

Air Filter Testing  
Preliminary Report

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# 1 Introduction

The performance of air filters is critical to the efficient operation of a wide range of equipment from heavy rock crushers to the standard vacuum cleaner. This report reviews the testing of air filters, outlines a campaign of field testing on a new patented product improvement for air filters and examines the economic advantage of this new process.

The report relies on Field testing to measure the difference between the product improved and the standard filter. Field tests have the advantage of taking into account the real operation of the equipment in its normal environment which includes the effects of climate, vibration and also environmental dust levels.

There are also standard laboratory tests which offer a baseline comparison on laboratory conditions between various filters available on the market.

There are three basic ways to measure the differences between air filters or in this case to check if retrofitting with Webb's air membrane mat improves filter quality and efficiency. The first way and a clear industry standard is a test of filtration efficiency ISO 5011 [1] (formerly SAE J726).

## 1.1 Filtration Efficiency

The ISO 5011 is a test procedure or protocol with built in options. In order to compare two ISO 5011 test results, you need to understand which options have been selected. The test measures the Percentage of dust retained by an air filter as the dust is introduced into a stream of air flowing through the air filter at a constant rate. There is both an initial measurement and an overall measurement, both of which will be percentages. For example, a filter efficiency result of 95% means that the air filter retained 95% of the test dust allowing 5% to be passed through the air filter. The particle size and mix of the test dust itself is specifically defined by an ISO standard. For most applications, coarse test dust is used and is comprised of a precise mix of particles ranging in size from 5.5 microns to 176 microns. By way of comparison, a human hair width is approximately 50 microns, so even coarse test dust includes a significant amount of microscopic particles. Some companies design their own dirt test to save the money of doing it right, but there is only one generally accepted standard test procedure and that is the ISO 5011. K and N Air Filters for example tested generally range between 96% and 98% in overall efficiency using coarse test dust.

## 1.2 Capacity

The second test of air filter capabilities is also measured using the ISO 5011 test procedure and is called capacity.

**Capacity results show how much dust the air filter can retain before reaching a predetermined point of air flow restriction, generally held to be harmful to engine performance and life.**

Capacity is generally conveyed in grams and is impacted by several variables such as the technical performance of the filtration medium, the physical amount of filtration medium present, and size of the air filter itself.

As an example, an air filter with a dust capacity of 250 grams means it will hold that much dust before cleaning or replacement is necessary.

Individual air filters can have capacity as low as 100 grams or as high as 1000 grams. K and N air filters are designed to have enough capacity to provide a service life of up to 50,000 miles for O/E replacement filters or up to 100,000 miles for large universal conical filters

## 1.3 Restriction

The third test historically overlooked by the entire disposable air filter industry is the amount of restriction created by the filter medium.

**Higher restriction means more engine effort is required to provide the engine with one of the four critical components of combustion. Air!**

Use a flow bench and increase the rate of airflow until restriction equals a pressure drop sufficient to displace 37.5 mm of a consistent quantity of water.

## 1.4 Extract Section 6 ISO 5011

Performance tests shall be performed on a complete air cleaner assembly or on a single air cleaner element; tests on a complete air cleaner assembly are preferred. The tests shall consist of an air flow Restriction/differential pressure test, an efficiency test and a capacity test. In addition, a pressure collapse test shall be performed on the air filter element.

**Restriction Test** The purpose of this test is to determine the restriction/differential pressure/pressure loss across the unit under test which will result when air is passed through under Predetermined conditions. Airflow restriction or differential pressure is measured with a clean filter element

## **Efficiency test.**

The purpose of this test is to determine the retention capabilities of the unit under test. This test can be conducted with either constant or variable air flow and with coarse dust or fine test dust.

If desired, efficiency tests can be performed concurrently with capacity tests (see 6.5). Determination of the efficiency at constant test air flow can be performed at the rated air flow or any percentage thereof, as agreed upon by the user and manufacturer. Determination of efficiency at variable air flow can be performed using variable air flow cycle according to 6.7.

