TEXTEST INSTRUMENTS

Testing instruments for quality control

FX 3350
Dynamic Air Permeability Tester
AIRBAG-TESTER

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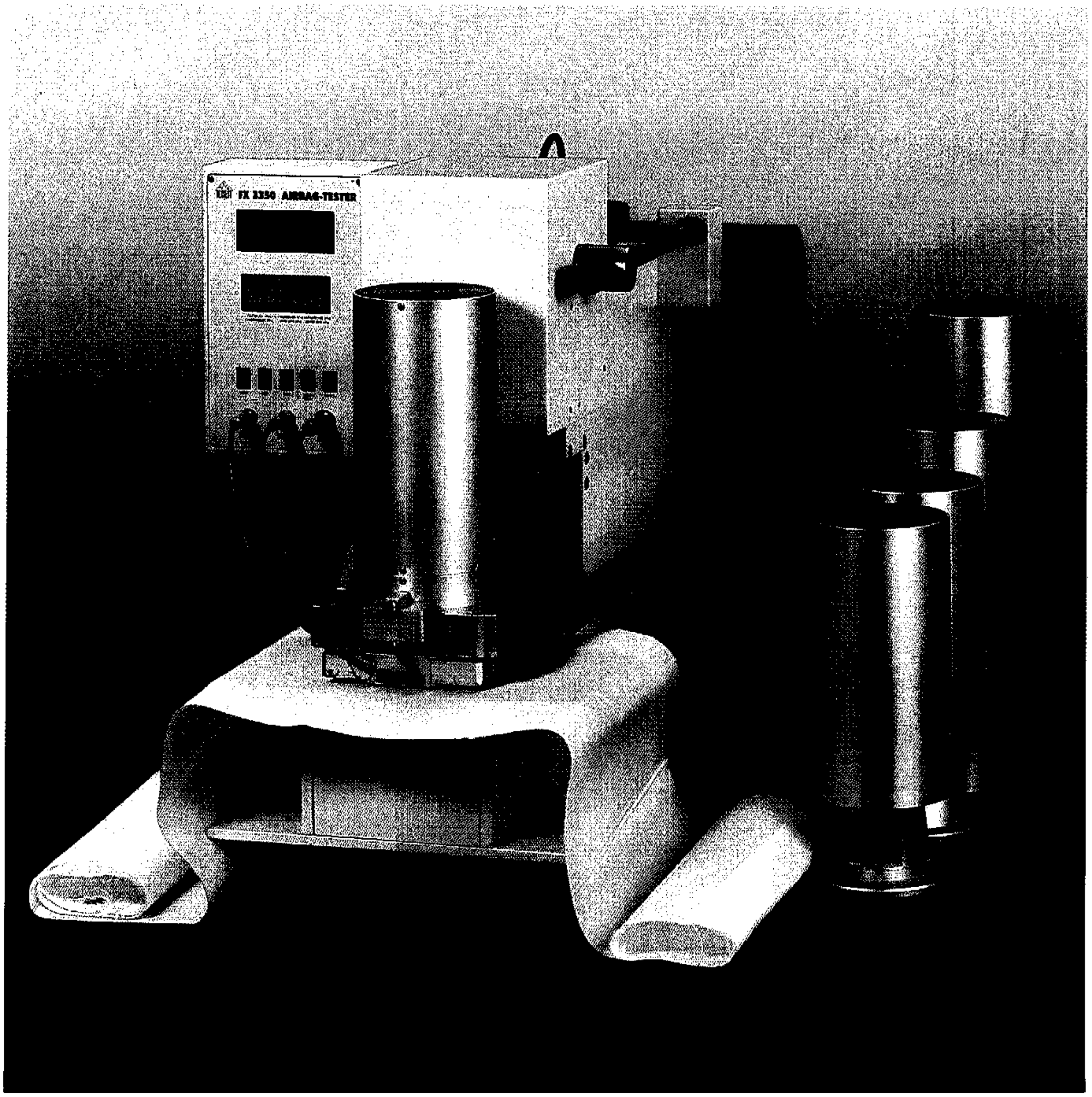

DYNAMIC AIR PERMEABILITY TESTING - AN IMPORTANT NEW TOOL

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ABSTRACT

A new method and instrument is discussed for dynamic air permeability testing of airbag fabrics. This new method provides for much more representative test results as the commonly used static, low pressure air permeability test. The use and significance of the dynamic air permeability and air permeability curve exponent are explained for both, the airbag system designer and the airbag fabric designer.

1. CURRENT METHOD FOR DETERMINATION OF THE AIR PERMEABILITY

Undoubtedly, the air permeability is one of the most important properties of airbag fabrics, and to ensure the proper function of the airbag, it is necessary to control this fabric property both accurately and regularly.

The standard method for determination of the air permeability of airbag fabrics is the same as the one being used for determination of the air permeability of other industrial fabrics. This method determines the velocity at which air passes through the fabric at a given pressure differential across the fabric. Such tests can easily and quickly be conducted with commercial air permeability testers, such as the Textest FX 3300 Air Permeability Tester (figure 1).

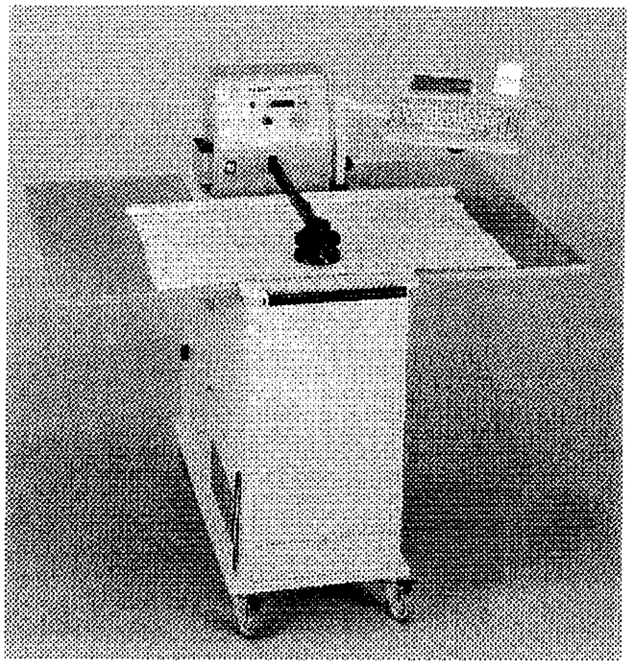

Figure 1: Textest FX 3300 Air Permeability Tester.

Unfortunately, the various test standards used internationally do not prescribe the same test parameters. Consequently, the test results obtained using different test standards do not agree. More important, they cannot easily be compared with each other or converted into each other, if the test methods prescribe different test pressures, which is almost always the case. Figure 2 shows the test parameters prescribed by the most important test standards used for determination of the air permeability of airbag fabrics.

