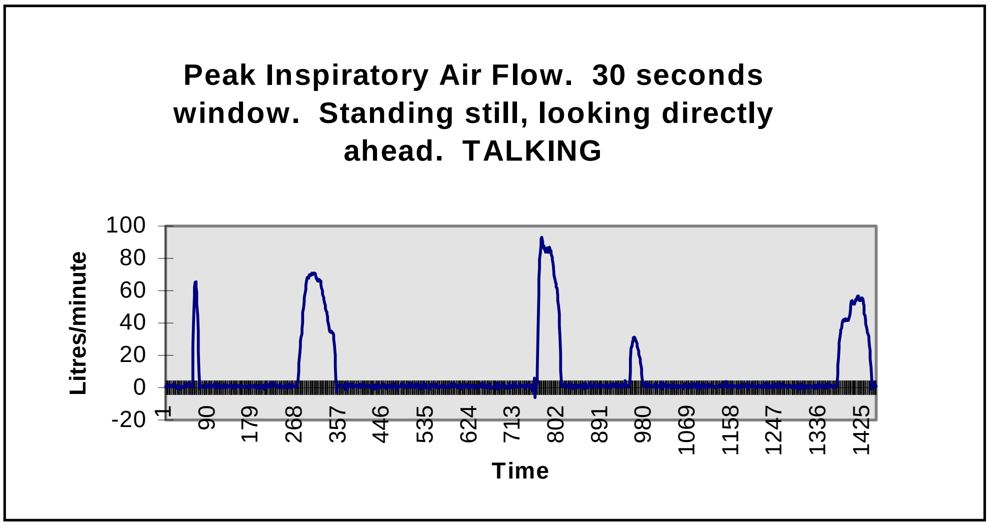
Graphically

A typical graph of breathing pattern obtained from an individual taking part in Part 1 of the trials is shown in graph 1. The Peak Inspiratory Air Flow peak can be observed.



Subject 10. Standing still with no talking. Peak Inspiratory Air Flow. Minute Flow 7.5 L/min.

GRAPH 1



Subject 10. Standing still and talking. Peak Inspiratory Air Flow.
Minute Flow 9.1 L/min.

GRAPH 2

Note that the height of the peaks have altered as has the pattern of breathing.

If the heart rate variations and the variations in Peak Inspiratory Air Flow are now summarised, the results can be seen in Appendix A.

(The graphs are shown in more detail in Appendix A)

Part 2

Subjects performing light work, i.e, lifting a very light object from ground level to a table to and back.

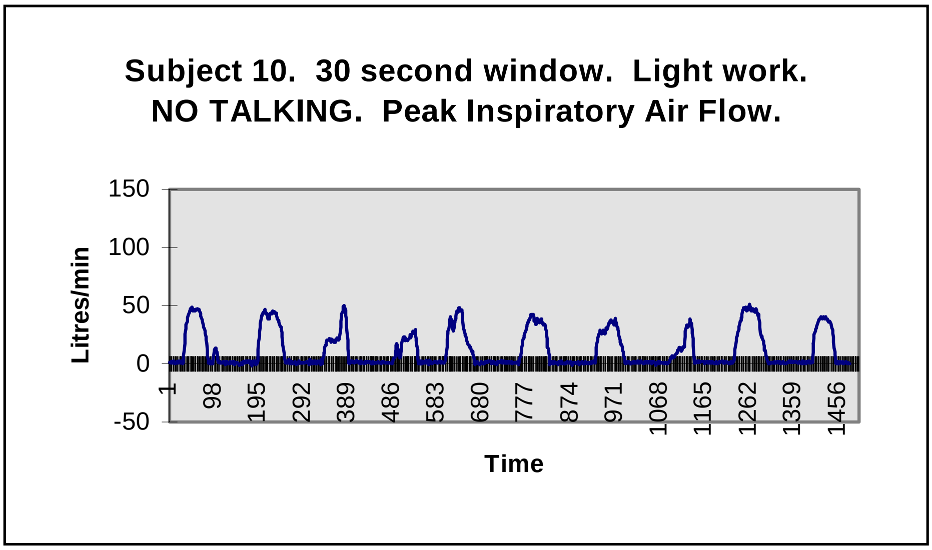
Identification	**NO TALKING**			**WITH TALKING**		
	Average heart rate (bpm)	*Average Minute Flows (litre/min)*	*Peak Inspiratory Air Flow (litre/min)*	*Average heart rate (bpm)*	*Average Minute Flows (litre/min)*	*Peak Inspiratory Air Flow (litre/min)*
10	78	11.3	53	78	12.5	142
11	85	15.3	41.5	86	16.9	164
12	93	9.8	55	93	10.3	77
13	86	21.8	77	89	23	228
14	90	10.6	80	89	14.8	168
15						
16	69	12.8	91	69	13.4	123
17	100	18.8	68	100	22.7	160
18	106	21.8	93	110	24.3	135
19						
20						
21	102	13.3	65	106	15.9	160
22						
23	77	17.2	95	74	17.9	118
24	88	17.7	88	87	20.0	162
25	73	15.6	92	79	13.4	178
26	91	11.6	55	91	13.5	88
27	81	10.8	62	87.5	9.7	61
28	105	12.9	54	137	17.1	111
29	86	15.9	71	96	15	170
30						
31						
32						
33	96	13.4	67	90	15.7	92.5
34						
35						

