



Support material

Including references and bibliography



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SE400 is the only fan-supplied positive pressure demand respirator in the world with a Workplace Protection Factor greater than 2000.

Excerpt from a recent test report:

The SE400AT positive pressure powered filter device exhibited a 95th percentile Workplace Protection Factor >2,000 when worn by contractor's employees during asbestos removal operations.

It is therefore concluded that an Assigned Protection Factor of 2,000 could validly be assigned to the SE400AT model evaluated in the Workplace Protection Factor study reported herein.

(Howie, R. M., 2001: *Effectiveness of SE400AT Positive-Pressured Demand Filtering Device during Asbestos Removal Operations*, report RMH/01/196, Robin Howie Associates, Edinburgh.)

Unique features of the SE400 Respirator

Main feature:	SE400	Other types
INTERACTIVE AIR SUPPLY	Senses the user's breathing pattern and adjusts itself dynamically	Continuous flow or other unchanging supply
POSITIVE PRESSURE	Keeps up with user's breathing: true positive pressure up to and above 400 l/min Positive pressure air supply without long hoses or heavy cylinders	PAPR: Pressure likely to periodically dip into negative, even at light work SCBA: Negative pressure will occur if fixed supply pressure is exceeded by user
INTERACTIVE OPERATION	Instant alert in the event of any problem, such as low battery or expired filters	No indication in the case of a problem. No indication when filters need changing.
SELF-DIAGNOSTICS	Continuous checking of the unit's functions. Immediate alarm if unit does not provide adequate protection.	No checking. No alarm
BACK-UP	Positive pressure unit becomes an ordinary filter respirator if motor breaks down	SCBA: ZERO protection immediately Loose-fitting respirators: lethal oxygen deficiency and CO ₂ levels within 1 minute
USAGE RECORDING	Complete audit information on user ID, usage periods, and function of the unit	No idea how the device was used, when, for how long, or by whom
PARTICLE FILTER WARNING	User alert when particle filter needs changing	No indication
GAS CARTRIDGE WARNING	User alert when gas cartridge needs changing	No indication
VOICE COMMUNICATION	Microphone in respirator. Loudspeaker or 2-way com-radio can be hooked up to the system. The SE400 responds to increased airflow demand caused by changed breathing pattern.	Even if units are fitted with microphones or speech diaphragms, changed breathing pattern may easily cause negative pressure in the mask

Comparison chart — assigned protection factors

Type	OSHA	NIOSH	British Standard
SCBA	1000	10,000	2,000
SAR (Supplied air):			
Hood	25	25	40
Full face (continuous flow)	–	–	100
Full face (pressure demand)	1000	2000	2000
Half face	1000	1000	10
PAPR:			
Hood/helmet	25	25	40
Loose-fitting	25	25	40
Full face	250	50	40
Half face	50	50	20
Negative pressure:			
Full face	50	50	40
Half face	10	10	10–20
Limited use mask	10	10	4–10

The SE400 is not included in the above list, as these standards have yet to establish a class for positive pressure demand air purifying respirators. Therefore, the SE400 has as yet no assigned protection factor.

However, as mentioned before, the SE400 has an attainable protection factor equal to that of an SCBA, that is, between 2000 and 10,000 depending on the jurisdiction.

It is important to note that these protection factors do NOT indicate that by wearing a respirator with a protection factor of, say, 250, a user can enter an area with a contaminant concentration 250 times the hygienic limit level.

All air purifying respirators have the same limitations. They must NOT be used:

- In oxygen-deficient atmospheres
- In IDLH (immediately dangerous to life and health) atmospheres
- In non-filtrable atmospheres
- In atmospheres containing a contaminant concentration above the capacity of the gas absorber (this level depends on jurisdiction)

Types of respirators: their features and limitations

What is a respirator?

A respirator is a device that stops contaminants from entering the lungs of a person. These contaminants may be of many types:

- *toxic or non-toxic*
- *irritating nuisance materials or completely unnoticeable by the person*
- *detectable by smell or taste, or entirely without smell or taste*
- *gas, vapour, fume, dust, smoke or aerosol — or a combination of two or more types.*

In order to prevent the contaminant from entering the lungs, the respirator must be worn **all the time**. Even if the respirator is removed for a very short time, its performance will be rendered **NIL**.

