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Fog removal with a fog mesh – mist eliminators and multiple mesh systems

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The aim of this study was to define feasibility of a fog mesh system as a fog removal method in a mine. Previous studies at the Pyhäsalmi Mine and at the Orivesi Mine showed that a practical application based on the adhering nature of water on a net is possible. The questions concerning effectiveness and resistance of a mesh system are covered now.

In order to evaluate these factors multiple mesh tests were used. Also a mist eliminator, which was developed for fog removal, was tested. Two multiple mesh tests with different material combinations and independent material tests were performed. Air velocity, relative humidity, temperature, dew point, and particle concentration were measured.

The multiple mesh tests indicated increased resistances. Unfortunately desired efficiency was not reached with any system. Even if reduced relative humidity and particle concentration were observed, the capacity did not reach the requirements of a fog removal system.

Keywords: mine ventilation; fog; mesh; mist elimination; relative humidity; particle concentration

AMS Subject Classification: 62B99; 80A10

1 Introduction

The common fog removal methods, heating, cooling, refrigeration, and increasing air velocity in different ways are expensive, ineffective or difficult to use in declines of underground mines of sub-arctic Finland. After field research on the most suitable of these methods, an idea of a new approach surfaced.

The water collecting characteristic of a surface prompted a research about fog meshes. With a large surface area and surface coverage of a mesh, nets with water adhering aptitude were taken under study.

The meshes were expected to gather water and impurities decreasing both relative humidity and particle concentration. The expected problem was increased resistance of airway possibly resulting in air-rerouting.

The study started with testing of four materials with different characteristics at the Pyhäsalmi Mine, Finland. All materials decreased the particle concentration and relative humidity of the air at the measurement location downstream of the mesh installation. The highest relative humidity decrease was achieved with a grey mosquito net and was 2 %.

Another set of tests was carried out at the Orivesi Mine to study the effect of different airway and fog characteristics on the fog mesh system. Also a more efficient material was sought after. One of the materials tested at the Pyhäsalmi Mine was tested again at the Orivesi Mine. Out of the three new materials, an aluminium net gave best results, reaching up to a considerable 6.7 % of decrease of relative humidity, with the second best material, a fibrous filter fabric Bidim S02 also surpassing the best result of the Pyhäsalmi Mine by a percent. Changes in dew point temperatures and particle concentrations were also notable.

At this stage of the research the method has been proven to work in practise as expected decreasing relative humidity and number of particles acting as nuclei in fog formation. Unfortunately only one of the tested materials, the aluminium net, has been effective enough to change fog thickness visibly for the better. It can be said that the efficiency of the method is thus still questionable.

Could this efficiency problem be overcome by a multiple mesh system? It is expected that with multiple meshes installed in series each is capable of decreasing humidity and particle values. Of course with decreased initial values after passing one mesh, the second mesh can not be expected to reach the same decrease. If a multiple mesh system is used, will the increased resistance become an issue? Also, is there such a material available that could by itself reach even better results than the aluminium net and thus be effective enough as a stand-alone fog removal device?

In this study the results of two multiple mesh tests with different materials as well as individual material tests are presented in search for answers to the above-mentioned questions. A material developed solely for fog removal purpose, the mist eliminator, was found and taken to be studied. Mist eliminator theory and the characteristics of the chosen mist eliminator pad are presented. The mist eliminator and multiple mesh tests were performed both at the Pyhäsalmi Mine and at the Orivesi Mine. The results are compared with each other, the previously measured values, and analysed based on both theoretical knowledge and field study findings. The objective is to determine the feasibility of this fog mesh fog removal method in an underground mine.

2 Mist eliminator theory

2.1 General

Mist elimination can be defined as the mechanical separation of liquids from gases. Mist eliminators are typically woven mesh fabrics that catch the liquid droplets from the air.
The wire mist eliminators, commonly referred to as knitted mesh mist eliminators, collect droplets by the inertial impaction and interception mechanisms of collection. They are commonly used to collect droplets above 5 microns in diameter. However, when the separation of droplets in the 1-3 µm range is required, these wire mist eliminators are largely ineffective because of the mesh’s random structure, irregular density, and coarse fibre diameters. A structured mesh to combat the weaknesses of the wire mesh has been developed by the Kimre company. The material has been described as ladder-like or honeycomb-like and is comprised of three-dimensionally interlocked plastic monofilaments. The material structure is shown in Figure 1. Since 93 % of the fibres are perpendicular to the gas flow, the pressure loss through the media is dramatically lower for the same level of efficiency as a traditional knitted mesh mist eliminator. [4]