Heart Rate, Minute Flows and Peak Inspiratory Air Flows for subjects carrying out light work.

TABLE 2

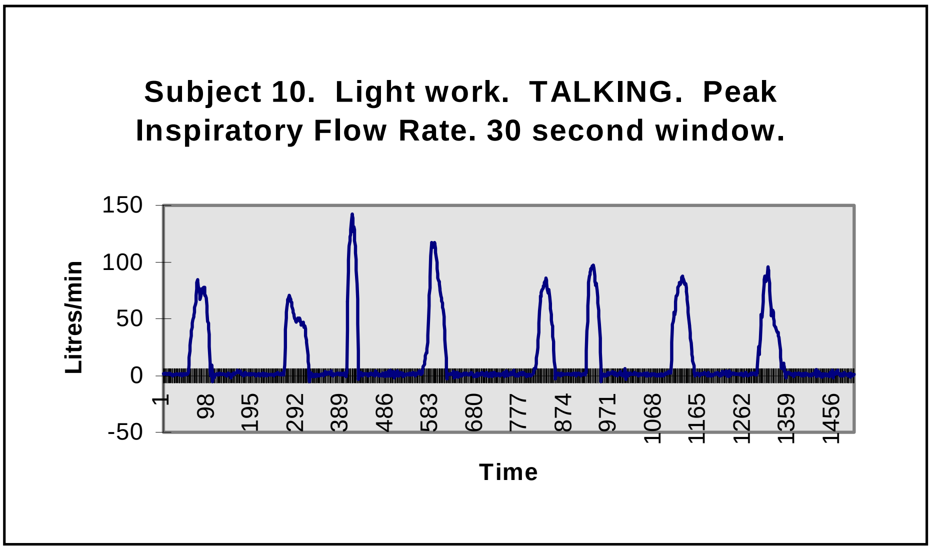
Light work involved picking up a set of small, lightweight articles from a box at ground level, straightening the knees, placing the articles on the table directly ahead, and returning to pick up another lot of small articles.

Graphically, the Peak Inspiratory Air Flow results from subject 10, carrying out light work while not communicating, and while communicating are shown in graph 3 and 4.



Subject 10. Performing light work with no talking. Peak Inspiratory Air Flow. Minute Flow 11 L/min.

GRAPH 3



Subject 10. Performing light work with talking. Peak Inspiratory Air Flow. Minute flow 12.5 L/min

GRAPH 4

The graphs are shown in more detail in Appendix B.