Test standard	Test pressure	Test area	Unit of measure of the air permeability
BS 5'636	98 Pa	5 cm^2	$cm^3/cm^2/s$
JIS L 1096-A	125 Pa	38 cm^2	$cm^3/cm^2/s$
ASTM D 737	125 Pa	38 cm^2	cfm
DIN 53'887	200 Pa	20 cm^2	$l/m^2/s$ or $l/dm^2/min$
informal	500 Pa	100 cm^2	$l/m^2/s$, $l/dm^2/min$ or cfm
informal	2'500 Pa	100 cm^2	$l/m^2/s$, $l/dm^2/min$ or cfm

Figure 2: The most important test standards for the air permeability of airbag fabrics.

The various units of measure used for the air permeability may be rather confusing, particularly in view of the fact that the air permeability is a velocity. However, at a closer look, the above units of measure can be simplified by converting and cancelling out to clearly resemble a velocity (figure 3).

Air permeability unit of measure	expressed as a velocity
$cm^3/cm^2/s$	cm/s
$l/m^2/s$	mm/s
$l/dm^2/min$	dm/min
cfm ($ft^3/ft^2/min$)	ft/min

Figure 3: Units of measure showing the air permeability as a velocity.

During practical use, industrial fabrics are being exposed to an operating pressure which deviates by say, a factor of 2, 3, or 4 from the test pressure at which the air permeability of the fabric is being tested. In exchange for the benefits of a uniform test pressure, such differences between the test pressure and the operating pressure must be accepted.

In case of airbag fabrics the situation is, however, very different, because the operating pressure is much higher than the test pressure. According to figure 2, the air permeability of airbag fabrics is being tested at a test pressure of 98, 125, 200, 500 or 2,500 Pa, depending on the test standard. The operating pressure of airbag fabrics varies, however, from approximately 30 to 80 kPa. Assuming an average of 50 kPa, airbag fabrics are being used at a pressure 20 to 500 (!) times the test pressure. To extrapolate a test result by one or two orders of magnitude is generally difficult, but in the case of airbag fabrics it is totally impossible, because the shape of the air permeability curve is not known.

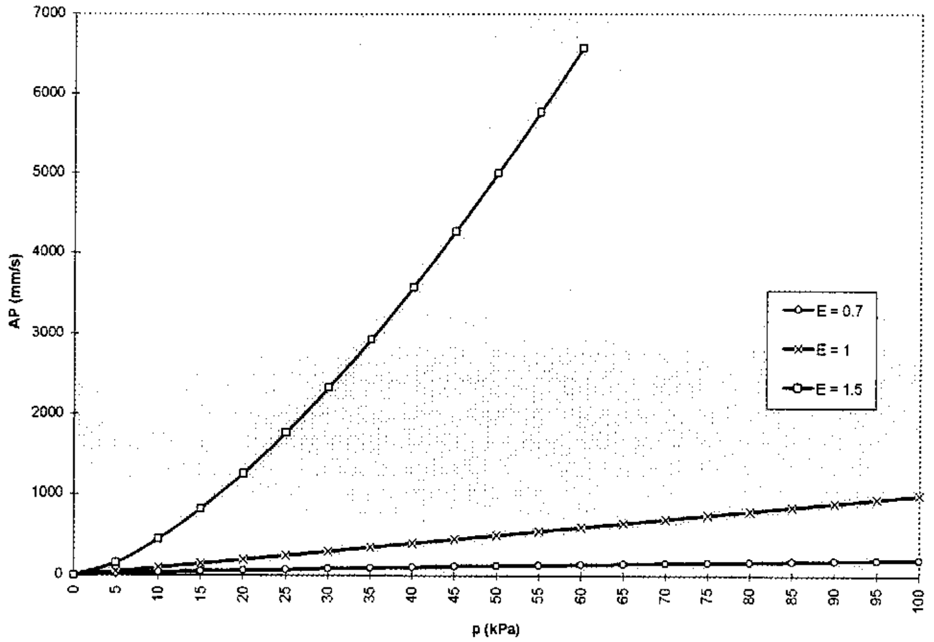

Figure 4: Air permeability curves with different exponents and the same air permeability at a pressure differential of 500 Pa.

Figure 4 shows the air permeability curves of three hypothetical air bag fabrics which have exactly the same air permeability of 5 $l/m^2/s$ or 5 mm/s at a test pressure of 500 Pa. The shape of the three air permeability curves is, however, fundamentally different. Therefore, the air permeability at an operating pressure of 50 kPa varies from 125 to 5,000 $l/m^2/s$, depending on the shape of the air permeability curve. Even if such a large variation may not in any case be possible, it is fair to say, that the static air permeability, measured at a low pressure, does not allow any reliable prediction whatsoever for the air permeability of the fabric at a high pressure, if the shape of the air permeability curve is not known.

Considering that the airbag is a safety device on which human life may depend, testing the air permeability of airbag fabrics in accordance with the current low pressure test method is almost negligent.

There are known cases, where airbag fabrics passed the quality control of the weaving mill and the receiving inspection of the system manufacturer, because the static air permeability was well within the specified range. In the crash test, however, the airbag failed. It turned out, that the weaver had made what appeared a minor change to the construction of the fabric in order to save cost. Although the manufacturer made sure that the static air permeability was the same before and after the change, it escaped their observation that the shape of the air permeability curve had changed. This in turn caused the air permeability at the operating pressure to be outside the safe range.

For these reasons Textest decided a few years ago to design, build, and market a new air permeability tester, specially geared to the requirements of airbag fabrics. The design specifications for this instrument are shown in figure 5.

- Determination of the air permeability in the same pressure range, in which the airbag fabrics are actually being used (up to 100 kPa or 14 psi), in order to avoid extrapolation of the test results over a wide pressure range.
- Dynamic measurement with a realistic pressure/time curve to capture possible dynamic effects on the air permeability.
- Determination of both, the air permeability *and* the shape of the air permeability curve in a simple mathematical way, as an important input for the airbag system model of the module manufacturer.
- Uniform SI unit of measure for the air permeability, to avoid the current variety of units used for the static air permeability.
- Optional data output to a PC for documentation and detailed evaluation of the test results for R & D work on airbags and on airbag fabrics.
- Short testing time, to keep the cost for testing low.
- Simple operation, to avoid operator errors.
- Self contained table top instrument, to keep space requirements to a minimum.

Figure 5: Design specifications for the Dynamic Air Permeability Tester AIRBAG-TESTER.

After several years of R & D work with many setbacks, Textest introduced in mid 1995 the FX 3350 Dynamic Air Permeability Tester AIRBAG-TESTER. This instrument meets the above specifications and in addition provides valuable data regarding the elastic properties of the airbag fabrics (figure 6).

