Alarm Bells Ringing

The respiratory physiology of an emergency evacuation from a high-rise building

Objectives

This brief outline is about an experiment conducted in Sydney, Australia by The S.E.A. Group in January 2002.

The **main objective** of the exercise was to explore how human breathing works during an emergency evacuation drill in a high-rise building — especially with a view to determine the desired function and capabilities of escape respiratory protection devices.

The **secondary objective** was to compile a simple knowledge base and clear demonstration of the mechanics of human breathing during a simulated evacuation, upon which both authorities such as NFPA and NIOSH and end-users can base their selection of emergency escape equipment.

Introduction

If you live or work in a high-rise building, you will have noticed the various safety features of the building. There are perhaps fire extinguishers on every floor. Often, fire hydrants are available in the common areas. There might be sprinklers and fire detectors in the ceiling. An alarm system. And, always, a set of fire stairs.

Some time ago, these measures might have seemed adequate, giving people in the building ample warning of an emergency, tools with which to douse a small local fire, and an opportunity to evacuate the area.

But sadly, these days, with the added awareness that an emergency is not always an accidental fire, the need for extra protection has arisen.

Personal escape hoods

Whether to protect against acrid smoke, toxic chemicals released in the fire, or sinister bio-chemical agents purposely designed to cause destruction and death, one further emergency device has become a requisite in some quarters: the personal escape hood.

The purpose of the hood is to be always at the ready, within its owner's reach, and capable of being operational within seconds.

The device, incorporating a filtering mask mounted inside a protective hood with visor, is designed to protect the user's lungs and eyes while making his or her egress.

Whereas an unprotected person might succumb to smoke, gas, fumes and other air-borne hazards long before even reaching the door of the emergency exit, or simply not being able to find the exit, a protected evacuee has both vision and respiration safeguarded during the entire escape.

Not the whole story

It might seem simple: you put on the mask and make your way down the stairs to the ground level. That's it: you're safe.

However, this is too simplistic a notion.

In the respiratory protection industry, we have learnt over many decades that the human body is greatly affected by wearing a respirator — especially a negative pressure respirator such as an escape hood.

Therefore, respirators have to be designed to cope with human breathing.

We have shown on countless occasions that Standards testing and Standards requirements in no way reflect the volumes and movements of air in human breathing.

In other words, respirators that have achieved Standards approval may still be completely unsuitable for any human work more strenuous than, say, getting out of your armchair.

Let alone getting out of your room, along long corridors, and down 25 flights of fire stairs in the throng and near-panic of hundreds of others.

The experiment

At S.E.A., we decided to conduct an experiment to find the answer to two major questions:

- ***How does human breathing work while escaping a high-rise building?***
- ***What is really required of an escape respirator?***

The experiment included 10 people of varying age, sex, weight and level of physical fitness. A run-down is given here:

Age range:	16—60 years
Weight range:	56—100 kg 123—220 lbs
Gender:	8 male 2 female

The participants were fitted with an SE400 respirator, featuring a visored hood which covered the head and shoulders. The respirator was connected to a data-logger, a device that continuously plots the user's breathing pattern: the volume and air flow of each and every breath is measured and recorded. The information can then be downloaded to a computer for further analysis.

In order to make the exercise as realistic as possible without jeopardising public safety, S.E.A. had reserved 25 floors of the fire escape in a high-rise building. The participants were asked to make their way down as quickly, but also as safely, as they could.

Floor numbers were clearly marked, and a camera crew captured the descent on the tape of a continuously running video camera. This way, the resulting breathing curves could be matched up with each stage of the descent.

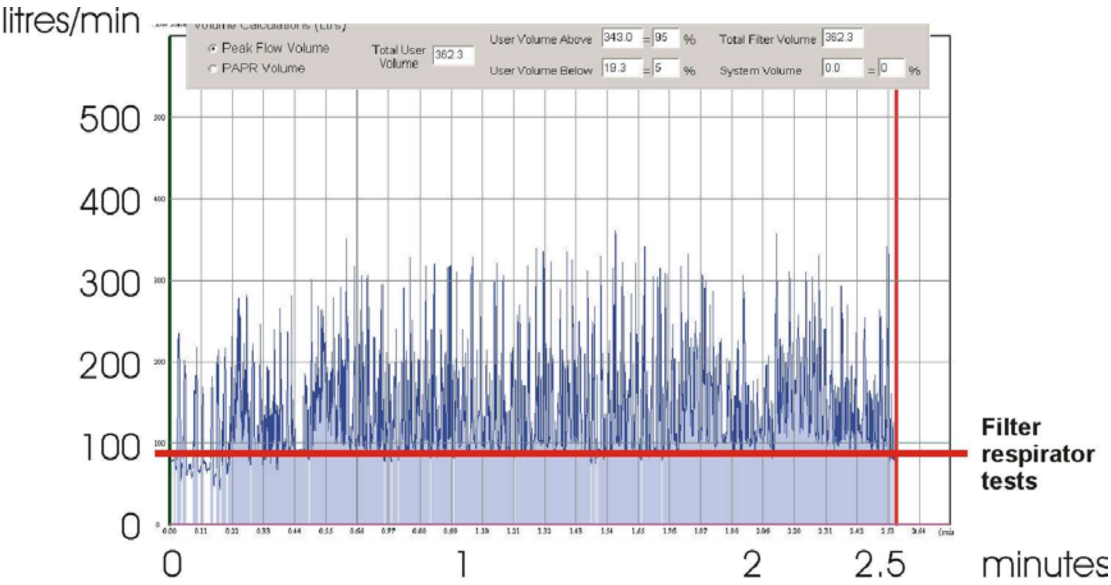
Why not use negative pressure respirators?