## **Capacity test.**

The purpose of this test is to determine the total mass gain of the unit under test at the terminating condition. This test can be conducted with either constant or variable air flow and with coarse or fine test dust contaminant. If desired, the capacity determination can be performed concurrently with the efficiency test (see 6.4).

## **Filter element pressure collapse test.**

The purpose of this test is to determine the ability of an air filter element to withstand a specified differential pressure and/or to determine the differential pressure at which collapse occurs.

## **2 Comparative ISO5011 tests Diesel Forum USA**

Reproduced below is a test campaign by some USA diesel enthusiasts.

It is informative in that they commissioned a testing lab to investigate claims for a range of filters and then published the results on their forum.

In essence the process they used can be adopted for our testing campaign with different retrofitted filters.

On a diesel forum posted in July 2004 [?] the members banded together to conduct an independent study regarding air filters for the Duramax Diesel. They claim that there is a lot of marketing hype surrounding certain aftermarket air filters and they wanted to know if the filters could stand up to their claims.

Claims of "superior" filtering ability and dirt holding capacity are among some of these claims. Additionally, many filters are claimed to allow for "better" air flow giving you more horsepower.

This claim of better flow giving more horsepower is a debate all its own, but dyno tests run with a paper filter vs. NO FILTER AT ALL have shown NO INCREASE IN POWER OUTPUT.

Therefore a filter with "better flow" will not only give you no increase in performance, it will also let in a lot of dirt while doing it.

The following data is provided by Testand Corp. in Rhode Island. Testand makes the \$285,000 machines that perform the SAE J726/ISO 5011 air filter test standard. Any air filter that wants to be tested for performance and efficiency uses this test.

These tests cost \$1,700 per filter when done by an independent laboratory. Testand Corp. was interested in the comparison study and agreed to do the study for us.

Every filter listed was tested in an identical manner according to the SAE/ISO 5011 test standard;

Here are the results:

In the order of EFFICIENCY (ability to filter dirt) the results are as follows: FLOW RESTRICTIONS

Table 1: Efficiency

FILTER % EFFICIENCY

AC Delco OE	99.93%
Baldwin paper	99.72%
No name pargain paper	99.32%
AFE Pro Guard 7 panel filter	99.23%
WIX/Napa Gold	99.03%
Purolator paper	98.73%
Amsoil, new style	98.63%
UNI	97.93%
KandN	96.80%

Remember, 27.7 inches of water = 1 psi. So, 1 inch of water = .036 psi.

The worst (AC Delco) at 6.23 in. water and the best (KandN) at 4.54 in. water is a difference of 1.69 in. of water or a "whopping" .0608 psi. Virtually negligible.

In order from least restrictive to most:

DIRT HOLDING CAPACITY. From best to worst. This is the AMOUNT of test dirt it took to create an ADDITIONAL 10 inches of restriction. At that point the test is terminated.

This is an indication of HOW LONG a filter is good before it must be cleaned or replaced.

TOTAL DIRT PASSING THE FILTER DURING THE TEST. This is how much dirt your engine will take in if you use the filter for the duration that would cause the filter to become "dirty" enough to need replacement or cleaning. The "Dirt Passing The Filter" is the dirt collected by the "POST

FILTER” during the SAE/ISO test.

In order from best to worst, the filters performed as follows:

Table 2:

Restriction Inches of Water

FILTER RESTRICTION in inches of water

KandN	4.54
Mystery bargain	4.78
AFE Pro Guard	4.99
Purolator	5.05
WIX/Napa Gold	5.06
UNI	5.40
Baldwin	5.71
Amsoil	5.88
AC Delco	6.23

### 3 IBR testing facility

From: Susan Goldsmith [mailto:sgoldsmith@ibr-usa.com] Sent: 23 October 2015 11:57 To: Thomas Dooley  
Cc: David Wright Subject: Re: Contact Form Submission: ISO 5011 Filter testing

Hello Tom- Thanks for contacting IBR. The ISO 5011 is within the scope of accreditation for IBRs USA lab. I have copied David Wright, IBR USA Air Lab Supervisor. He will be able to assist. Will these be panel or cylinder filters? Do you have the air box (housing)? The full Air Induction System? Or is this filter media alone? Will you want steady flow or cycling? For R and D, steady is more common.