2.2 Choosing a mist eliminator

Choosing a mist eliminator is based on the air velocity and the droplet size. The theoretical effectiveness of the material can be calculated based on manufacturer-provided charts. Also, calculation of the airway pressure drop caused by the mist eliminator is possible. An example of a manufacturer chart is presented in Figure 2.
On the chart the X-axis represents the droplet diameter, while the Y-axis represents the Effectiveness Factor, *K1**. *K1** is used to determine penetration, *Pt*, of the droplet through the media.

$$Pt = \exp(-K1 * N) \qquad (1)$$

where *N* is the number of layers of material. The percent collection efficiency *E* can then be calculated from penetration, *Pt*:

$$E = (1 - Pt)100 \qquad (2)$$

On the graph the formula for the pressure drop *P* of the material is given. The chart shows that with higher air velocities better water collection results are to be expected. Also, the effect on gas-liquid resolution with different droplet diameters is obvious.

3 Planning and design for the tests

3.1 Mist eliminator considerations

A mist eliminator by Kimre was chosen for testing because it is the only available eliminator in the market advertised to be able to handle droplets with a smaller diameter than 5 microns. From the droplet size distribution study by Schimmelpfennig [9] it can be seen that it is very likely for most fog droplets in a mine to be smaller than that. A graph showing this is presented in Figure 3. Also, information concerning atmospheric fog and the interdependency of very small droplet size and a large

amount of impurities in the air, which is typical in underground mines, resulted in choosing one of these mist eliminator pads for this study. [2]
Another advantage of the mist eliminator by Kimre that led to the decision to use it for this study is that it is cleanable and reusable with extended service life, even in harsh environments. [4] The chosen B-GON® mist eliminator by Kimre is made of polypropylene. The availability of different mesh sizes allowed the optimal mesh size for a mine environment to be determined by calculation. Also, the lower pressure drop over the mesh compared to that found with a conventional wire mesh separator is an important design factor.

3.2 Other test materials

To enable easy comparison of results, other test materials were chosen from among the materials previously tested. The best mesh of the previous tests was used at the Pyhäsalmi Mine. This grey mosquito net was chosen to be used in this study in combination with the mist eliminator [6]. This decision was motivated by a desire to achieve the best possible performance. Unfortunately the best material tested at the Orivesi Mine is no longer available. Instead, the second best material, a fibrous filter fabric Bidim S02, was used. [7]

3.3 Test locations

In both mines both the multiple mesh tests as well as individual mesh tests were carried out at the same test sites as the prior tests. This allowed the differences in conditions to be identified and taken in consideration during result analysis.
The test site at the Pyhäsalmi Mine is in a ramp just below level +600 where fog is usually thick. The tunnel dimensions in the test site are about 5.5 m x 4.5 m. The area to be covered with a mesh is approximately 20 m^2. [6]
The chosen test site at the Orivesi Mine is in the decline a short way underneath level +164 m. The height of the frame opening is 3.8 m and the width 4.6 m. [7] During the prior tests the mine was in a standby mode with no operation, but since then the operation has restarted.

3.4 Fog mesh system design issues

The fog mesh system design developed for the tests at the Pyhäsalmi Mine was reconsidered before the mist eliminator and multiple mesh tests. The attachment of the electrical cable used as a weight caused problems in one of the previous tests, so now wood with a different attachment system was used instead. In this case two heavy wood planks were placed on each side of the mesh fabric and nailed together. This way no additional wire, which could get caught on passing vehicles, was required to attach the weight. The wood installation was also sturdier than the electric cable. Figure 4 shows the mesh combination installation at the Pyhäsalmi Mine.
Another new idea was to slip a wire through the mesh fabric so it could be lifted up like a window blind. This way the fog mesh could be easily removed in case of better climatic conditions. The narrow wires threaded through the mesh in three different rows were working well until the attachment of the weight. Unfortunately the weight was too much for the wires, one of which snapped under the tension during the testing. The remaining two wires were unable to lift the mass. With sturdier wires the system can be expected to work.

3.5 Testing procedure

Tests were performed 50 m apart, 25 m upstream and 25 m downstream of the mesh, respectively. The measurements taken were air velocity, relative humidity, dew point temperature, air temperature, and particle concentration. Also fog thickness, fog droplet size, and effects of the meshes on the airflow were observed.