Therefore, a respirator must be designed for continuous use. The user's ability to wear the respirator 100% of the time spent in a hazardous environment depends on a number of factors, including:

- *the user's **health***
- *the **type of work** performed*
- ***design factors**, such as compatibility with other protection equipment (communication, ear muffs, hard hats etc.)*
- ***environmental factors**, such as temperature and humidity*
- ***motivation** (understanding the consequences of **NOT** wearing the respirator)*

Types of respirators

Respirators can be classified into two main groups — **Air-purifying** respirators and **Air-supplied** respirators, and operate on two different principles:

- Air-purifying respirators operate by **filtering out** the contaminant from the atmosphere in the work environment, before allowing the user to breathe the air
- Air-supplied respirators operate by **channelling fresh air** directly from an uncontaminated source to the user's lungs

These two main categories can further be subdivided into sub-groups as follows:

Air-purifying respirators:	Air-supplied respirators:
<p>Non-powered:</p> <ul style="list-style-type: none">• Half mask filtering face pieces• Half mask elastomer face pieces• Full face masks <p>Powered:</p> <ul style="list-style-type: none">• PAPR (Powered Air Purifying Respirators)• Power-assisted masks• FPBR (Fan supplied, Positive pressure, Breath responsive Respirators)	<p>Remote source:</p> <ul style="list-style-type: none">• Fresh air hose supplied• Compressed air line supplied <p>Carry-on source:</p> <ul style="list-style-type: none">• Self-contained breathing apparatus

General features and limitations

The all-encompassing limitation of all respiratory devices is that all devices, regardless of type or construction, rely on being **correctly** worn **100% of the time** while the user is in the contaminated environment. No respirator provides protection if it is not worn, and the level of protection can decrease rapidly or instantly if the respirator is not worn correctly.

All respirators should therefore be designed in such a way that they not only are **capable** of being worn 100% of the time, but also **be practical** to wear for long periods or an entire shift. This means that a number of considerations must be taken into account, such as effective voice communication without removing the respirator, and wearing the respirator together with other safety equipment, such as goggles, helmets and ear muffs.

An equally important limitation is the role of speech. Voice communication is difficult or impossible while wearing most respirators, resulting in the intermittent removal of the respirator for the sake of communication.

Other respirators may be fitted with a speech diaphragm or even an internal microphone, thus encouraging the user to keep the respirator on while speaking.

However, most of these respirators have no means of keeping up with the much higher peak flow rates of the user's breathing during speech communication. The result is that the respirator, while allowing the user to speak, also allows inward leakage.

Type-related features and limitations

The following table outlines some important features and limitations of the two main categories of respiratory protection:

Type:	Features:	Limitations:
Air-purifying respirators	<ul style="list-style-type: none"> • Light weight • Highly portable • Easy maintenance • Low cost 	<ul style="list-style-type: none"> • Can only be used in places with normal 20%* oxygen level • Can only be used for contaminants that can be filtered out • Can not be used for IDLH contaminants (Immediately Dangerous to Life and Health) • Filters must be replaced before they expire • Filters may not provide adequate protection (see below) • Non-powered models rely on good facial seal • Powered models may provide zero protection in case of motor failure
Supplied air respirators	<ul style="list-style-type: none"> • Can be used in oxygen-deficient areas • Assumed to have a high protection factor • Can be used for IDLH contaminants (Immediately Dangerous to Life and Health) 	<ul style="list-style-type: none"> • Poor mobility because of hoses or air cylinders • Heavy and bulky cylinders • Expensive to buy and run • Complex maintenance • Zero protection level in case of failure

**) concentrations vary slightly between different countries*

Model-related features and limitations

The following table outlines some important features and limitations of various specific models of respiratory protection:

Model:	Description:	Limitations:
Half mask filtering face pieces	Previously known as disposable masks or limited use masks. Mainly constructed as a single-piece of filtering material, shaped or moulded to fit the face. Some masks feature an exhalation valve.	<ul style="list-style-type: none"> • Impossible to perform facial fit test • Inward leakage likely around the facial seal, especially during moderate to heavy breathing • Filter material usually electrostatic (may not function in certain environments — see filter section below)
Half mask elastomer face pieces	Tight-fitting respirators made of silicone, rubber or elastic material. Cover the user's nose and mouth. Feature inhalation and exhalation valve(s). Can be fitted with disposable particle filters, gas cartridges, or combination cartridges. Particle filters can be electrostatic, mechanical, or a combination of both.	<ul style="list-style-type: none"> • Require correct fitting and good facial seal to work • Impossible to know whether inward leakage is occurring • Filters and cartridges must be changed regularly • Cartridge replacement schedule complex to calculate • Impossible to know if gas penetration occurs
Full face masks	Tight-fitting respirators made of silicone, natural rubber, chloroprene or similar materials, featuring a visor and covering the user's entire face. Higher protection factor than half masks. Feature inhalation and exhalation valve(s). Can be fitted with disposable particle filters, gas cartridges, or combination cartridges. Particle filters can be electrostatic, mechanical, or a combination of both.	<ul style="list-style-type: none"> • Require correct fitting and good facial seal to work • Impossible to know whether inward leakage is occurring • Filters and cartridges must be changed regularly • Cartridge replacement schedule complex to calculate • Impossible to know if gas penetration occurs • As full face masks can be used in highly contaminated areas, it is very important to select a mask material that can withstand the contaminant
Power assisted masks	Battery-operated blowers attached to a mask, feeding air into the mask at a slight over-pressure of about 120 l/min. Usually used with full face masks, fitted with particle filters, gas cartridges or combination cartridges.	<ul style="list-style-type: none"> • Reliant on an adequately charged battery • Require correct fitting and good facial seal to work • Impossible to know whether inward leakage is occurring • Filters and cartridges must be changed regularly • Much shorter cartridge life than negative pressure

		<p>respirators</p> <ul style="list-style-type: none"> • Cartridge replacement schedule complex to calculate • Impossible to know if gas penetration occurs • Peak air flow likely to exceed feed rate even at light work (esp. during voice communication), causing inward leakage
PAPR (Powered Air Purifying Respirators)	<p>Battery-driven fans drawing contaminated air through a filter and supplying the filtered air to a tight-fitting half- or full face mask, or to a loose-fitting hood, helmet-visor or blouse. Typically supplies a continuous air flow at a constant pressure of 120—170 l/min. Used with particle filters, gas cartridges or combination cartridges.</p>	<ul style="list-style-type: none"> • Reliant on an adequately charged battery • Impossible to know whether inward leakage is occurring • Filters and cartridges must be changed regularly • Much shorter cartridge life than negative pressure respirators • Impossible to know if gas penetration occurs • Peak air flow likely to exceed feed rate even at light work (esp. during voice communication), causing inward leakage • Loose-fitting models (hoods, helmets, blouses) cause lethal levels of oxygen deficiency and CO₂ concentration within one minute of the motor failing.
Fresh air hoses	<p>Tight-fitting respirators fitted with an air hose leading to a fresh air location. The air is drawn in by the user's lungs; no motor is used.</p>	<ul style="list-style-type: none"> • Unacceptable breathing resistance if hose is longer than about 9 metres. • Limited moveability • Breathing resistance may not permit hard work
Compressed air line supplied respirators	<p>Air is channelled from a remote source to the user's lungs by way of a hose. Available in three main types: Continuous flow (a constant flow of air pumped to the user) Negative pressure demand* (a valve opens at inhalation, letting the air supply in. There is negative pressure in the mask during inhalation.) Positive pressure demand (a valve opens at inhalation. A slight positive pressure is maintained in the mask at all times.)</p>	<ul style="list-style-type: none"> • Air source must be pure • Hoses may hamper mobility • If air is contaminated at the source (car exhaust, smoke, etc), the contaminant will be supplied to the user • Negative pressure demand models rely on good facial seal • Efficient in-line filters must be fitted to absorb oil mist and any other contaminants in the system • A warning system for Carbon Monoxide is preferable (required in some countries) • Air supply in all models is fixed, and will not adjust to

		<p>the user's air demands. In principle, the pressure in the respirator can become negative, causing inward leakage of the contaminant</p> <ul style="list-style-type: none"> • Loose-fitting models (hoods, helmets, blouses) cause lethal levels of oxygen deficiency and CO₂ concentration within one minute of the motor failing.
Self-contained breathing apparatus	<p>Air is supplied from high-pressure cylinders worn by the user. Some models of this type of respirator have the highest protection factor of all. There are two principal types:</p> <p>Negative pressure demand (a valve opens at inhalation, letting the air supply in. There is negative pressure in the mask during inhalation.)</p> <p>Positive pressure demand (a valve opens at inhalation. A slight positive pressure is maintained in the mask at all times.)</p>	<ul style="list-style-type: none"> • Heavy and bulky • Constant checking of air levels in cylinders required • Very high standard of training required in use and maintenance • Specialist repair and service • If the user's peak flow rate exceeds the operating pressure, negative pressure in the mask will result • Zero protection level results immediately upon equipment failure.