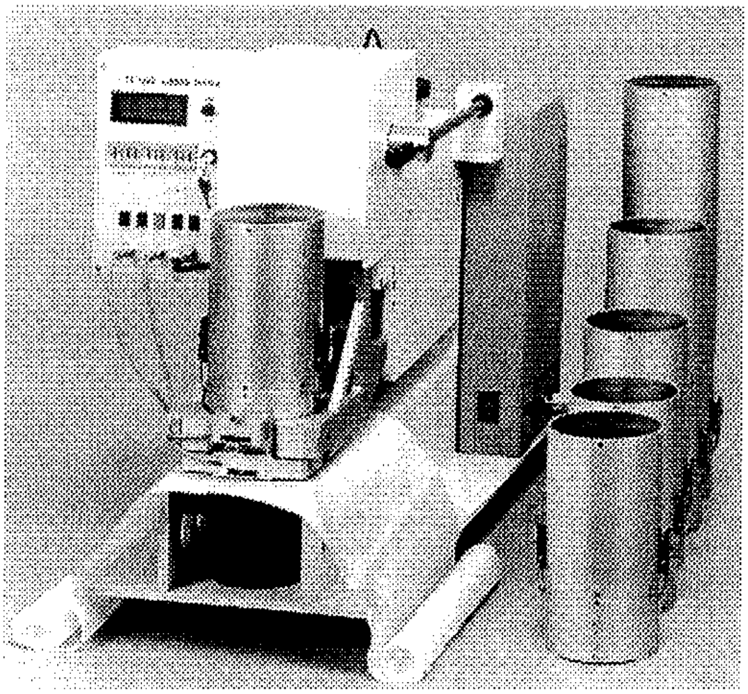

Figure 6: Textest FX 3350 Dynamic Air Permeability Tester "AIRBAG-TESTER".

2. THE OPERATING PRINCIPLE OF THE AIRBAG-TESTER

The FX 3350 AIRBAG-TESTER is an easy-to-use table top instrument with the outside dimensions 42 x 80 x 58 cm or 17 x 31 x 23". It consists of a storage volume V_1, connected by a high speed valve to a second volume V_2. One side of this second volume is open, and the test specimen is firmly clamped over this opening (figure 7).

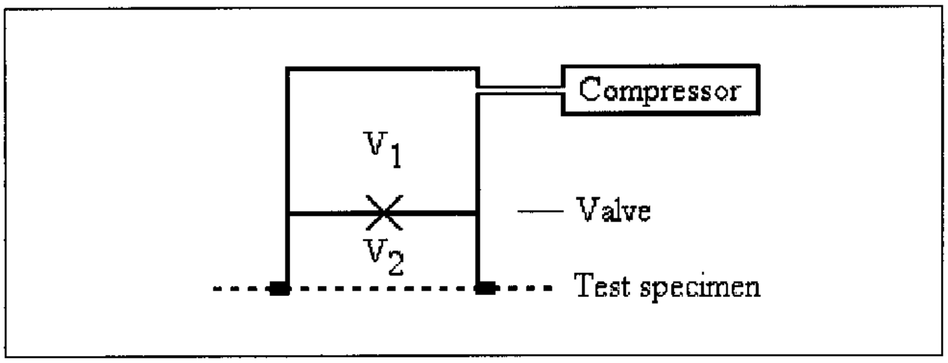

Figure 7: Operating principle of the AIRBAG-TESTER

For the test, the storage volume is charged with dry air to a selectable start pressure by means of a small compressor. After the compressed air has cooled down to the ambient temperature, the high speed valve opens automatically, and the storage volume discharges through the second volume and through the test specimen into the open air. If the storage volume and the start pressure are properly selected, the pressure in the second volume, and with it, the pressure across the test specimen, rise sharply, within 10 to 30 ms, to a maximum pressure of approximately 100 kPa or 14 psi, and subsequently drops back to zero within approximately 100 to 300 ms. This pressure/time curve is rather similar to the one observed in an airbag after deployment.

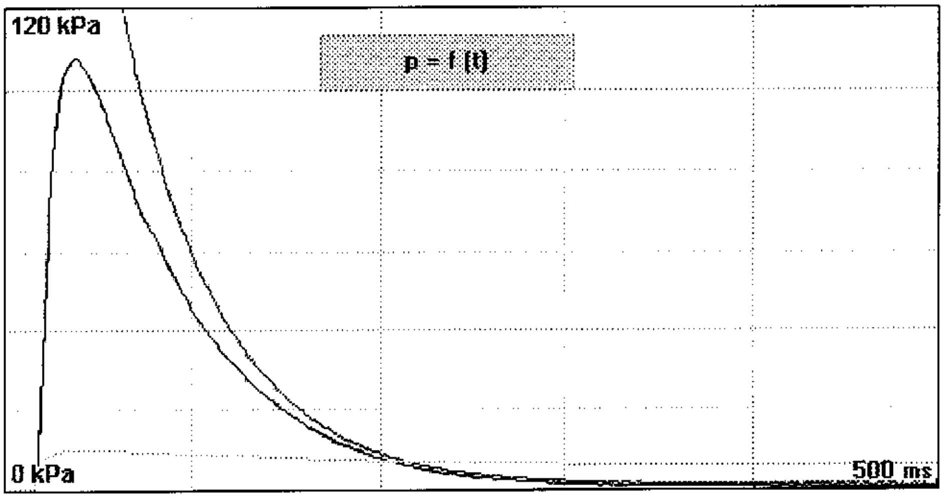

Figure 8: Typical pressure/time curve across the test specimen.

Figure 8 shows a typical pressure/time curve of the storage volume and the second volume. As the pressure in the storage volume drops continuously from the start pressure to zero, the pressure in the second volume, and the pressure drop across the test specimen, rise sharply to the maximum test pressure and subsequently drop back to zero. In this example the test pressure reaches a maximum of

108 kPa. The rise time of the pressure curve is 20 ms and its fall time is 125 ms. The fall time is, by the way, defined as the time, in which the pressure drops from the peak value to 15 % of that value.

During the entire duration of the test, which is 0.5 s, the pressure in the storage volume and in the second volume is measured in intervals of 125 µs. The built-in microprocessor computes from these data for any pressure differential across the test specimen the velocity of the air through the test specimen. This is the air permeability of the test specimen as a function of the test pressure.

The measurement is much complicated by the fact that the test specimen does not remain in place when the blow of air is applied. The maximum force of 500 N, exerted by the air blow, causes the test specimen to bulge. At a circular test area of 50 cm^2, corresponding to a diameter of 80 mm or 3.15", the bulging amounts to 10 to 15 mm or 0.4 to 0.6", depending on the test specimen! In figure 8 the bulging height of the test specimen as a function of time is shown as a third curve.

The bulging of the test specimen changes the size of the intermediate volume. In addition, the movement of the specimen causes an additional air movement, but this air movement must not be attributed to the air permeability of the specimen, because the air moves *behind* the specimen and not *through* it. Therefore, this share of the measured air velocity must be determined and subtracted by the microprocessor with considerable computing effort.