Air velocity and temperature measurements were performed with a hot wire anemometer, model Kimo VT200. Humidity measurements and verification air temperature measurements were done with an Ebro TFH100 hygrometer, which measures relative humidity of 0 - 100 % and temperatures from -10 °C to +80 °C. An aerosol meter, DustTrak TSI 8520, with a maximum particle size range of 0.1-10 µm was used for dust content measurements. [5]

The measurements were started 5 minutes after finishing the construction. Each test took 5 minutes to perform in one location. In previous tests a waiting period of 30 minutes was used to allow time for the airflow to stabilize. In these tests the effect of the waiting time on the results was also studied. In addition, the measurement duration was previously twice as long. The measurement sampling rate with the aerosol meter was increased, allowing the duration to be decreased. The procedure was changed to enable a larger number of measurements with one mesh system.

With each material or material combination five measurements were taken both upstream and downstream of the mesh system. With both material combinations the mist eliminator fabric was placed upstream of the second fabric. The gap between the materials was about 30 cm in both cases.

4 Results and analysis

4.1 Pyhäsalmi Mine

Particle concentrations obtained from the Pyhäsalmi tests are comparable with the earlier results as well as measured relative humidity values, temperatures and dew points. The only value which changed dramatically was the air velocity at the test site. This was caused by changed exhaust fan settings, which resulted in increased airflow in the ramp.

The performance of the mosquito net of the prior tests was of the same order in both trials. In the previous tests the measured value was 2 %, while a value of 1.9 % was measured now.

The decrease of relative humidity by the mist eliminator was about 0.8 %, which was, unfortunately, much lower than expected. The combination of the mist eliminator and the mosquito net resulted in worse performance than of the mosquito net by itself with a bit over 1 % relative humidity decrease. On the other hand the combination worked better than the mist eliminator alone. The results are shown in Tables 1-5. Also calculated averages and variances are shown.

The new method of weighting the fabric worked well. Unfortunately, the lifting system failed to work because of the too frail wires when enough weight was added to keep the mesh perpendicular to the airflow.

4.2 Orivesi Mine

The results received from the Orivesi Mine show the humidity decreasing effect of the fog mesh consistently with each mesh tested. It can be seen, however, that fibrous filter fabric Bidim S02, which performed very well in previous tests with a 3 %

decrease in relative humidity, only reached about 1 % decrease in these trials. The reason for this is very likely the increased traffic in the mine. The maximum particle value obtained was almost twice as high as in the previous tests. This increase in particle concentration must have caused a decrease in the average fog droplet size, thus decreasing the efficiency of the mesh.

At the Orivesi Mine air velocity had also increased. With the operation restarted more fans were now turned on in the mine resulting in higher air velocities. Temperatures and dew points were higher too because of the operation as well as the warm weather outside. The relative humidity compares well with the prior results.

The mist eliminator fabric decreased the relative humidity by about 0.8 %. However, it affected the dew point noticeably.

The mesh combination resulted in a visibly decreased fog thickness. Neither of the two materials of the combination used individually could attain this by themselves. In this case the combination was the most efficient with a relative humidity decrease of about 1.2 %. It did not, however, reach a decrease similar to the sum of the single meshes that would have been 1.6 %. Reaching the sum exactly was not expected, but getting close to it was. Also, the mesh combination had a distinct effect on the dew point. These results as well as the averages and variances of the results are shown in Tables 6-10.

4.3 Result comparison

Due to the newly active operation at the Orivesi Mine the results received from the two mines are more comparable to one another than in the previous tests. The droplets at the Orivesi Mine have decreased in size and are now well below visible threshold.

In both test cases the mesh combination was more effective than the mist eliminator used individually. Unfortunately, the air velocity drop caused by the combinations was dramatic. At the Pyhäsalmi Mine the effect was mainly seen downstream of the mesh, so even with the increased resistance, no rerouting of air was realized. At the Orivesi Mine the situation was the opposite. With every system tested part of the air found another route, resulting in a noticeable decrease of air velocity at the test site.

The dew point change observed in both cases with the mist eliminator at the Orivesi Mine was puzzling because this did not occur at the Pyhäsalmi Mine. It seems, however, that this kind of behaviour is essential for fog removal as the only tests that have resulted in visible fog thickness decrease were the ones with a notable effect on the dew point. The materials behaving this way were the aluminium net used in the prior tests, the mist eliminator, and the mist eliminator – filter fabric combination. All these tests were performed at the Orivesi Mine. It can be seen that the dew point decrease resulted solely from relative humidity drop with the aluminium net. In the case of the mist eliminator the dew point decrease was caused by both relative humidity decrease and the decrease in air temperature.