*) *Possibly no longer on the market*

Standards testing: why the SE400 is different:

Air-purifying	Powered	Air-supplied	FPBR
<ul style="list-style-type: none"> • Half mask filtering face pieces • Half mask elastomer face pieces • Full face masks 	<ul style="list-style-type: none"> • PAPR • Power-assisted 	<ul style="list-style-type: none"> • Fresh air hose • Compressed air line • Self-contained breathing apparatus 	<p>SE400</p>
<p>All tested in laboratory conditions. All ASSUMED to work in real life.</p>			<p>Standards approved. Then testing itself during work in real life.</p>

Limitations of filters

The performance of all known types of particle filtering techniques is affected by at least three factors:

- Air velocity through the filter
- Air temperature
- Relative humidity

These factors must be taken into consideration when selecting any air-purifying respirator, whether powered or not.

Standards Testing v. Real Life

Standards testing can only be described as pure type-testing, that is, designed only to determine the category a filter belongs to — not to grade filters in terms of relative performance.

Standards testing is done in laboratory conditions, using almost the same testing criteria in all major International Standards (America, Europe and Australia). It may be useful to compare the conditions filters are tested in, and the conditions to which they are commonly subjected in real life:

	Air velocity	Air temperature	Relative humidity
Standards testing	85—95 l/min	+20°C approx. +68 F approx.	60% approx.
Workplace	10—400+ l/min	-30—+50°C approx -22 — +124 F appr	10%—100%

It is therefore impossible to use Standards testing to determine whether a filter will perform adequately in the actual workplace.

Real life use: putting filters through the hoops

There are two main types of particle filters: **electrostatic** and **mechanical** filters. Both types are Standards tested in exactly the same way.

However, a number of independent tests have established the differences in performance between the two filter types in various environments and with various air velocities.

These tests have found cause for concern that certain types of filters may be severely affected by the three major factors, i.e. air velocity, temperature and humidity.

Detrimental effect:	Electrostatic filters	Mechanical filters
Air velocity	The higher the speed and the smaller the particles, the greater penetration. Between 11% and 64% penetration by particles <1 micron has been measured at air speeds equivalent to peak flows at light to moderate work load (100 l/min)	P100 filters are affected to some extent. Recent tests show average penetration for one model as: 95 l/min — 0.00138 250 l/min — 0.00476
Elevated temperature	Filter material starts to degrade at exposure to heat. Severe loss of protection after some hours	Effect unknown
Humidity (90%) during storage prior to use	Between 5% and 50% higher particle penetration after 1 hour's use, compared to filters that have been stored in a dry place	No adverse effect
Temperature AND humidity during storage prior to use	Slight increase in penetration of solid particles — about twice the aerosol particle penetration compared to filters stored in dry, cool conditions	No adverse effect
Work in liquid aerosol atmospheres	Very rapid loss of electrostatic charge, resulting in 4 to 8 times higher particle penetration after 60 minutes' work	No adverse effect

What does this mean?

Mainly, it means that it is very important to select the correct filter material for the workplace. If the work is performed in hot and humid areas, electrostatic filters are less likely to be a suitable choice.

Note that the tests mentioned above are concerned not only with **work** performed in hot and humid workplaces, but also to a great extent with **storage** of filters in hot and humid areas. In other words, **even an unused filter** can be severely degraded simply by being stored in a hot and humid place for a few days.

P100 filters (previously known as HEPA filters) have been shown in independent tests to be much more stable in their performance, and are able to better withstand the effects of temperature and humidity.

The FPBR type respirator

FPBR stands for Fan supplied, Positive pressure, Breath responsive Respirator.

- Fan supplied*** means that the FPBR uses a fan unit to draw contaminated air through a set of filters before supplying the cleaned air to the user
- Positive pressure*** means that the FPBR maintains positive pressure in the mask, according to the relevant Standard requirements for positive pressure (for example, 314 l/min in Europe)
- Breath responsive*** means that the FPBR dynamically and continuously adjusts the air flow to suit the user's breathing pattern.
- Respirator*** means a tight-fitting half mask or full face mask.