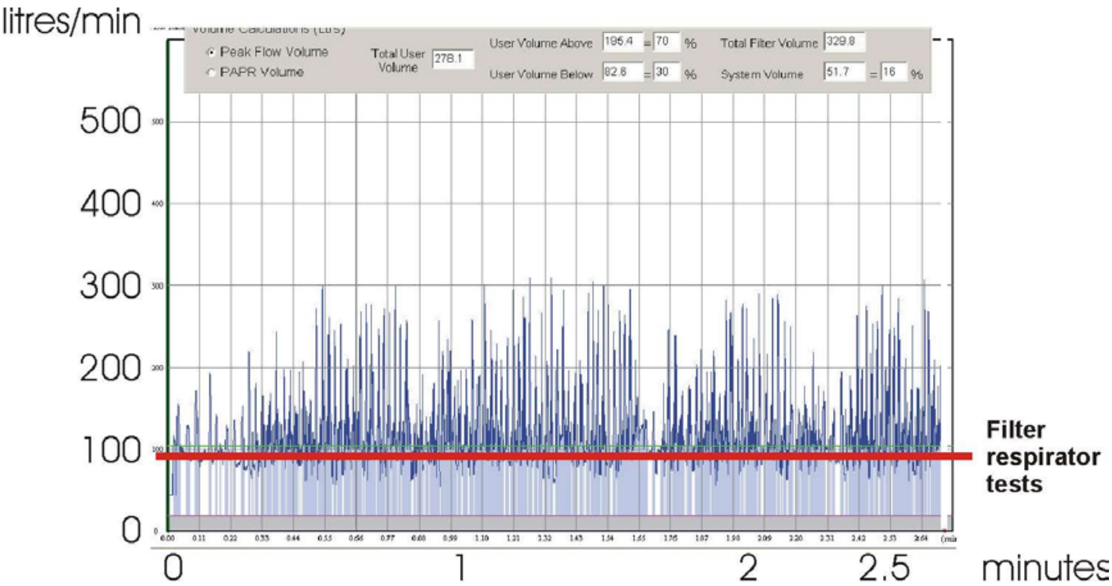
In this experiment, we used the SE400 respirator, which is a positive pressure device. Why?

Because we wanted to document human respiration while *breathing freely*. Only by measuring people's breathing as though they weren't wearing a respirator at all can we determine what the 'ideal' respirator should be capable of.

Readings

The resulting breathing curves showed some remarkable similarities regardless of age or fitness, and a number of startling revelations. Below are just two sample graphs:





After collecting and analysing all the data, a full compilation was made, averages and standard deviations were calculated, and all information was presented in the form of a spreadsheet. Below are some averages:

	Range	Average
Age of participants	16–60	35.9 years
Body weight	56–100 kg (123–220 lbs)	78.6 kg (173.3 lbs)
Total air required	278–407 litres	359 litres
Time of descent	2.5–3.4 minutes	2.9 minutes
Minute volume	99.3–144.4 litres/minute	124.5 litres/minute
Peak inhalation air flow	180–350 litres/minute	272 litres/minute

Observations

A number of important observations can be made on the basis of our simple test. Among them are the following:

- All participants, regardless of age or fitness, reached very high peak air flows very rapidly. In fact, within only two flights of stairs, most participants had reached their optimum lung function, which then held steady throughout the descent.
- The actual peak flows measured in real people were between 2 and 4 times greater than the flow levels used in Standards testing (**RED** line in graphs).
- It must be kept in mind that this exercise was performed in relaxed and orderly circumstances. Also, that voice communication did not form part of the test. In a *real* emergency, the air flows are likely to reach significantly higher levels, due to two major factors:
    - **Fear and anxiety.** Severe emotional stress, excitement, perhaps panic, tend to make human breathing more shallow and, consequently, more rapid. This means much higher peaks.
    - **Speech.** In a real emergency, voice communication is much more likely to be a factor in the breathing pattern. As has been shown in numerous tests, speech can generate extremely high peaks in the air flow.

Discussion

Apart from the capability to filter out various hazardous and toxic materials, an escape respirator must fulfil one important requirement:

The respirator must be able to cope with human breathing at sustained hard work, in an emergency situation

A Standards approval cannot be relied upon: as shown by the graphs, the level at which respirators are Standards tested is unrealistically low. Therefore, only additional tests can ascertain whether a respirator can cope with realistic air flows.

What happens if it can't?

Two things occur when a respirator cannot keep up with the user's demand for air:

- **It begins to leak**. The respirator becomes deformed and air is drawn in around the rims of the mask.
- **It causes great stress** on the lungs, heart, body and, consequently, on the mind as well. Exhaustion and anxiety set in, which might hamper the progress of the evacuation. The lack of free breathing causes the brain to tell the body to slow down. The person may faint. The stress on the lungs and heart — especially in a highly stressful situation — might prove to be fatal.

Conclusion

In selecting a suitable respirator for emergency evacuation purposes, it is important to choose a respirator that best can meet the breathing demands of a person performing the type of work required in this test.

Apart from being able to provide adequate **face seal** in most people, the respirator must also be capable of allowing the user **enough air** to perform the evacuation. This factor cannot be ascertained simply by ensuring that the equipment carries a Standards approval.

The S.E.A. Group