Part 3

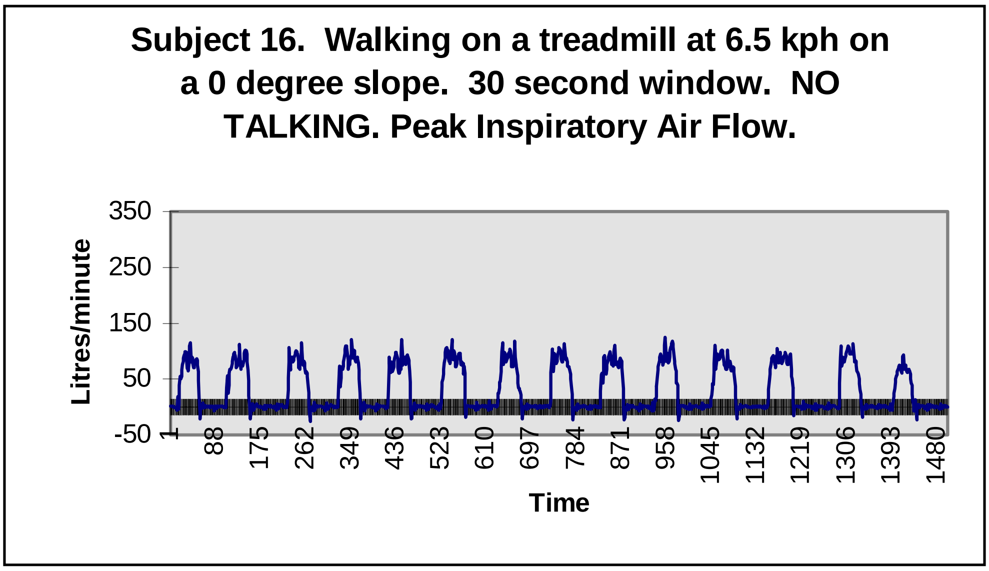
Subjects were asked to walk on a treadmill set at 6.5 kph inclined at a zero degree incline. Volunteers were then asked to shout as if giving a warning message.

Identification	**NO TALKING, WALKING AT 6.5 kph ON A 0 DEGREE SLOPE**			**WITH TALKING, WALKING AT 6.5 kph ON A 0 DEGREE SLOPE**		
	Average heart rate (bpm)	*Average Minute Flows (litre/min)*	*Peak Inspiratory Air Flow (litre/min)*	*Average heart rate (bpm)*	*Average Minute Flows (litre/min)*	*Peak Inspiratory Air Flow (litre/min)*
10	-	-	-	-	-	-
11	111	21.7	70	-	-	200
12	-	-	-	-	-	-
13	101 115 105	30.7 25.2 30.6	140 178 108	-	-	260 300 275
14	110	20.0	78	-	-	88
15	108 113	21.0 27.1	90 118	-	-	360 290
16	100 91 90 83 84 91	27.2 31.5 30.9 24.3 27.7 29.6	140 130 138 115 95 185	-	-	320 345 308 270 285 270
17	122 130	44.2 48.4	175 165	-	-	315 340
18				-	-	
19				-	-	
20	113	24.8	87	-	-	154
21	120	23.3	115	-	-	215
22				-	-	
23	106	24.7	191	-	-	267
24	105 114	32.9 30.3	220 223	-	-	325 325
25	105 115 109 109 101 108	25.2 23.8 26.8 28.1 29.0 30	145 178 165 180 135 130	-	-	240 242 320 285 265 260
26	108	21.7	90	-	-	305
27	85	18.6	73	-	-	180
28	115	17.5	73	-	-	
29	120	22.6	105	-	-	295

Identification	**NO TALKING, WALKING AT 6.5 kph ON A 0 DEGREE SLOPE**			**WITH TALKING, WALKING AT 6.5 kph ON A 0 DEGREE SLOPE**		
	Average heart rate (bpm)	*Average Minute Flows (litre/min)*	*Peak Inspiratory Air Flow (litre/min)*	*Average heart rate (bpm)*	*Average Minute Flows (litre/min)*	*Peak Inspiratory Air Flow (litre/min)*
30	130	21.3	88	-	-	125
31	102	23.1	80	-	-	215
32	95	21.3	104	-	-	355
33	104	26.9	90	-	-	143
34	110 115	16.4 17.2	96 95	-	-	161 152
35	-	-	-	-	-	-