4.4 Error estimation

Taking five samples with each mesh and mesh combination both upstream and downstream enables error estimation of the results. This way an average can be calculated and used as a final measurement result. With the calculation of the variance an error can be estimated. Calculated averages and variances are shown in Tables 1-10. Averages of the differences between downstream and upstream values are shown in Table 11. These show especially well the effect of meshes on the dew point at the Orivesi Mine, the particle concentration decrease with each mesh and combination,

and the humidity decrease with each mesh and combination in both mines. Also the changes of baseline values are shown to be small enough to be irrelevant in comparison with the mesh effects.
More samples show how much the waiting period affects the result. It also helps in estimating the importance of the length of the measurement time.
The waiting period of 30 minutes in prior tests is longer than required. The results received first with the shortest waiting times gave only slightly lower relative humidity values than the other measurements. So it can be concluded that the optimal waiting period is in between 30 minutes and 5 minutes. As only the first pair of results shows a difference in values when compared with the rest of the measurements, it can be seen that a fifteen minute waiting period before the measurements is optimal. It allows enough time for the airflow to stabilize and the performance of the mesh to reach its capacity.
The 10 minute measurement time of the previous tests gave similar results to the ones received in these tests. It is apparent that the length of the test is not a critical parameter. Because of the limitations of the testing devices the testing time can't be decreased below 5 minutes, so this time is an optimal measurement time.

4.5 Mist eliminator

The theoretical efficiency of the mist eliminator increases with an increase in the droplet diameter, as shown in Figure 2. With the measured air velocities the theoretical efficiency ranges from 9.5 % with a droplet size of 1 µm up to the maximum efficiency of about 65 % with 8.5 µm diameter of the droplet.
Part of the explanation for the rather poor efficiency of the mist eliminator in comparison with the theoretical values may be found from mist eliminator research in other arenas. In Hering et. al [1] the mist eliminator pad was found to be ineffective in light fogs because of the low sampling rate and fog/water retention on the mesh. In another reference [8] it is said that with light liquid loads most of the liquid mass is retained on the polypropylene mesh. The use of coatings or changes in the materials is suggested to be investigated for the purpose of reducing retention.
The most important factor affecting the efficiency of the mist eliminator is the droplet size. Based on the only available information concerning fog droplet size distribution in a mine, the droplet size is a lot smaller than in surface fogs. In a surface fog size distribution the droplet diameter typically ranges from 5 to 65 µm and is thus much easier to be removed with a mesh. Unfortunately, recent droplet size distribution information from mines is unavailable. The only measurement results are from 1982, when the smaller end of the size distribution could not be reliably recorded (Figure 3). It must be also noted that these results are based on information from one mine and one study only. [9]
Air velocity is a parameter having impact on the efficiency as well. In this case the air velocity of both test sites was close to the curve in the middle of the theoretical effectiveness chart (Figure 2). A higher air velocity would likely have resulted in improved results.

5 Conclusions

The mist eliminator pad did not perform as well as expected based on the theoretical values. This was partly due to the low air velocities and partly due to the small fog droplet size. Also the light liquid loading, which has caused inefficiency in other applications as well, was considered to have a negative effect on the results.

Two-mesh multiple mesh systems gave an improved relative humidity decrease from the mist eliminator pad itself. In one of the tests the combined efficiency was well above the individual results, but did not quite reach close to the sum of the individual efficiencies. In the other, the combination did not perform as well. The fibrous filter fabric performed better by itself than in the combination of that fabric and the mist eliminator. Both multiple mesh systems decreased the air velocity notably. Also, air rerouting was observed in one of the two tests.
As the performance of a fog removal mesh is very dependent on the droplet size, more information concerning this would be beneficial. The knowledge could be helpful in improving existing fog removal methods and in developing new methods.
The only study providing droplet size distribution of an underground fog shows the median droplet size to be considerably smaller than those of surface fogs. This hinders the performance of a fog mesh system underground.
Even if only one out of twelve tests during the complete study gave a negative result, only two resulted in visible fog thickness decrease. One thing in common for these cases was the decreased dew point by the fog mesh. If further study in this field is performed, this influence should be investigated.
It can be concluded that almost every mesh is capable of reducing both relative humidity and particle concentration. Thus, it also decreases fogginess and the likelihood of fog formation. Unfortunately, it is also obvious that this effect is not powerful enough for complete fog removal in an underground mine with the tested materials or material combinations.

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Table 1. Particle concentrations, their averages and variances at the Pyhäsalmi Mine.

Particle Concentration (mg/m^3)								
	Mist eliminator		Combination		Mosquito net		Baseline	
	Upstr	Downstr	Upstr	Downstr	Upstr	Downstr	Upstr	Downstr
	0.331	0.303	0.481	0.447	0.059	0.079	0.078	0.139
	0.446	0.288	0.407	0.515	0.120	0.187	0.184	0.373
	0.499	0.391	0.603	0.459	0.237	0.139	0.958	0.737
	0.495	0.331	0.538	0.317	0.251	0.156	0.450	0.614
	0.562	0.411	0.598	0.394	0.200	0.184	0.726	0.584
Average	0.4666	0.3448	0.5254	0.4264	0.1734	0.1490	0.4792	0.4894
Variance	0.0074	0.0029	0.0069	0.0056	0.0067	0.0019	0.1348	0.0555

Table 2. Air velocities, their averages and variances at the Pyhäsalmi Mine.

