

Dust Protection, Total Inward Leakage Testing and The Bellows Effect

The Bellows Effect is an important consideration in protection against hazardous dry particles. Unlike liquids, dust floats freely and will move and penetrate inside a garment only with air-flows. Thus the tendency of a garment to generate air-flows in and out of gaps or holes in the construction or ensemble (such as the zip, seam holes or gaps between the coverall and other PPE) is important in understanding a garments effectiveness in preventing the ingress of particles.



Bellows Effect theory states that a non breathable fabric will generate greater air-flows through gaps such as a zip and seam holes than will a breathable fabric because in the latter the air can pass through the fabric more easily. By contrast a breathable fabric has a lesser tendency to create such air-flows. Thus the theory suggests that a garment of breathable material can achieve better overall dust protection than a similar garment made of non-breathable material, even though the latter fabric may feature a more effective particle filtration.

..... So much for the theory. But does it work in the real world? Is the Bellows Effect real? **We can test it by using the Type 5 whole garment inward leakage test and analysing the results.**

Type 5 Whole Garment TIL Testing

Testing of Type 5 garments for protection against hazardous dust particles includes a finished garment spray cabin test defined in EN 13982-2:2004.



The test involves:

- 10 test garments (5 different wearers of at least 2 sizes) entering a spray cabin and performing three "exercises" - standing, walking (on a treadmill) and squatting.
- Three probes inside the garment at the chest, waist and back of the knee count the particles that penetrate during each exercise
- A fourth probe outside the garment counts the number of particles in the spray cabin (the "Challenge Count"), allowing the count of particles penetrating inside the garment to be expressed as a Total Inward Leakage Percentage (TIL) of the challenge count.
- The test produces 90 individual TIL results (10 tests x 3 probes x 3 exercises), along with average inward leakages per user and per exercise, and a total average TIL over the full test.
- To investigate the bellows effect, two garment types have been tested: SafeGard™ GP - an SMS breathable fabric garment and MicroMax® NS, a non-breathable microporous film laminate garment. Both feature the same stitched seams, design and sizing to avoid variation as a result of other factors.

To find out more about different Type 5 & 6 coverall fabric types and best practice selection of garments, download our ['Guide to Type 5 & 6 Coverall Selection'](#)



Air Permeability and Particle Filtration efficiency

Air Permeability in cubic feet per minute	
SafeGard™ GP	40
MicroMax® NS	<0.5

SafeGard™ GP features a much higher air permeability

Particle Filtration Efficiency (IEST-RP-CC003.3, Appendix B, Section B.1.1)					
Particle Size	>0.3µm	>0.5µm	>1.0µm	>5.0µm	>10.0µm
SafeGard™ GP	19.00%	40.20%	60.00%	99.40%	99.90%
MicroMax® NS	94.90%	97.90%	98.30%	99.00%	99.60%

MicroMax® NS features a superior barrier to particles.

MicroMax® NS fabric features the superior particle barrier and SafeGard™ GP fabric features the superior air permeability.

Note: The challenge with testing particle filtration is that particles move only with air-flows - a problem when testing fabrics that have lower air permeability. The test above works by maintaining an air flow of 1 cfm through the fabric. This is not necessarily a reflection of the real world where such air flow levels are unlikely to be achieved. Thus this is not a reflection of particle filtration efficiency of these fabrics in a real world garment situation (i.e, it does not mean that the percentage efficiencies quoted above would be matched in a garment worn by a user. It does however serve as a method of comparing the effective filtration efficiency between different fabrics.

To assess the real world consequences of the bellows effect, full test results of Type 5 TIL tests on SafeGard™ GP and MicroMAX® NS were analysed, and to show the effect of additional taping of the zip on the MicroMax® NS coverall, an additional single test was conducted. All tests were conducted independently by the Institute of Occupational Medicine in Edinburgh, Scotland. Test reports are available on request. Results are summarised with conclusions overleaf.