Thanks very much Susan

Susan Goldsmith Managing Director IBR Laboratories + 1 517 522 8453

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On Oct 23, 2015, at 4:23 AM, Dr Thomas Dooley ;thomas.dooley@dkit.ie; wrote:

From: Dr Thomas Dooley ;thomas.dooley@dkit.ie; Subject: ISO 5011 Filter testing Channel: IBR Europe  
Company: CREDIT Dundalk Institute of Technology Ireland Phone: 0035342700200

Message Body:

I am looking for a quotation to test air filters for efficiency, capacity and restriction to ISO 5011 for a client who has commissioned our research centre (CREDIT) in Dundalk Ireland regarding an air filter design improvement.

Regards Tom

– This mail is sent via contact form on IBR-USA - <http://ibr-usa.com/>

Table 3: Capacity

Dust holding Capacity

AC Delco	573.898 g
WIX/Napa Gold	447.366 g
Purolator	388.659 g
Baldwin	388.154 g
UNI	374.638 g
Mystery bargain	350.402 g
AFE Pro Guard	7 232.516 g
KandN	211.580 g
Amsoil	196.323 g

## 4 Field Testing

Field testing was arranged at two sites as per letters in appendix A attached.

The purpose of the field tests is to comparatively determine the filtration efficiency and capacity of wrapped versus unwrapped filters.

### Efficiency test

The purpose of this test is to determine the comparative retention capabilities of the units under test. This test is conducted in the operating environment with the actual air flow and environmental dust conditions.

### Capacity test

The purpose of this test is to determine the comparative total mass gain of the unit under test at the terminating condition. The capacity determination is performed concurrently with the efficiency test.

The tests were carried out on four filters in Test site 'A' in the Roadstone quarry, Duleek Co Meath, beginning in November 2015.

The Filters are numbered and described as follows:

- Filter ID. 01 Wrapped on PowerScreen 27
- Filter ID. 02 Unwrapped on TESAB32 623C
- Filter ID. 03 Wrapped on Pegasus
- Filter ID. 04 Unwrapped on PowerScreen 5103