Air velocities (*m/s*)								
	Mist eliminator		Combination		Mosquito net		Baseline	
	Upstr	Downstr	Upstr	Downstr	Upstr	Downstr	Upstr	Downstr
	2.3	2.0	2.3	1.7	2.4	2.2	2.4	2.6
	2.3	2.1	2.2	1.6	2.5	2.1	2.5	2.6
	2.3	2.0	2.4	1.8	2.4	2.1	2.4	2.5
	2.4	2.0	2.3	1.8	2.3	2.1	2.4	2.5
	2.4	1.9	2.3	1.7	2.3	2.1	2.5	2.4
Average	2.34	2.00	2.30	1.72	2.38	2.12	2.44	2.52
Variance	0.003	0.005	0.005	0.007	0.007	0.002	0.003	0.007

Table 3. Temperatures, their averages and variances at the Pyhäsalmi Mine.

Air temperatures (˚*C*)								
	Mist eliminator		Combination		Mosquito net		Baseline	
	Upstr	Downstr	Upstr	Downstr	Upstr	Downstr	Upstr	Downstr
	18.6	18.8	18.9	18.7	18.6	18.9	19.1	18.9
	18.8	18.9	18.9	18.7	18.6	18.7	18.6	18.9
	18.6	18.7	18.6	18.6	18.5	18.6	18.9	18.6
	18.8	18.6	18.6	18.7	18.7	18.7	18.6	18.6
	18.7	18.7	18.6	18.7	18.7	18.6	18.6	18.6
Average	18.70	18.74	18.72	18.68	18.62	18.70	18.76	18.72
Variance	0.010	0.013	0.027	0.002	0.007	0.015	0.053	0.027

Table 4. Relative humidity values, their averages and variances at the Pyhäsalmi Mine.

Relative humidity (*%*)								
	Mist eliminator		Combination		Mosquito net		Baseline	
	Upstr	Downstr	Upstr	Downstr	Upstr	Downstr	Upstr	Downstr
	91.7	91.0	91.7	90.7	92.3	90.8	89.6	89.9
	92.2	91.4	92.6	91.4	92.3	90.4	90.1	90.9
	93.3	92.5	93.3	92.2	93.0	91.1	92.6	92.6
	93.5	92.8	93.8	92.9	93.6	91.4	93.2	93.1
	93.3	92.4	93.4	92.2	93.3	91.5	93.7	93.5
Average	92.80	92.02	92.96	91.88	92.90	91.04	91.84	92.00
Variance	0.64	0.60	0.68	0.72	0.35	0.20	3.48	2.36

Table 5. Dew point temperatures, their averages and variances at the Pyhäsalmi Mine.

Dew point temperatures (˚*C*)								
	Mist eliminator		Combination		Mosquito net		Baseline	
	Upstr	Downstr	Upstr	Downstr	Upstr	Downstr	Upstr	Downstr
	17.7	17.7	17.7	17.6	17.7	17.6	17.6	17.7
	17.7	17.7	17.8	17.7	17.7	17.6	17.6	17.6
	18.1	17.6	17.8	17.7	17.8	17.6	17.8	17.7
	17.7	17.7	17.8	18.0	17.9	17.7	17.8	17.7
	17.7	17.8	17.8	17.7	17.8	17.6	17.8	17.7
Average	17.78	17.70	17.78	17.74	17.78	17.62	17.72	17.68
Variance	0.032	0.005	0.002	0.023	0.007	0.002	0.012	0.002

Table 6. Particle concentrations, their averages and variances at the Orivesi Mine.

Particle Concentration (mg/m^3)								
	Mist eliminator		Combination		Bidim S02		Baseline	
	Upstr	Downstr	Upstr	Downstr	Upstr	Downstr	Upstr	Downstr
	0.446	0.245	0.856	0.156	1.520	0.605	0.063	0.074
	0.571	0.234	0.815	0.369	1.195	0.639	0.074	0.114
	0.819	0.209	1.238	0.607	1.273	0.767	0.089	0.066
	0.859	0.209	1.063	0.243	1.400	0.672	0.213	0.240
	0.766	0.198	0.745	0.233	1.234	0.490	0.293	0.341
Average	0.6922	0.219	0.9434	0.3216	1.3244	0.6346	0.1464	0.1670
Variance	0.0312	0.0004	0.0411	0.0319	0.0179	0.0102	0.0104	0.0143

Table 7. Air velocities, their averages and variances at the Orivesi Mine.