This complication, which initially appeared to be a disadvantage of the system, later proved to be a real asset, because with little effort, from the bulging of the test specimen, the biaxial strain/stress curve can be computed. So, in addition to the air permeability, the instrument generates extremely valuable information regarding the biaxial elastic properties of the test specimen, and this information is not easily obtainable otherwise.

3. THE TEST RESULTS OF THE AIRBAG-TESTER

3.1 THE AIR PERMEABILITY

Which kind of test results does the AIRBAG-TESTER provide?

As required by the design specifications, the instrument determines the air permeability *dynamically* with a pressure/time curve that is rather similar to the one observed in a deployed airbag. The test pressure is, therefore, approximately the same as the actual operating pressure of the airbag fabric. This makes the test results much more reliable and representative than the static air permeability, measured at a low pressure. The measured air permeability includes any dynamic component that may be present, and - since it is determined at a high pressure - it eliminates the need for unreliable extrapolations over a wide pressure range. At this point it should, however, be noted that the AIRBAG-TESTER does *not* simulate the deployment of the airbag, even though the name AIRBAG-TESTER may suggest just that. The instrument merely measures the air permeability of the airbag fabric under idealized conditions which are, however, much more representative for the actual working conditions of the airbag fabric than all other test methods known so far.

The instrument uses “mm/s“ as the only unit of measure for the air permeability. This eliminates the large number of units of measure, currently in use for the static air permeability. This unit of measure is a SI unit. It is, by the way, also prescribed in the latest ISO test standard for measurement of the static air permeability. It can easily be visualized and it makes it clear, that the air permeability is a velocity. In addition, this unit of measure is identical to one of the two units of measure, currently used in the DIN standard (l/m²/s), and it can easily be converted into all other units of measure, currently used for the air permeability (figure 9).

mm/s → other units	other units → mm/s
1 mm/s = 1,00 $l/m^2/s$	1 $l/m^2/s$ = 1,00 mm/s
1 mm/s = 0,60 $l/dm^2/min$	1 $l/dm^2/min$ = 1,67 mm/s
1 mm/s = 0,10 $cm^3/cm^2/s$	1 $cm^3/cm^2/s$ = 10,0 mm/s
1 mm/s = 0,0197 cfm	1 cfm = 5,08 mm/s

Figure 9: Conversion table for various units of measure for the air permeability.

Contrary to the static air permeability, the dynamic air permeability is not specified at a particular, single test pressure, but it is defined as the average air permeability in a specified pressure *range*. This pressure range has been selected to match the typical operating pressure range of an airbag fabric. Due to this definition, the dynamic air permeability becomes even more valuable for airbag fabrics.

3.2 THE EXPONENT OF THE AIR PERMEABILITY CURVE

The real particularity about the dynamic air permeability is, however, that it is not defined by a single number, as the static air permeability. Instead, the dynamic air permeability is complemented by a second number, which is the exponent of the air permeability curve.

What is the significance of this exponent of the air permeability curve?

It is known, that the function air permeability AP versus pressure differential p across the fabric can be described with sufficient accuracy by the following algorithm (figure 10).

$$\boxed{AP = A \cdot p^E}$$

Figure 10: Function air permeability AP versus pressure differential p.

The factor A and the exponent E in this algorithm are two constants, determined only by the fabric. The factor A represents the air permeability of the fabric, and the exponent E describes the shape of the air permeability curve.

Figure 11 shows the air permeability curves of three hypothetical fabrics with different exponents and the same air permeability at a pressure differential of 40 kPa.

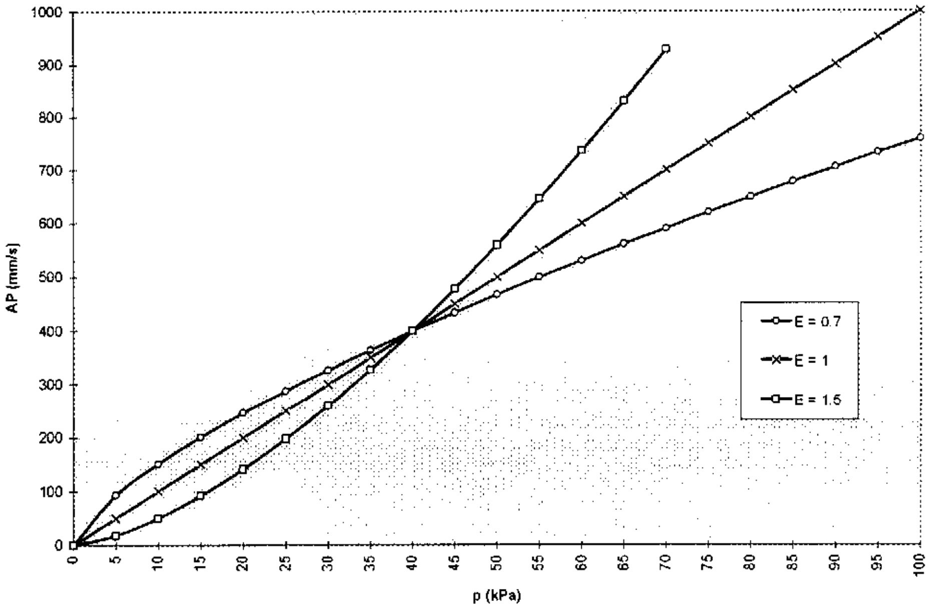

Figure 11: Air permeability curves with different exponents and the same air permeability at a pressure differential of 40 kPa.

The curve with an exponent E = 1 is a straight line. This means, that the air permeability AP increases linearly with the pressure differential p. An increase in pressure differential of 1 % causes an increase in air permeability of also 1 %.

Curves with an exponent E < 1 have a digressive characteristic. This means, that the air permeability AP increases less than proportionally with the pressure differential p. The air permeability of a fabric with a curve exponent E of 0.7, for example, will increase by only 0.7 %, if the pressure differential increases by 1 %. Since 0.7 is the lowest exponent we have experienced so far at airbag fabrics, the curve shown in the graph is about the most digressive curve one may expect to see.

Curves with an exponent E > 1 have a progressive characteristic. This means, that the air permeability AP increases more than proportionally with the pressure differential p. The air permeability of a fabric with a curve exponent E of 1.5, for example, will increase by 1.5 %, if the pressure differential increases by 1 %. Since 1.5 is the highest exponent we have experienced so far at airbag fabrics, the curve shown in the graph is about the most progressive curve one may expect to see.

The curve exponent E is of great importance, because it describes in an easy way the shape of the air permeability curve. It can be visualized as being a measure for the "softness" of the airbag. This is not to be confused with the mechanical softness of the airbag fabric, but it means the softness of the airbag, caused by the change in air permeability at a given pressure change.

