Bachelor Assignment:
Analysis and design of in-line package leaking indicators

CONFIDENTIAL

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Report

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This report is addressed to operating companies within Friesland Foods who are considering in-line leak detection methods for their production lines and for the examiners of both Friesland Foods and the University of Twente.

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In-line package leaking indicators

Final report Bachelors Assignment

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1. Abstract

More and more products are moving from offline leakage detection where only a portion of the products is tested for leaks to in-line leakage detection systems, where 100 percent of the products is monitored for leaks. There have been many development in this area lately.

Friesland Foods wants to extend their knowledge about these techniques, their applicability, possibilities, advantages and disadvantages.

The goal of this Bachelors Assignment can be separated in two phases, a research phase where present available techniques are researched and a second phase where a design concept is produced for a packaging form which does not have a good market-ready solution available.

To complete the first phase, market research has been performed. Internet research, patent research, company documentation, interviews with different operating companies within Friesland Foods and visits to exhibitions on packaging have been performed to find out which techniques are available on the market. The focus was not only the food and beverage market, but research was also extended to medical systems, since product safety plays an ever more important role there, which makes the medical industry a good indicator of what is to come.

This information was generalized as good as possible and is presented in an overview table, which operating companies can use as a starting point when in-line leakage detection is considered.

A choice has been made for micro perforated 25 kg sacks to be the subject in the second phase. These sacks proofed to have very little options available for leakage detection in the first phase. Together with multiple operating companies which might benefit from a concept in this terrain this choice was made. A concept for micro perforated 25 kg sacks might be able to work for different sized sacks too, and even non-perforated ones. This was also accounted for when developing a concept.

The final concept is based on compressing the head space of a sack with a standardized force and thereafter measuring how this force descends over time. Leak sacks tend to have steeper slopes over time which can be detected, so the leaking sack can be ejected from the production line.

To test whether such a concept would work or not, several tests have been performed. A calculation shows that the present available head space is suffient for measuring. A second tests shows that both for micro perforated and barrier (air-tight) sacks a different slope is measurable after punching a small needle through it. It also shows that these particular sacks have quite long settling times: the time it takes before the force decreases linear over time can be up to 120 seconds, although testing might start when the sack has not yet completely settled.

To overcome this long settling time, tests indicate that this time might be lowered by increasing the initial load force that is applied to the sacks. Of course, this load force cannot be increased indefinitely, so another tests was carried out to see how much force could be applied before a burst occurs. This test showed that forces up to a maximum of 6500N could be used for leakage testing the microperforated sacks and 10500N for barrier sacks.

Further research needs to be done on the concept, but the tests which are described in this report give reason to be optimistic, certainly in case of the micro perforated sacks where, when leaks occur, leaks are usually quite large.

2. Table of contents

3. Terminology

Here a list of terms is given, which might differ in meaning from conventional standards or which are considered unknown to part of the public of this report.

Leak	any opening in a packaging that, contrary to intention, either allows the contents to escape or substances to enter
Merit value	a calculated number determined using an algorithm to compute a resultant from a set of data values
Head space	space within a sealed packaging which is not filled with the product, but often with gas (air, nitrogen etc.)
Fill level	up to what contents a packaging is filled
Ejector	apparatus for mechanically removing a packaging out of the normal production line, generally in a form of a rod pushing the packaging off a conveyer belt
Micron[1]	10^{-6} meter
TeCi	technology circle, group within Friesland Foods that aims to make knowledge universally available in the organization, extending the borders of individual operating companies and to give aim to the knowledge development within the company
OpCo	operating company
Aseptic processing[2]	method for sterilizing both product and packaging to extend the shelf life
HACCP[3]	Hazard Analysis and Critical Control Point, systematic preventive risk assessment for foods
CCP[4]	Critical Control Points, key actions in the HACCP system
MAP[5]	modified atmosphere packaging, replacing air in a packaging with an inert gas to extend the shelf life
GMP[6]	Good Manufacturing Practice
Liner	Plastic inner packaging of sacks
Active packaging	packaging material which interacts with the internal gas environment of the packaging, usually to extend shelf-life

4. Preface

In 2001, the Technology Circle (TeCi) was introduced within Friesland Foods, which was at that time called Friesland Coberco Dairy Foods. The aim for the TeCi was to make knowledge universally available in the organization, extending the borders of individual operating companies (OpCo's) and to give aim to the knowledge development within the company. TeCi Packaging was set-up to allow knowledge exchange within the area of packaging. This year, it has initialized seven subjects on which to bundle and extent the available knowledge. These seven subjects are active packaging, modified atmosphere packaging, moulding of plastic bottles, filling machines for plastic bottles, labelling technology, filling technology for flexibles and package leaking indicators.