This is a separate class of respirator: because of certain aspects of its function and operation, FPBRs do not fit into any one of the groups of respirators outlined previously.

The SE400 respirator

The SE400 is an FPBR class respirator with extremely high performance and capabilities, including positive pressure up to and exceeding 400 l/min. The SE400 satisfies Standards requirement not only for negative pressure filter respirators and powered respirators, but also for breathing apparatus.

The main differences between the SE400 and **all other types of respirators** can be expressed in four chief points:

- Interactivity
- Self-monitoring
- Back-up
- Usage recording

These four features are not available in **any** other respiratory device, whether a simple disposable filtering face piece or a top-of-the-range self-contained breathing apparatus. The following table may explain, in broad terms, what is meant by these four unique features:

INTERACTIVITY	<p>The FPBR interacts with the user in two ways:</p> <ul style="list-style-type: none"> • Interactive operation <i>The FPBR operates on a principle of dynamic air flow. It senses the user's breathing patterns and air requirements, and responds accordingly. The harder the user works, the more air the FPBR supplies</i> • Interactive reporting <i>If the FPBR senses that something is (or soon will be) functioning at less than optimum performance, it alerts the user immediately, letting the user decide what should be done about the problem. Alerts may include:</i> <ul style="list-style-type: none"> — <i>Low battery power</i> — <i>Negative pressure</i> — <i>Particle filters need changing</i> — <i>Gas cartridges need changing</i> — <i>Contaminant breakthrough (NB: this feature will be added to future generations of SE400)</i>
SELF-MONITORING	<p>The SE400 keeps a constant check of its own function and performance. The user's every breath is monitored in real-time, checking whether more or less air is required, ensuring that the pressure in the respirator is positive, and much more. Battery power, fan functionality, pressure drop over filters and much more are monitored continuously.</p>
BACK-UP	<p>Because the SE400 features a tight-fitting half- or full face mask connected to air purifying filters, the SE400 will function as a negative pressure demand respirator in case of motor failure. In other words, should the SE400 cease to function, the user will still achieve adequate protection while exiting the area, and without having to remove the respirator.</p>
USAGE RECORDING	<p>The SE400 is fitted with its own data-logging device which records every important event in the operation of the respirator. In addition to normal events such as switch-on and switch-off, the SE400 records all unusual events, e.g. mask removed during use, battery status, changed filters, expired filters, sudden pressure drop, and so on.</p> <p>All of these events are recorded, time-stamped, and can be down-loaded to a computer after the shift. A user identification code can also be added to the record.</p>

Start-up and continuous checks in the SE400

As mentioned earlier, the SE400 positive pressure demand respirator continuously checks the air going through the filters, the pressure in the respirator, the pressure in the housing, the battery charge level, and so on. These continuous checks could be described as *user-side monitoring*.

However, a further feature of the SE400 is its constant checking of the motor, the circuit board and other essential factors. This could be described as *internal monitoring*.

There are three ways in which the SE400 can check its own operation.

START-UP

At start-up, the unit goes through a number of tests, including the following:

- Communication between various micro-chips on the circuit board
- Critical voltages at various points in the unit
- Calibration data (check-sum tests to ensure that the downloaded data has not been corrupted)
- Memory testing

The objective of the start-up test is that the SE400 will not allow the user to wear the equipment if there is any imminent maintenance or other action required. For instance, a user about to enter a hazardous area will not be able to do so if there are only a few minutes left of battery life.

The unit will alert the user by light and sound warnings. For example, in a noisy area the user cannot hear whether the motor is running or not. The light display will confirm this.

OPERATION

About once per second during operation, the SE400 keeps a check on three crucial factors:

- Motor is on and is running normally
- Temperature is below 105°C (220 F) inside the housing
- Battery power is sufficient for all functions

Some of these features are there to preserve the SE400 unit itself. For example, the motor will shut down if the interior temperature reaches a point where the circuit board or other components could be damaged.

Others are there to alert the user of factors or events that might otherwise be hard to notice in a noisy workplace.

SELF-TEST

A self-test can be performed by the user at any convenient time and place. The self-test procedure ensures that the entire operation of the SE400 is in working order, including physical functions such as positive pressure inside the mask, and electronic functions such as the calibration data.

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