Air velocities (*m/s*)								
	Mist eliminator		Combination		Bidim S02		Baseline	
	Upstr	Downstr	Upstr	Downstr	Upstr	Downstr	Upstr	Downstr
	1.6	1.4	1.4	1.1	1.6	1.5	2.1	2.1
	1.8	1.6	1.4	1.1	1.6	1.5	2.1	2.1
	1.8	1.6	1.3	1.2	1.7	1.4	2.1	2.0
	1.7	1.5	1.5	1.2	1.6	1.4	2.0	2.0
	1.7	1.5	1.4	1.3	1.6	1.4	2.1	2.1
Average	1.72	1.52	1.40	1.18	1.62	1.44	2.08	2.06
Variance	0.007	0.007	0.005	0.007	0.002	0.003	0.002	0.003

Table 8. Temperatures, their averages and variances at the Orivesi Mine.

Air temperatures (˚*C*)								
	Mist eliminator		Combination		Bidim S02		Baseline	
	Upstr	Downstr	Upstr	Downstr	Upstr	Downstr	Upstr	Downstr
	14.8	14.8	14.8	14.4	14.8	14.6	14.8	14.7
	14.7	14.6	14.8	14.6	14.7	14.4	14.8	14.8
	14.7	14.7	14.8	14.4	14.7	14.6	14.8	14.9
	14.7	14.7	14.7	14.5	14.6	14.6	14.8	14.8
	14.8	14.6	14.8	14.6	14.7	14.6	14.8	14.8
Average	14.74	14.68	14.78	14.50	14.70	14.56	14.80	14.80
Variance	0.003	0.007	0.002	0.010	0.005	0.008	0	0.005

Table 9. Relative humidity values, their averages and variances at the Orivesi Mine.

Relative humidity (%)								
	Mist eliminator		Combination		Bidim S02		Baseline	
	Upstr	Downstr	Upstr	Downstr	Upstr	Downstr	Upstr	Downstr
	92.3	91.9	93.4	92.2	94.3	93.8	91.1	91.1
	93.5	92.8	94.3	92.7	94.5	93.8	91.3	91.4
	93.6	92.8	94.0	92.8	94.7	93.9	91.7	92.0
	93.9	92.6	94.0	93.0	94.7	93.6	92.4	92.1
	93.7	92.9	94.2	93.1	94.9	93.9	92.5	92.2
Average	93.40	92.60	93.98	92.76	94.62	93.80	91.80	91.76
Variance	0.40	0.17	0.12	0.12	0.05	0.02	0.40	0.23

Table 10. Dew point temperatures, their averages and variances at the Orivesi Mine.