This last one is the subject of this Bachelors Assignment.

An inventarisation about what OpCo's are interested in all of the seven subjects was also carried out. The OpCo's were also asked to prioritize the subjects. It showed that for the subject of package leaking indicators, there was a high priority for Friesland Foods Kievit, Friesland Foods DOMO, Friesland Foods Consumer Products, Friesland Foods Cheese, Friesland Foods Thailand and Friesland Foods International. Only Friesland Foods Western Europe claimed not to be interested.

Due to the nature of this assignment where information first of all needs to be collected and bundled, a lot of people where involved in this study. Roland ten Klooster from the University of Twente was not only a valuable source of information, but his enthusiasm about packaging in general was uplifting. Wietse van der Veen and Klaas Kuiper have opened many doors within the organization and their directions during the weekly meetings have helped me to focus on what's important. Especially Wietse has made a great effort accompanying me on some of the earlier meetings and also showing me around the production facility in Leeuwarden.

Other colleagues at Research & Development also proved a source of information and I have very much enjoyed my time with them, especially during lunch. I also would like to thank Bastienne Peelen (Kievit) and Afke Fokma (DOMO) in particular for their feedback and all other Friesland Foods employees which have contributed to this study, which I cannot all name in particular.

5. Introduction

Leak detection is a small niche within packaging which is used as a way to check the integrity of a given packaging with certain accuracy. Leak detection can be performed both offline or online and both destructive or non-destructive. Offline and online testing refers to whether the actual testing takes place as part of the process on the production line, or if the product is manually taken of the production line to test it for leaks. The product could after testing be placed on the production line again, but obviously not when the test method used was of a destructible nature. All products on the production line could be tested, or just one or more samples could be tested. When all products are tested, this is referred to as a 100% test.

100% testing of products has several advantages when compared with ordinary sample testing. The number of products which are not according to specification which end up at the customer can be lowered. When a series of faulty products is detected using samples, a whole production batch might be disposed of, whereas with 100% detection only the actual faulty products can be removed. Failing processes can more quickly be detected and resolved. On the other hand, 100% testing increases the costs of the machine park and might incur more breakdowns on the production line (when the machine for testing breaks down). Furthermore, the accuracy of testing might be lower than when tests are performed offline.

Leak detection can take place in a multitude of ways, all with different characteristics. Techniques can differ in terms of suitability for certain products and packaging, accuracy of the method, detection speed, costs etc.

This study focuses on in-line, non-destructive, 100% leak detection methods for food and beverage packaging. However, there is to a certain degree overlap with other leak detection methods which do not suit the above description, like offline methods or methods where a sample is taken of the production batch instead of testing the whole batch. Especially in the first part of this report some attention is also paid to these methods.

This report (and in fact, this study) can be roughly divided into two parts. The first part researches the different packaging and products which are currently used and/or produced by Friesland Foods. Furthermore, techniques for leak detection are researched and tried to match with the described product/packaging combinations. The second part of the report elaborates on the first part. In this part, a product/packaging combination where no leak detection is offered on the market and where there is severe interest from the different operating companies for leak detection, a functional design is proposed.

Chapter 6 discusses the product portfolio of Friesland Foods and discusses the details of the different packaging and products. These specifications are focussed on requirements for leak detection and are also introductorily to the subject.

In Chapter 7 leak detection techniques are discussed in general. A description of the workings of diverse methods is given. A distinction between pressure based and non-pressure based methods is made in this chapter.

Chapter 8 gives insight in suppliers of leak detection which arose from market research. It shows which methods based on what techniques are being offered and also gives more information on relationships between the suppliers.