Suppose, a fully deployed airbag of a particular size has been inflated to an internal pressure of 40 kPa (or 5.7 psi). Further suppose, the internal pressure of the bag increases to 60 kPa (or 8.5 psi) when the driver (or passenger) falls into the bag. This 50 % pressure increase of 20 kPa (or 2.8 psi) causes an increase in air permeability which is determined by the exponent of the air permeability curve. If the airbag is made from a fabric with an air permeability curve exponent E of 0.7, its air permeability will increase only by 33 %. If the same airbag is made from a fabric with an air permeability curve exponent E of 1,5, its air permeability will increase by 84 %! In the latter case, more gas escapes through the fabric, and the airbag appears softer, while the first airbag releases less gas, and therefore appears harder. The curve exponent can, therefore, be visualized as being the "softness" of an airbag of a given size, at a given internal pressure, and at a given pressure rise, and under the assumption, that the entire airbag is made from the same airbag fabric.

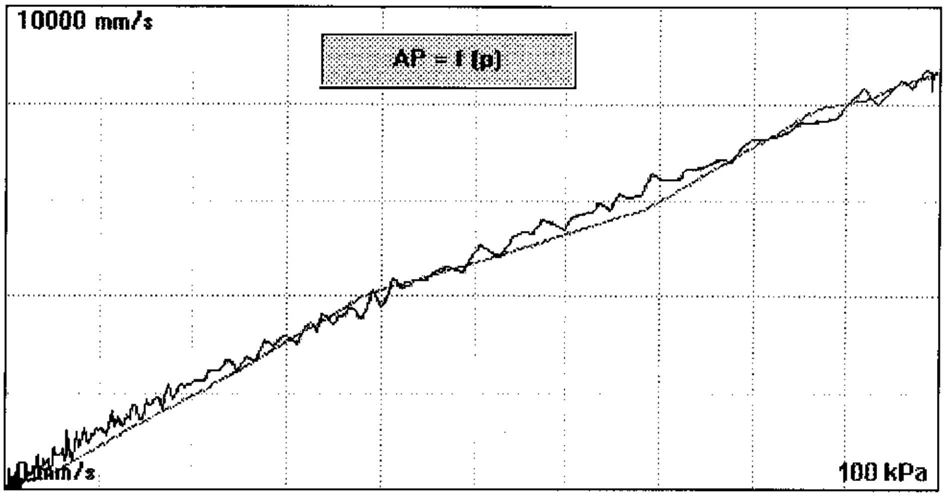

Figure 12: Air permeability curve, ADAP = 4810 mm/s, E = 0.85.

Figure 12 shows the air permeability curve of an airbag fabric, measured with the AIRBAG-TESTER. The x-axis of the graph shows the test pressure, or the pressure differential across the fabric, in kPa. The y-axis shows the dynamic air permeability in mm/s. The red curve represents the *in*flation phase, during which, in this case, the pressure rises from zero to 99 kPa with a rise time of 12 ms. The black curve represents the *de*flation phase, during which the pressure drops back to zero with a fall time of 106 ms. The average dynamic air permeability ADAP of the fabric in the pressure range from 40 to 60 kPa is 4810 mm/s, and the curve exponent E is 0.85. This means, the tested fabric is relatively open and has a low curve exponent. Thus, an airbag made from this fabric will be relatively hard.

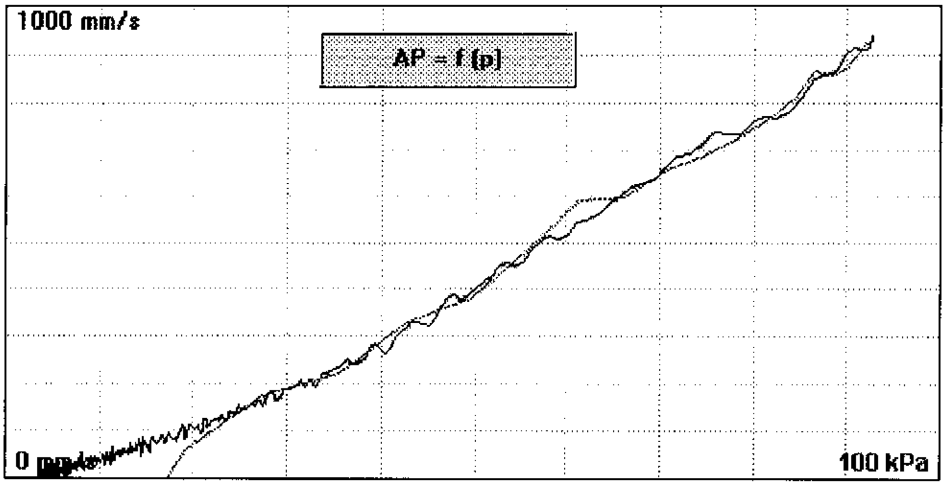

Figure 13: Air permeability curve, ADAP = 388 mm/s, E = 1.59.

Figure 13 shows the air permeability curve of another fabric with a relatively *high* curve exponent E. Note the *pro*gressive shape of the curve, compared to the *di*gressive shape of the previous curve. In this test the rise time of the test pressure was 21 ms, and the fall time 160 ms. The test pressure rose to a maximum of 93 kPa. The average dynamic air permeability ADAP of this fabric in the pressure range of 40 to 60 kPa is 388 mm/s, and the curve exponent E is 1.59. This means, the tested fabric is relatively dense and has a high curve exponent. Thus, an airbag made from this fabric will be relatively soft.

The second and more important significance of the curve exponent E is, however, that it precisely describes the shape of the air permeability curve. Therefore, it makes it possible to compute the air permeability of a fabric at *any* pressure differential, from the known air permeability at a known pressure differential. The algorithm for the air permeability of a fabric, shown in figure 10, can be converted to the algorithm shown in figure 14. With this simple algorithm the air permeability AP of the fabric at any pressure differential p can be computed from the known air permeability AP_0 at the pressure differential p_0.

$$\boxed{AP = AP_0 \bullet \left(\frac{p}{p_0}\right)^E}$$

Figure 14: Determination of the air permeability AP at any pressure differential p, from the known air permeability AP_0 at a known test pressure p_0.

Since the AIRBAG-TESTER provides the values for AP_0, p_0 and E, all information is available to compute the air permeability of the tested fabric in the entire pressure differential range. The airbag system designer can use this simple algorithm in the mathematical simulation model of the airbag system to describe the air permeability of the airbag fabric at any pressure differential.

How well do the two test results of the AIRBAG-TESTER, the average, dynamic air permeability ADAP and the curve exponent E, describe the measured air permeability curve of the tested fabric in the entire pressure range?