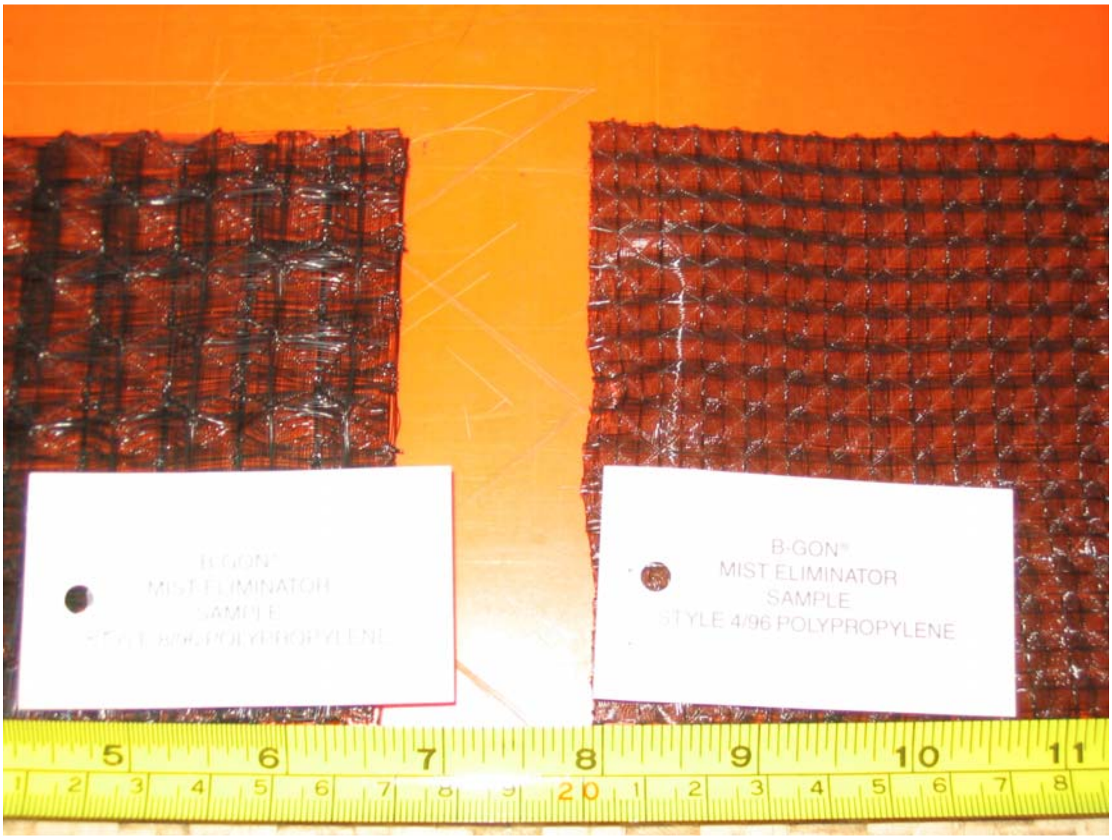
Dew point temperatures (˚*C*)								
	Mist eliminator		Combination		Bidim S02		Baseline	
	Upstr	Downstr	Upstr	Downstr	Upstr	Downstr	Upstr	Downstr
	14.4	14.2	14.5	14.1	14.5	14.4	14.0	14.0
	14.4	14.1	14.5	14.1	14.5	14.2	14.3	14.1
	14.5	14.4	14.6	14.1	14.5	14.4	14.3	14.3
	14.6	14.2	14.5	14.1	14.4	14.4	14.4	14.2
	14.6	14.2	14.5	14.1	14.5	14.4	14.3	14.4
Average	14.50	14.22	14.52	14.10	14.48	14.36	14.26	14.20
Variance	0.010	0.012	0.002	0	0.002	0.008	0.023	0.025

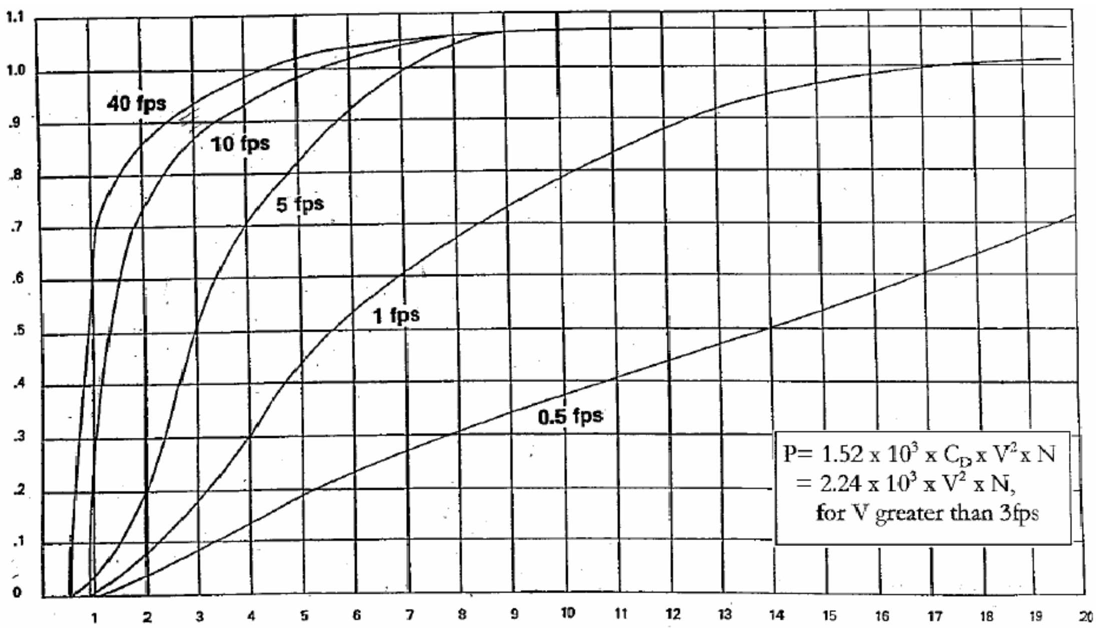
Table 11. Averages of the differences between downstream and upstream values