Figure 1: PowerScreen Crusher at Duleek Quarry



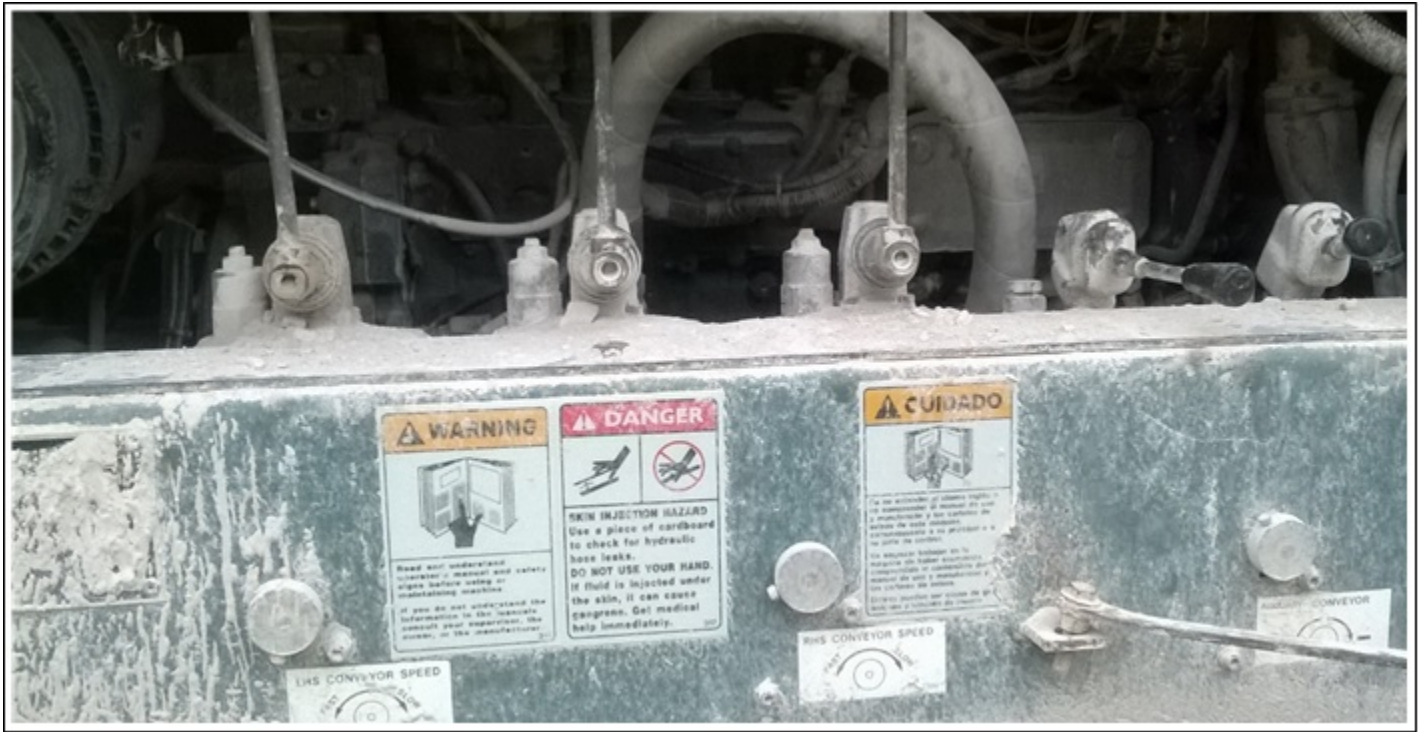


Figure 2: Filter Location



Figure 3: Filter in Housing

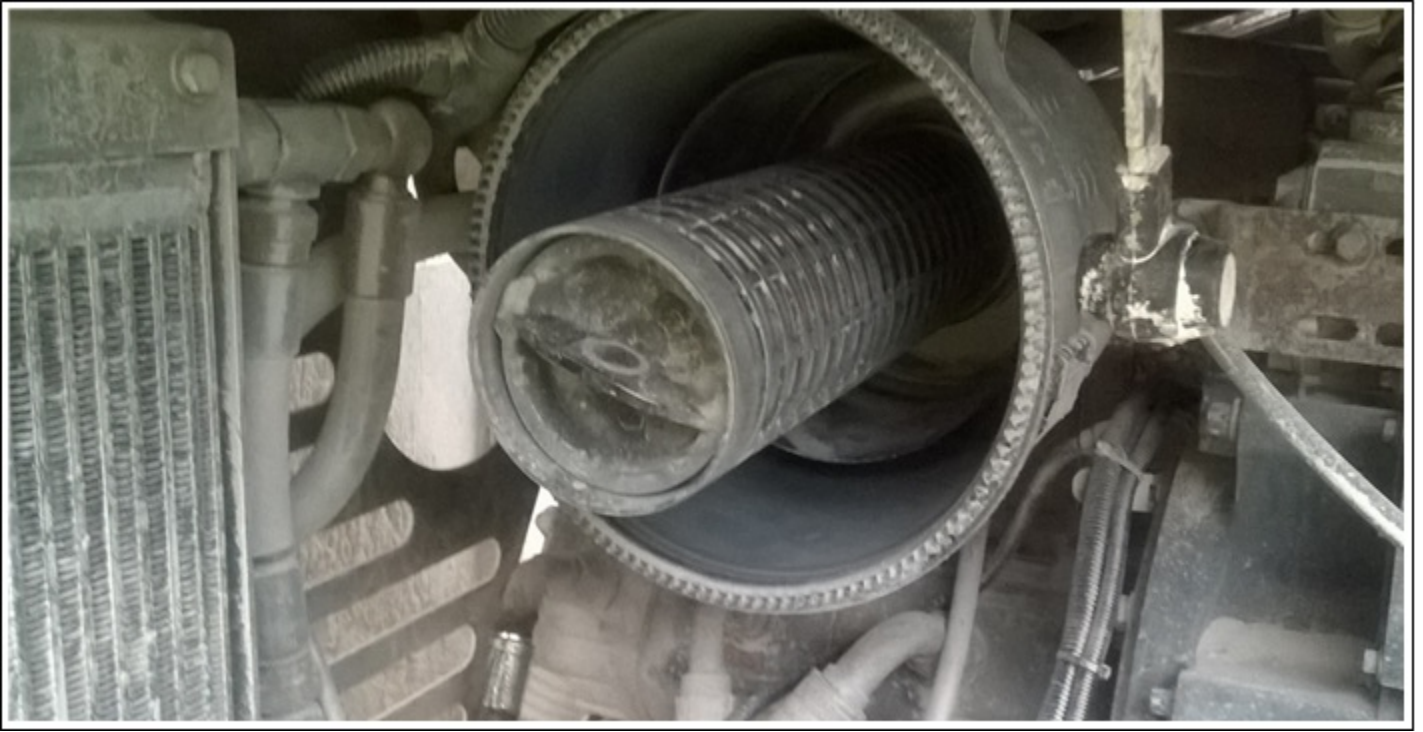


Figure 4: Filter removed



Figure 5: Filter with Dust layer on Wrapping prior to weighing





Figure 6: Filter being weighed



Figure 7: Filter No.2 Removal



Figure 8: Filter No.2 after Removal- No Wrapping





Figure 9: Filter No.2 being weighed

[illegible]

Figure 10: Field Data Recorded Filter ID 03

## Table 4: Capacity 2

### FILTER DIRT IN GRAMS PASSED

AC Delco	0.4g
Baldwin	1.1g
AFE Pro Guard	7 1.8g
Mystery bargain	2.4g
Amsoil	2.7g
WIX/Napa Gold	4.4g
Purolator	5.0g
KandN	6.0g
UNI	7.9g

## 5 Case Study TESAB32 623C mobile rock crusher.

Machine Working for 48 weeks (1920 Hours) Requiring the air intake filter cleaned 720 times and new filters 10 minutes for each, filter site cleaning. 15 minutes for replacement Webbsair Webb fitting.

Washed air filters have an average two thirds life span versus new filters.

### Table 5: Maintenance costs breakdown-TESAB

	Site Cleaning	Washed Filters	New Filters	Webbsair
Number per 1920 Hours	720 times	6	4	48
Maintenance time Hours	120 hours	1 0	.75	12
Labour @ €22.50 per hour	€2,700.00	€22.50	€16.87	€270.00
Purchase cost per item		€62.67	€94.00	€62.00
Down time @ €300.00 per Hour	€36,000.00	€300.00	€225.00	€3,600.00
Purchase cost per 1920 hours		€376.02	€376.00	€2,976.00
<b>Item cost per 1920 Hours</b>	<b>€38,700.00</b>	<b>€698.52</b>	<b>€617.87</b>	<b>€6,846.00</b>

**Table 6: Maintenance Costs and Savings (48 weeks) TESAB**

Costs using washed filters	€ 39,398.52
Costs Using new filters	€ 39,317.87
Costs Using Webbsair Webb	€6,846.00
Saving over washed filters	€32,552.52
Saving over new filters	€32,471.87

The Savings achieved using, Webbsair Webb per hour are quite dramatic.