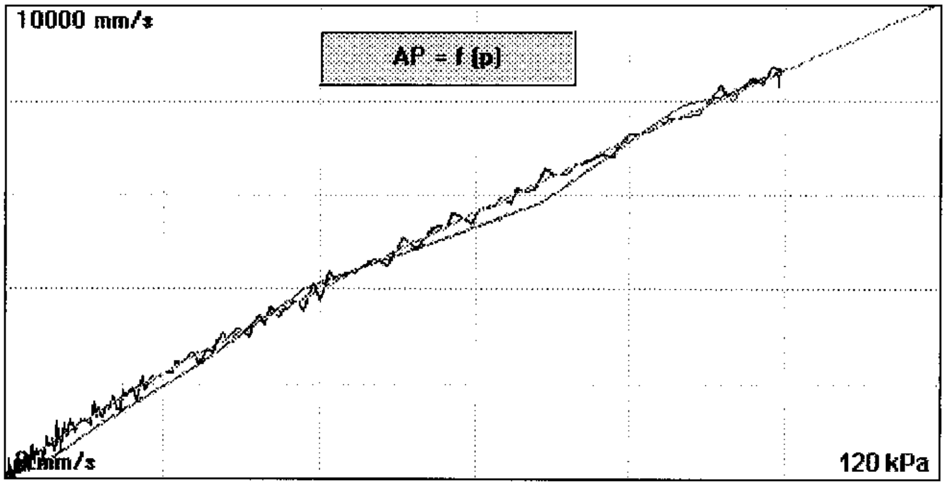

Figure 15: Measured and computed air permeability curve.

If one applies the two numbers measured and displayed by the AIRBAG-TESTER to the previously shown algorithm for the air permeability (figure 14), the resulting computed air permeability curve is the green curve shown in figure 15. This curve corresponds indeed very well with the measured air permeability curve of that fabric in the entire pressure range. It is therefore fair to say, that the two test results of the AIRBAG-TESTER are the shortest possible mathematical description of air permeability of the tested airbag fabric in the entire pressure range. With these two numbers and a simple algorithm the air permeability of the fabric can be described for any pressure.

To further assist the airbag designer, the air permeability of the fabric is defined as the velocity of the air through the fabric, converted to a constant pressure of 100 kPa and a constant temperature of 20°C. Thanks to this definition the measured air permeability can easily be converted, by means of the general gas algorithm, to a gas different from air, at a different pressure differential and a different temperature.

By means of the curve exponent E, the airbag system designer can clearly define the requirements for the airbag fabric, and the fabric manufacturer understands exactly what is needed. He can design the fabric to the requirements of the airbag system and make sure that the finished product maintains the specifications during production. This may save all parties involved a lot of unnecessary problems and frustration.

In some cases the computed and the measured air permeability curves match only in a portion of the pressure range. This means, the curve exponent is not constant, but changes with the test pressure.

This variation of the curve exponent with the pressure differential is mostly a result of the elongation of the fabric, caused by the pressure. Normally, when the fabric is being stretched, the average pore size increases, and the air permeability increases more than one should expect as a result of the pressure increase. Certain fabric constructions, however, behave in the opposite direction. In these fabrics the average pore size *decreases* when the fabric elongates. In this case the air permeability increases less than one should expect as a result of the pressure increase.

The variation of the curve exponent with the pressure differential may altogether be intended, because it makes it possible to adapt the shape of the air permeability curve to the requirements of the airbag system. Possibly, this technology may one day lead to the so called "intelligent" fabric, the air permeability curve of which perfectly matches the requirements of the airbag system.

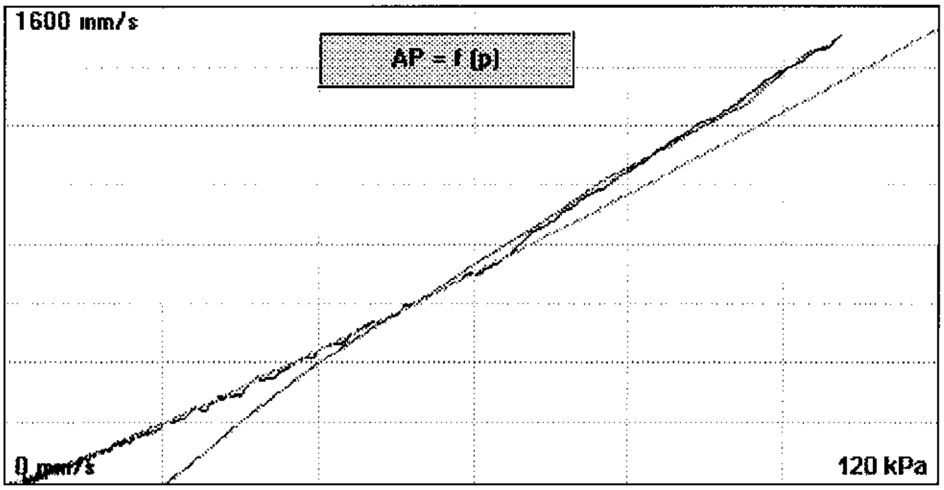

Figure 16: Air permeability curve with variable exponent.

Figure 16 shows an air permeability curve which visibly differs from the usual curves. The average dynamic air permeability of the fabric was measured to be 566 mm/s in the standard measuring range of 40 through 60 kPa, and the curve exponent in this range was determined to be 1.14. The computed curve, based on these numbers matches the measured air permeability curve very well, but only in the lower pressure range, up to a pressure differential of 65 kPa. At higher pressures, the computed air permeability curve deviates visibly from the measured curve. Apparently, the exponent of the measured air permeability curve is not constant, but differs from 1.14 at higher pressure differentials. This can easily be verified by displaying the air permeability curve in a double-logarithmic scale. In this scale, all air permeability curves with a constant curve exponent show as a straight line, regardless of the exponent value.

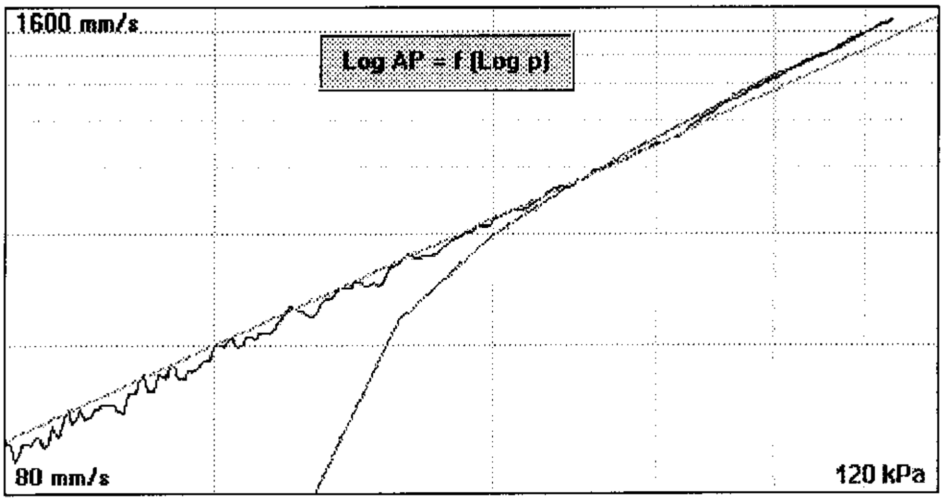

Figure 17: Air permeability curve in double-logarithmic scale.