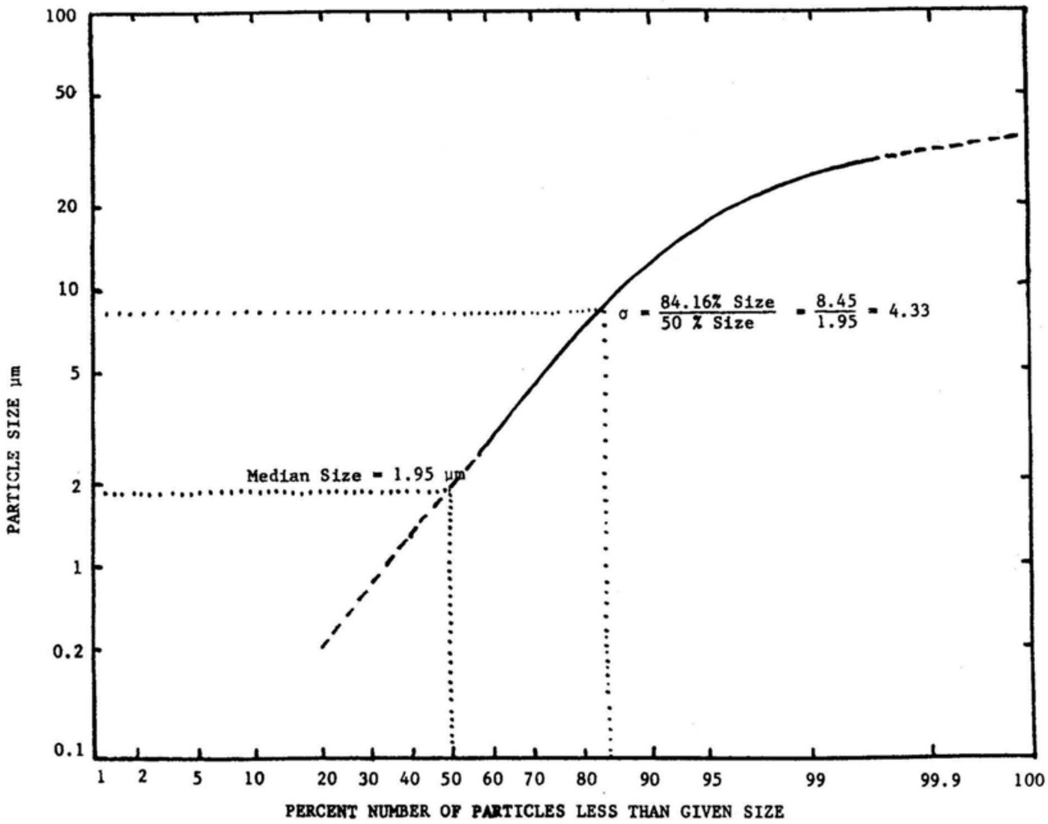
Pyhäsalmi/Orivesi										
	Particle difference		Velocity difference		Temperature difference		Humidity difference		Dew point difference	
	mg/m³		*m/s*		*˚C*		*%*		*˚C*	
Baseline	-0.010	-0.021	-0.08	0.02	0.04	3.55E-16	-0.16	0.04	0.04	0.06
Mist eliminator	0.122	0.473	0.34	0.20	-0.04	0.06	0.78	0.80	0.08	0.28
Combination	0.099	0.622	0.58	0.22	0.04	0.28	1.08	1.22	0.04	0.42
Mosquitonet/ Bidim S02	0.024	0.690	0.26	0.18	-0.08	0.14	1.86	0.82	0.16	0.12

Figure 1. The ladder-like structure of a B-GON® mist eliminator pad by Kimre.
Figure 2. Manufacturer chart for theoretical effectiveness of style 4/96. [3]
Figure 3. Median fog droplet size in an underground mine [9]
Figure 4. The mesh combination at the Pyhäsalmi mine.

Word count: 3875 (without title, affiliations, abstract, figures, and tables)
5068 (all)


B-GON®
MIST ELIMINATOR
SAMPLE
STYLE 4/96 POLYPROPYLENE


40 fps
10 fps
5 fps
1 fps
0.5 fps
P= 1.52 x 10³ x C_D x V² x N
= 2.24 x 10³ x V² x N,
for V greater than 3fps
1.1
1.0
.9
.8
.7
.6
.5
.4
.3
.2
.1
0
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20



100
50
20
10
5
2
1
0.2
0.1
PARTICLE SIZE µm
σ = 84.16% Size / 50 % Size = 8.45 / 1.95 = 4.33
Median Size = 1.95 µm
1 2 5 10 20 30 40 50 60 70 80 90 95 99 99.9 100
PERCENT NUMBER OF PARTICLES LESS THAN GIVEN SIZE