The saving over washed filters is € 16.95 per hour

The saving over new filters is € 16.91 per hour

## 5.1 Komatsu Dozer

A similar exercise was repeated for a Komatsu.

**Table 7: Maintenance costs breakdown –Komatsu**

	Site Cleaning	Washed Filters	New Filters	Webbsair
Number per 1920 Hours		2	1	1
Maintenance time Hours	30 hours	.5	0.25	1
Labour@ AC22.50 per hour	€675.00	€11.25	€5.63	€5.63
Purchase cost per item		€62.66	€94.00	€62.00
Down time @ 48.00 per Hour	€1,440.00	€24.00	€12.00	€12.00
<i>Item cost per 1920 Hours</i>	<i>€2,115.00</i>	<i>€160.57</i>	<i>€111.63</i>	<i>€79.63</i>



**Table 8: Maintenance Costs and Savings (48 weeks) Komatsu**

Costs using washed filters	€ 2275.57
Costs Using new filters	€2226.63
Costs Using Webbsair Webb	€79.63
Saving over washed filters	€ 2,195.94
Saving over new filters	€ 2,147.00
The saving over washed filters is	€ 1.14 per hour
The saving over new filters is	€ 1.12 per hour

## **6 Field Test Results**

The field testing began on 10/11/2015 in Roadstone Duleek Quarry Co Meath. The tests were carried out on four filters as follows:

- Filter ID. 01 Wrapped on PowerScreen 27
- Filter ID. 02 Unwrapped on TESAB32 623C
- Filter ID. 03 Wrapped on Pegasus
- Filter ID. 04 Unwrapped on PowerScreen 5103

Each filter was weighed and its mass recorded as follows

- Filter ID. 01 Wrapped 1662 g    unwrapped 1627 g
- Filter ID. 02 Unwrapped 4252 g
- Filter ID. 03 Wrapped 4429 g    unwrapped 4360 g
- Filter ID. 04 Unwrapped 672 g

When the filters were cleaned which only occurred for the unwrapped filters and was carried out by site operatives they were reweighed before being reinstalled and the retained dust mass recorded. The Wrapped filters were also weighed before being rewrapped.

The last sets of results available are for December 2nd.

The trend is fairly clear in that the wrapped filters are retaining the dust on the outer layer and it is not penetrating into the core of the filter.

There is also evidence that the vibration of the machinery is displacing dust from the surface of the wrapped filter.

Where the graphs return to zero dust retained around 24/11 is when the unwrapped filters are cleaned or wrapped filters re-wrapped. Figure (11) shows that the unwrapped filter is retaining more dust than the wrapped filter. The wrapped filter is not allowing the dust into the core of the filter and the vibration of the machinery is removing the dust cake from the wrapping. Therefore the life of the filter is being prolonged.