Figure 17 shows the same air permeability curve as in figure 16, but in a double-logarithmic scale. And, as expected, the curve is not straight, but slightly bent. This becomes obvious, if one compares the measured air permeability curve with the green, computed curve, which *is* a straight line, because it is based on a constant curve exponent of 1.14. Since in the double-logarithmic scale the slope of a curve is a measure for the curve exponent, it can clearly be seen, that the exponent of the measured air permeability curve at pressure differentials over 65 kPa is higher than 1.14. In order to describe the air permeability of this fabric correctly, it is necessary to divide the air permeability curve into an lower and upper section and to determine the average air permeability and the curve exponent for each of these curve sections. Thus, the shape of the entire curve is no longer characterized by two numbers, but by four. For this fabric the complete test result looks as follows:

- Pressure differential 5 through 60 kPa: ADAP = 344 mm/s, E = 1.20
- Pressure differential 60 through 99 kPa: ADAP = 1020 mm/s, E = 1.34.

It must, however, be noted that in this case the change in curve exponent is so small, that a division of the curve into two sections is really not necessary. For all practical purposes the air permeability curve of this fabric can be described by a single curve exponent, provided the measuring range is selected to incorporate portions of both curve sections. This example should only show, that with the AIRBAG-TESTER even complicated curve shapes can be described, which may become more common in the future than it is today.

An interesting question is which properties of a fabric do influence the curve exponent. Generally, it can be said, that the curve exponent is determined by the average size of the pores or air channels in the fabric. Larger pores lead to a low curve exponent and smaller pores to a high exponent. Since the average pore size also influences the air permeability of the fabric, one should expect a certain correlation between the air permeability and the curve exponent of a fabric. This correlation is, however, not very strong, since the air permeability is not only determined by the average pore size, but also conclusively by the number of pores per area unit of the fabric.

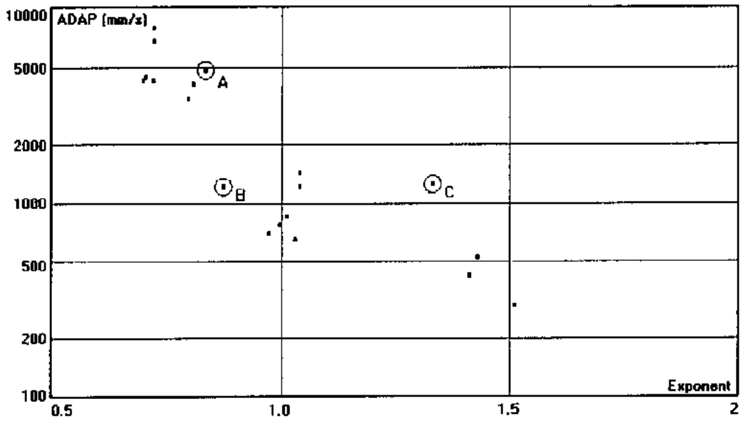

Figure 18: Correlation between average dynamic air permeability ADAP and curve exponent E for twenty different air bag fabrics.

The graph in figure 18 shows the average, dynamic air permeability ADAP of twenty different air bag fabrics, plotted against the exponent E of the respective air permeability curves. In this graph each dot represents one fabric. Please note that the vertical axis is in a logarithmic scale, so that the distance between neighboring horizontal lines is approximately a factor 2 in air permeability!

The graph clearly shows a certain correlation between the air permeability ADAP and the curve exponent E.. Generally, as expected, dense fabrics tend to have a low curve exponent and open fabrics tend to have a high curve exponent. The correlation is, however, not very strong. The fabrics "A" and "B", for example, have approximately the same curve exponent E of 0.8, but their air permeability is very different. While fabric "A" has an average, dynamic air permeability of 4830 mm/s, the air permeability of fabric "B" is only 1250 mm/s, four times lower than the air permeability of fabric "A". Two other fabrics, "B" and "C", have approximately the same air permeability of 1250 mm/s, but their curve exponents are very different, 0.8 and 1.3, respectively.

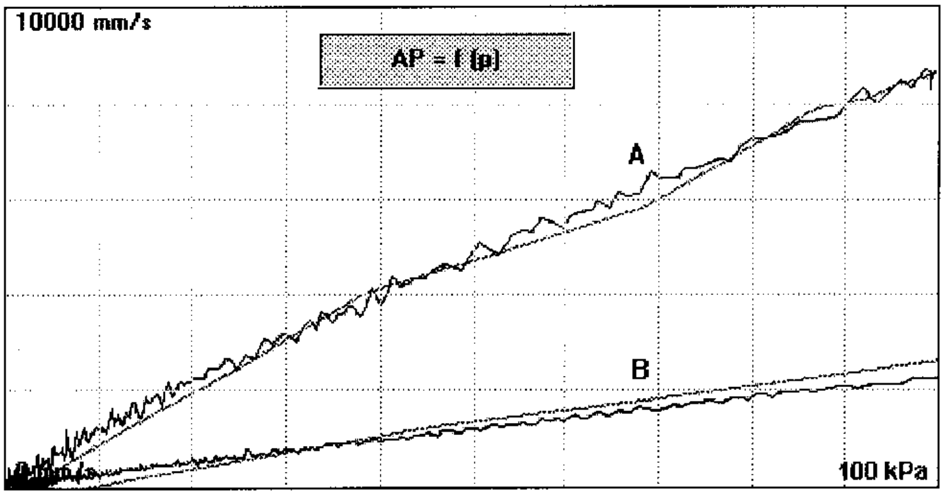

Figure 19: Air permeability curves of the fabrics "A" and "B".

Figure 19 shows the air permeability curves of the fabrics "A" and "B". Both curves have the same curve exponent and shape, but the air permeability is very different.

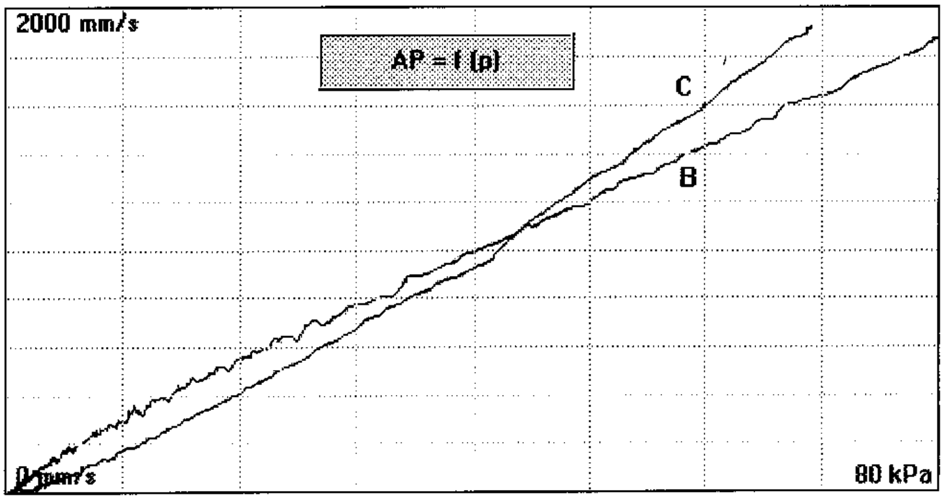

Figure 20: Air permeability curves of the fabrics "B" and "C".