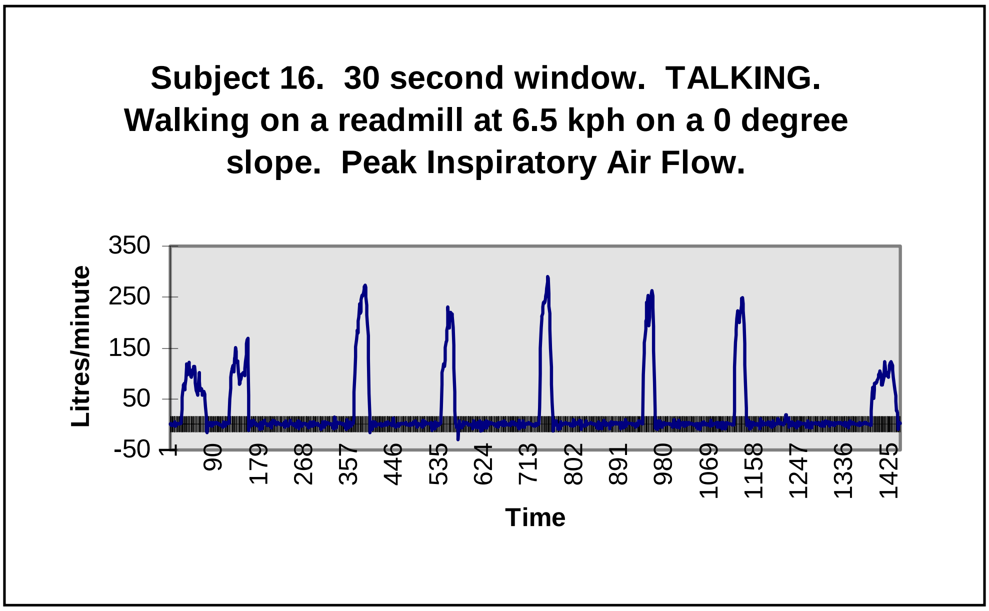
Heart Rate, Minute Flows and Peak Inspiratory Air Flows for subjects walking on a treadmill at 0 degree incline at 6.5 Kph.

TABLE 3



Subject 16. Walking on a treadmill at 6.5 kph on a 0 degree slope uphill with no communication.

GRAPH 5



Subject 16. Walking on a treadmill at 6.5 kph on a 0 degree slope uphill with shouting.

GRAPH 6

The graphs are shown in more detail in Appendix C

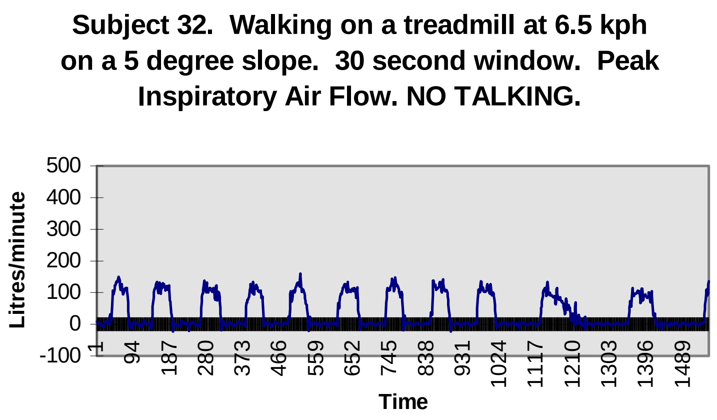
Part 4

Subjects are now performing additional work by walking at 6.5 kph on a 5 degree slope uphill. As before, subjects walked for 3 minutes on this angle and then shouted a command.
The increase in Peak Inspiratory Air flows are shown in Table 4.

Identification	**NO TALKING, WALKING AT 6.5 kph ON A 5 DEGREE SLOPE**			**WITH TALKING, WALKING AT 6.5 kph ON A 5 DEGREE SLOPE**		
	Average heart rate (bpm)	*Average Minute Flows (litre/min)*	*Peak Inspiratory Air Flow (litre/min)*	*Average heart rate (bpm)*	*Average Minute Flows (litre/min)*	*Peak Inspiratory Air Flow (litre/min)*
11	138	38.7	72	-	-	260
13	144	47.4	215	-	-	340
	135	58.4	210			335
	141	57.1	225			330
	133	51.8	165			430
14	142	42.3	210	-	-	285
15	124	29.5	124	-	-	310
20	-	35.1	138	-	-	250
23	135	46.7	210	-	-	320
24	162	65.2	315	-	-	325
25	138	38.1	190	-	-	190
	143	39.8	185			320
	123	52.9	240			290
	147	47.4	180			290
	136	45.8	235			300
	145	43.4	228			290
26	153	32.3	140	-	-	230
	145	37.2	135			280
27	124	29.1	123	-	-	231
28	158	27.1	100	-	-	147
31	127	35.1	140	-	-	283
32	135	29.1	108	-	-	313
	125	38.5	162			410