Filter 1 Wrapped vs Filter 4 Unwrapped Dust Mass Retained

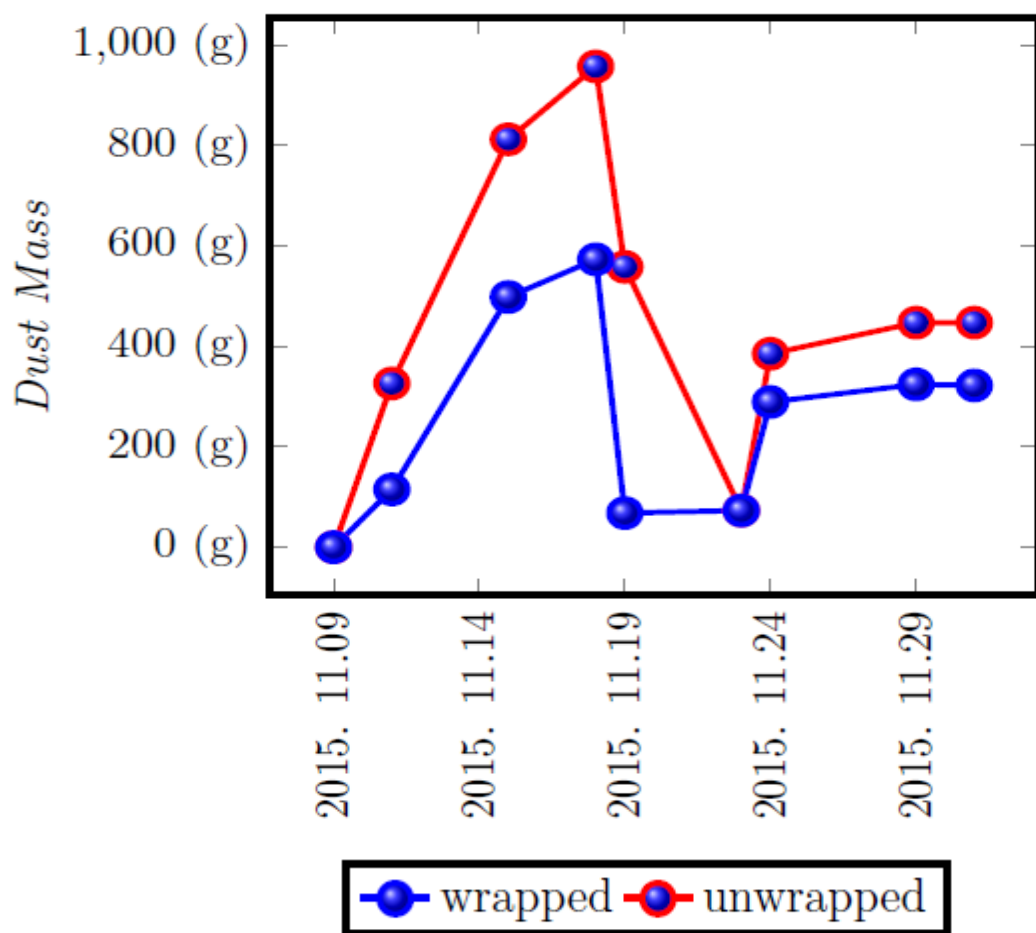


Figure 11: Comparative Efficiency Test

Figure (12) shows that the unwrapped filter is again is retaining more dust than the wrapped filter.

The wrapped filter is not allowing the dust into the core of the filter and the vibration of the machinery is removing the dust cake from the wrapping even more so than in the previous figure.

Therefore the life of the filter is being prolonged.