Figure 20 shows the air permeability curves of the fabrics "B" and "C". Both fabrics have the same air permeability at a pressure differential of approximately 45 kPa, but the curve exponents are 0.8 and 1.3 respectively. (For reason of clarity the inflation phase curves have been erased in this diagram).

Although the selection of fabrics shown in figure 18 is only randomly and by far not complete, it shows already a significant "band width" in the combination of air permeability and curve exponent. In reality, this "band width" is certainly much wider, and will get wider yet in the future. For the airbag designer this means, that there is a wide selection of fabrics available from which he can pick the one which best meets the requirements of his airbag system.

3.3 THE BIAXIAL STRAIN-/STRESS CURVE

The AIRBAG-TESTER has a test area of 50 cm^2, represented by a circular area with a diameter of 80 mm or approximately 3“. During measurement this test area is exposed to a sudden blow of air with a peak pressure of 100 kPa, causing a peak load of 500 N or 100 lbs. Since the test specimen is firmly clamped around the test area with a clamping force of 380 kg or 840 lbs, it can react to this sudden load only by bulging. The peak bulging height is 10 to 20 mm, depending on the fabric!

For determination of the dynamic air permeability and the exponent of the air permeability curve, the bulging height of the test specimen must be continuously measured for the entire duration of the blow of air. This is done by means of a laser sensor in time increments of 125 µs. Therefore, the bulging height of the test specimen as a function of the pressure differential is known with a high degree of accuracy. From these data two curves are being computed.

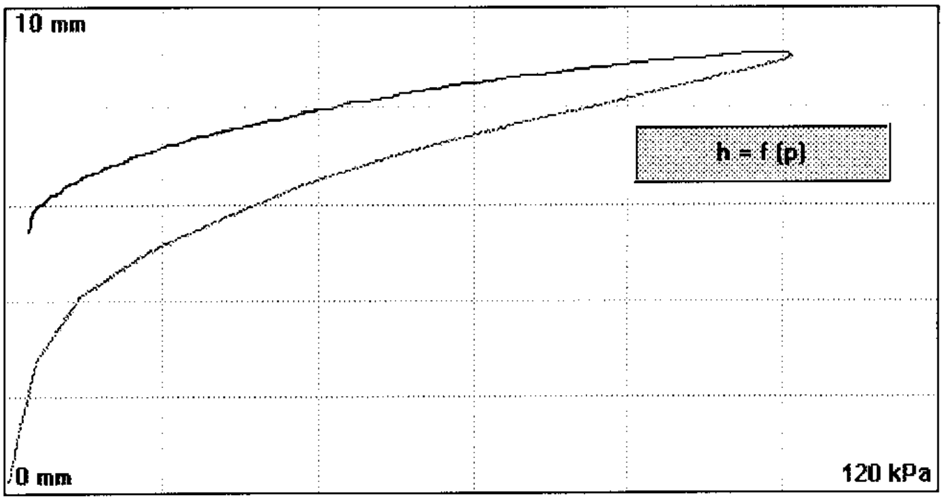

Figure 21: Bulging curve.

Figure 21 shows the bulging curve, which is the bulging height of the test specimen in mm as a function of the pressure differential in kPa. Already at a rather low pressure differential a significant bulging height can be observed, but this bulging is not caused by fabric elongation. It is merely a result of the slack, which is taken out of the fabric. Only at higher pressure differentials the fabric starts to elongate. Initially the elongation increases rapidly with pressure, but it slows down more, the higher the elongation is. After the pressure differential has reached its peak, the fabric recovers only partially. A large portion of the bulging height remains in the fabric, even after the pressure differential has returned to zero.

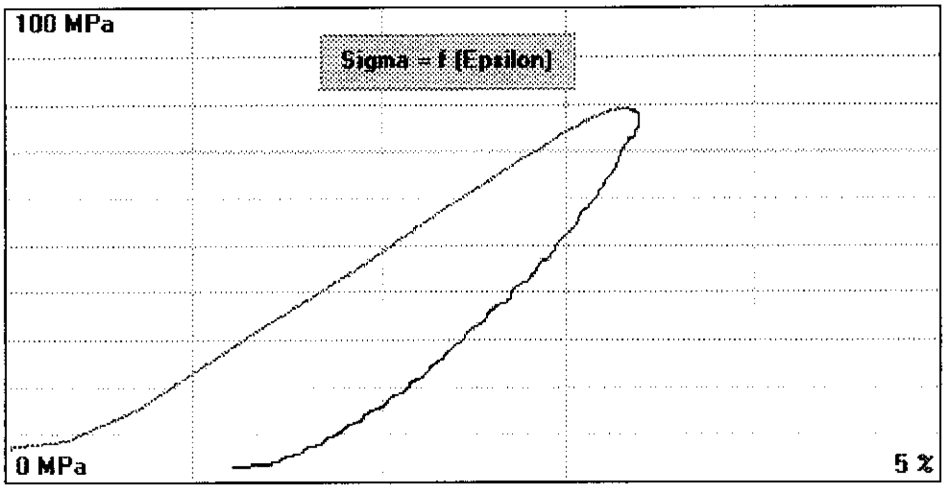

Figure 22: Biaxial strain/stress curve.

Figure 22 shows the biaxial strain/stress curve, which can be computed from the data shown in the previous graph. The curve shows the biaxial stress in the center of the test specimen in MPa as a function of the biaxial strain in %. This curve provides the airbag system designer with extremely useful information in regard to the elastic properties of the tested fabric, which are only difficult to obtain otherwise. The AIRBAG-TESTER provides these data as a side product.

4. SUMMARY

In summary, it can be said that the test results provided by the Textest FX 3350 AIRBAG-TESTER, comprising the average, dynamic air permeability of the tested fabric and the exponent of the air permeability curve, reliably describe the air permeability of the fabric in the entire pressure range. Therefore, these test results are best suited to represent the air permeability of the airbag fabric and to serve as an important input for the mathematical airbag system model.

By means of these two numbers, the airbag system manufacturer can precisely define the air permeability requirements for the airbag fabric, and the fabric manufacturer can design the fabric to meet these requirements. In quality control, these two numbers can easily and quickly be checked, to ensure that the produced fabric performs in actual use precisely as specified.

Therefore, the instrument potentially can save a lot of time and possibly one or the other expensive and time consuming tests. We hope, it may in the future contribute to the already impressive progress in the airbag industry and it will help to answer some of the open questions.