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Summary of Test Results and Conclusions

1 Does the Bellows Effect have real consequences for protection?

Summary of average TIL (Total Inward Leakage) results per wearer											Despite the fact that non-breathable MicroMax® NS fabric has a superior particle filtration efficiency - see <i>overleaf</i> - (so particles are not passing through the fabric), breathable SafeGard™ GP shows a Total Inward Leakage lower than the MicroMax® NS.	
	1	2	3	4	5	6	7	8	9	10		Average
SafeGard™ GP	2.786	1.658	1.963	2.677	3.137	3.347	4.762	4.834	2.466	3.771		3.14
MicroMax® NS	6.493	3.903	7.802	7.716	3.654	4.536	7.566	7.342	6.799	6.789	6.205	

This shows that the bellows effect results in a higher total inward leakage in the non-breathable fabric coverall. The breathable fabric coverall SafeGard™ GP provides the better protection.

2 Is the Bellows Effect affected by movement and how does this affect protection?

Summary of average TIL (Total Inward Leakage) results per exercise							The average Total Inward leakage during the squatting exercise is higher for both coveralls showing that the bellows effect is increased during a more strenuous movement such as squatting, as would be expected. However, the relative difference between the TIL during squatting and walking is much greater in the non-breathable MicroMax® NS coverall: 2.56% for the breathable SafeGard™ GP 4.83% for the non-breathable MicroMax® NS coverall
Exercise	SafeGard™ GP			MicroMax® NS			
	Standing	Walking	Squatting	Standing	Walking	Squatting	
TIL %	0.638	2.454	6.285	2.279	2.802	13.537	
% increase during squatting over walking			2.56%			4.83%	

This shows that the bellows effect is not only greater with a non-breathable coverall, it is enhanced during more strenuous movement. In this case the effect is doubled, resulting in more than four times the inward leakage than during a less strenuous exercise. *In other words the choice of a breathable fabric coverall is even more important in applications involving strenuous movement.*

3 Can protection be improved by taping up the zip flap on a Type 5 coverall?

Summary of TIL with untaped and taped zip flap on MicroMax® NS			Through the simple act of taping up the zip flap, the overall Inward Leakage has been substantially reduced on the MicroMax NS - from an average of 6.21% on the un-taped, to 0.27% on the taped.
	Average of 10 tests <i>without taping</i> of zip flap	Average of 10 tests <i>with taping</i> of zip flap	
Total Inward Leakage	6.21%	0.27%	

Thus protection can be dramatically improved through the use of a standard standard Type 5 coverall simply by taping up the zip flap and sealing the zip to prevent air-flows that will draw in dust particles. This also indicates that the route of a high proportion of the particles that do penetrate inside the coverall is through the zip.

4 Read the garment instructions carefully: What level of Total Inward Leakage does your Type 5 coverall really achieve?

<p>Some manufacturers of standard Type 5 coveralls have claimed very low Total Inward Leakage Test Results, such as less than 1%, to suggest their garment offers greater protection than others.</p> <p>However, invariably, such low results as these are achieved only through the act of taping up the zip flap to prevent ingress of particles by this route. Often this information is available but not clearly shown or perhaps shown only in small print in the User Instruction.</p>	<p>So when using Total Inward Leakage test results to assess the relative protection offered by different coveralls, always read the User Instructions to establish the parameters of the test and most importantly whether the zip-flap was taped or un-taped.</p> <p>The test results for MicroMax® NS detailed above show that by taping up of the zip flap, the Total Inward Leakage can be reduced to less than 0.5%</p>
<p>Thus users in the real world will not benefit from such low inward leakage claimed by some manufacturers UNLESS they are also taping up the zip flap before use. If not they may be subject to much higher inward leakage and greater contamination than expected.</p>	

CONCLUSIONS

- For protection against less toxic dusts of >1µm or in areas of low dust concentrations, especially in applications involving strenuous or regular movement, a breathable (SMS) garment may provide better protection as it will create a less pronounced bellows effect.
- When wearing non-breathable coveralls, taping up the zip flap may considerably improve protection.
- Selecting a garment with sealed seams and taped zip flap will increase protection even more, provided joints between the coverall and other PPE are taped up.
- If using TIL results for comparison purposes in selection of garments read the user Instructions carefully; very low TIL results are usually achieved by taping up the zip flap.
- Some degree of bellows effect, and therefore some level of penetration inside a standard Type 5 coverall is inevitable. In some high risk applications with highly toxic dusts therefore, a fully gas-tight suit might be required.