Filter 3 Wrapped vs Filter 2 Unwrapped Dust Mass Retained

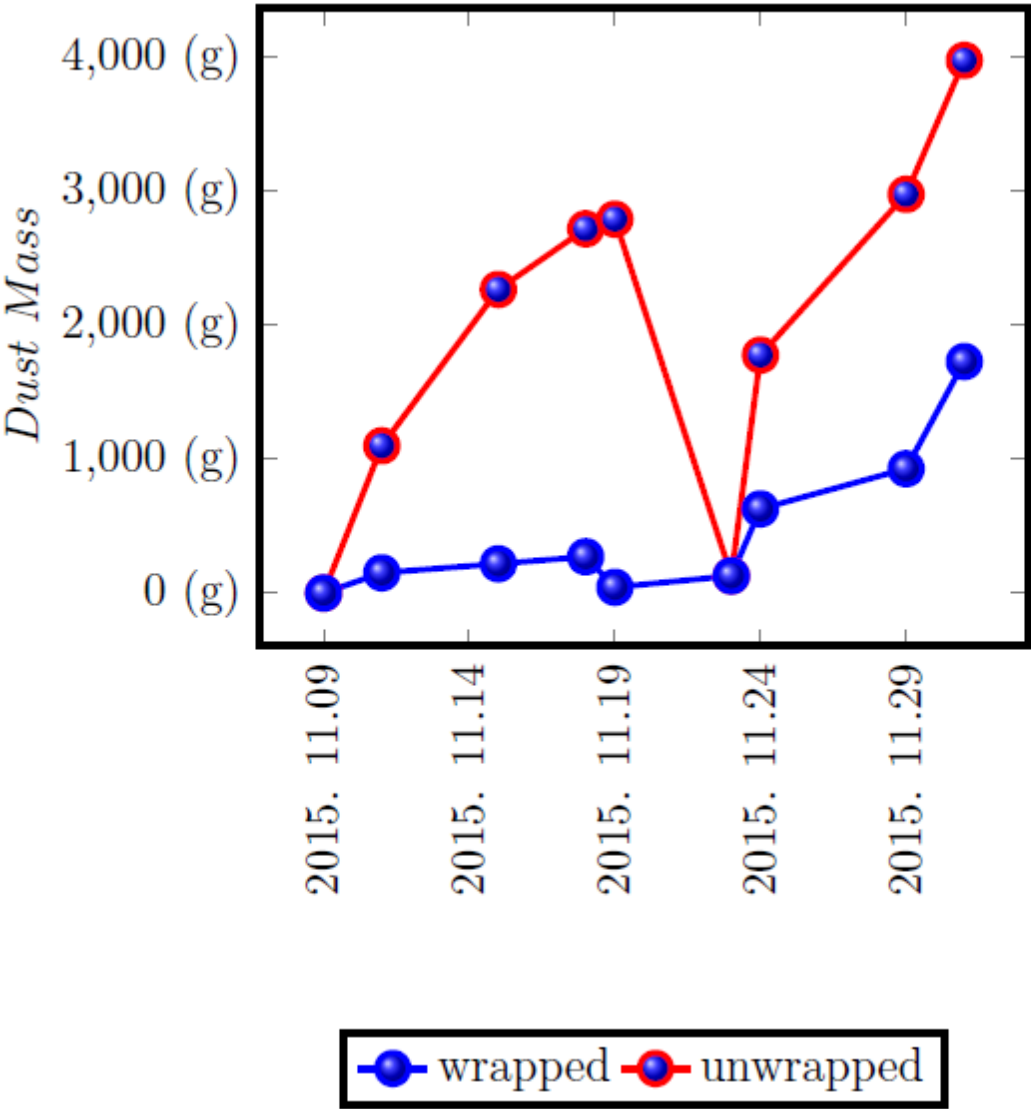


Figure 12: Comparative Efficiency Test

## 7 Conclusion

The retro -fitting of an existing air filter with Webbairs membrane will have an effect on all three numbers namely efficiency, capacity and Restriction.

From the field testing so far it would appear that the retrofitted filter has increased filtration efficiency and capacity.

I would hypothesize but tests would need to confirm that for new filters just in service, it will restrict air flow not least because of an additional layer albeit of benefit in the long term. This is not measured in the present field tests.

I would also hypothesize and again for new filters just in service that it will increase restriction in that the extra layer will contribute to a slightly higher pressure drop since the air will find it more difficult to flow, but as previously stated the long term benefits will outweigh this.

The Field tests so far demonstrate as the filter advances through its service life the air flow restriction for the unwrapped filter increases, thus restricting air flow.

The comparative air flow restriction visible in Figures (11) and Figure (12) between a wrapped filter with low dust penetration and quantity at its core is clearly better than the equivalent unwrapped filter.

The major quantitative conclusion from the tests so far is that the wrapping increases the efficiency and capacity of the filters and would seem to improve flow restriction by decreasing the resistance to air flow as the filter advances through its service life.

While the ISO 5011 tests as carried out by IBR will also give us figures for the efficiency, capacity and Restriction these results are very much restricted to the standard benign environmental conditions of the laboratory.

The Field Tests are more informative in that they give clear indications of comparative performance in the industrial environment.

### References

[1] Saso Iso. Inlet air cleaning equipment for internal combustion engines and compressors – Performance testing. 2007.