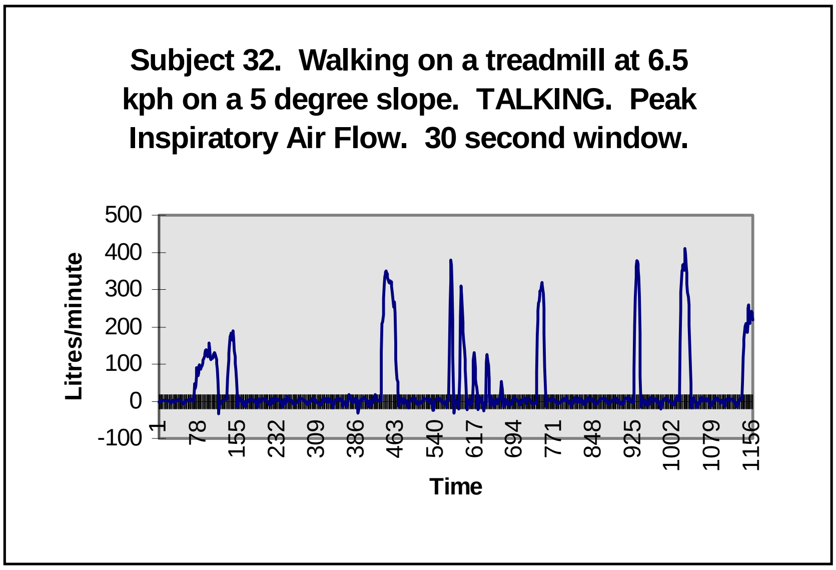
Heart Rate, Minute Flows and Peak Inspiratory Air Flows for subjects walking on a treadmill at a 5 degree incline at 6.5 Kph.

TABLE 4



Subject walking on a treadmill at 6.5 kph on a 5 degree slope uphill. No communication.

GRAPH 7



Subject walking on a treadmill at 6.5 kph on a 5 degree slope uphill. Talking

GRAPH 8

Photographs of test equipment in use

Walking on a treadmill at 6.5 kph on a 5 degree slope uphill

Photo 1

Conclusion

These and other similar studies can be expected to be increasingly important to industrial and other users of respiratory equipment because of the increasing awareness to ensure that the respirator equipment functions over all the normal roles performed during all phases of every-day industrial work situations.

It may be important for respirator certifying bodies to take these and other factors into account when evaluating new and used respirator equipment. Hitherto, the variations in breathing patterns and the large rates of inspiratory air being used as shown in this work have not been taken into consideration in any published standard that we are aware of. The large rates of Peak Flows are in excess of that reported in the literature to date and have important implications for users and manufacturers of respiratory equipment.

This work has been possible owing to specialised equipment being made to measure and instantaneously download the Minute Flows and Peak Inspiratory Air Flows while subjects were performing work at different rates. These facilities may not have been available to this time.

Current Standards do not consider the implications of the large values and variations in the Peak Values, and yet these form part of the normal use of the protective equipment in practice. Similarly, the design of respirators, particularly PAPR equipment, will need to duplicate the work and consider the new values shown.

End

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Appendix A

- Subject 10. Standing still, looking ahead. 30 second window. Peak Inspiratory Air Flow. NO TALKING

- Subject 10. Standing still, looking ahead. 30 second window. Peak Inspiratory Air Flow. TALKING.

Appendix B

- Subject 10. Light work. 30 second window. Peak Inspiratory Air Flow. NO TALKING.

- Subject 10. Light work. 30 second window. Peak Inspiratory Air Flow. TALKING.

Appendix C

- Subject 16. 30 second window. Walking on a treadmill at 6.5 kph on a 0 degree slope. Peak Inspiratory Air Flow. NO TALKING.

- Subject 16. 30 second window. Walking on a treadmill at 6.5 kph on a 0 degree slope. Peak Inspiratory Air Flow. TALKING.

Appendix D

- Subject 32. 30 second window. Walking on a treadmill at 6.5 kph on a 5 degree slope uphill. Peak Inspiratory Air Flow. NO TALKING.

- Subject 32. 30 second window. Walking on a treadmill at 6.5 kph on a 5 degree slope uphill. Peak Inspiratory Air Flow. TALKING.