The next chapter, Chapter 9 matches the information gathered in the previous chapters: techniques, suppliers and product/packaging combinations are presented in a matrix. This matrix can be used by the OpCo's when they want to have a starting point in researching if and what in-line leak detection method is suitable for their product/packaging combination.

Chapter 10 explains which legislation in the Netherlands can be linked to in-line package leak detection. It is included to explain to which extend in-line package leak detection is required by the government. It also discusses how future legislation in this area might develop.

In Chapter 11 one product/packaging combination is chosen to further elaborate on. The results from the first phase can be used as a starting point for companies wanting to research in-line leak detection methods for their products.

Chapter 12 shows some specifications regarding sacks and how these sacks are filled. This info is essential to the concept development. Multiple types of sacks are used within Friesland Foods, and this chapter tries to find common denominators as well as explain the main differences.

The main concept which has been developed is presented in Chapter 13.

Chapter 14 shows the test methodology to test the concept explained in the previous chapter. The results of this test are also presented.

Chapter 15 presents the conclusions and recommendations. What path should be followed to elaborate on the specific leak testing techniques, what inaccuracies might there be and how well does the proof of concept match a possible machine in a production environment?

Chapter 16 lists the used sources.

A list of figures has been added in Chapter 17.

Appendices can be found in chapter 18.

6. Products

This chapter describes which dairy products are produced and packed by the Friesland Foods. Some basic information is stated about these products and the packaging it is packed in.

6.1 Product portfolio

A brief description of the products which are packed is given in this paragraph:

6.1.1 Evaporated milk (Condensed unsweetened)

Evaporated milk is processed in such a way that about 60% of the water contents of the milk is removed[7]. It used to be an alternative before the age of refrigeration, since it can be reconstituted by adding water, while having a longer shelf-life. Milk fat could be replaced by vegetable fat[8]. In Malaysia for instance, palm oil is added. Sometimes used as drink milk.

The category of evaporated milk contains evaporated milk for the market (which is reconstituted by adding water or used in kitchen recipes), coffee milk and other products for coffee. Evaporated milk products should be stored at room temperature (max 25 degrees Celsius) and in the refrigerator after opening (max 7 degrees Celsius).

Packaging materials: cans, cartons, bottles, cups, bulk packaging and bulk cars.

6.1.2 Sweetened condensed milk

Condensed milk is, like evaporated milk, processed milk from which water is removed, but in contrary to evaporated milk, sugar is added[9] to improve shelf-life. Milk fat could be replaced by vegetable fat.[10]

Condensed milk can be consummated directly by adding water, is used in coffee to enrich and sweeten it, is used in kitchen recipes and is used by sweets manufacturers as a resource for the caramelizing process[11] and snacks. Condensed milk should be stored at room temperature (max 25 degrees Celsius) and in the refrigerator after opening (max 7 degrees Celsius).

Packaging materials: cans, bags, sticks, bag-in-box, bulk packaging and bulk cars.

6.1.3 Chocolate drink concentrates

Chocolate drink concentrates are a mix of concentrated milk, dairy and cacao paste[12]. It is used for hot chocolate products, where the concentrate is mixed with hot water in a vending machine. The product should be stored at room temperature (max 25 degrees Celsius).

Packaging material: bag-in-box

6.1.4 Chocolate drinks

Chocolate drinks contain a mix of milk parts, cacao or cacao paste, sugar and/or dextrose and stabilizers. The product should be stored at room temperature (max 25 degrees Celsius).

Packaging materials: cans, beakers, cartons

6.1.5 Liquid baby food

Liquid baby food is used for liquid products which are either directly or after adding water usable as baby food or infant food[13]. Liquid baby food should be stored at room temperature.

Packaging materials: small cartons, cans

6.1.6 Food drinks
This category includes food drinks, sports drinks and slimming drinks. These drinks are suitable for direct consumption. Storage at room temperature (max 25 degrees Celsius).[14]

Packaging materials: cans

6.1.7 Sour drinks
All fermented[15] dairy drinks: they contain full cream milk, semi-skimmed milk, dyes, aroma compounds, stabilizers and in some cases sugar. These products are poured into a glass and consumed or directly consumed from the packaging. Storage at room temperature (max 25 degrees Celsius).[16]

Packaging materials: carton packaging, cans, beakers

6.1.8 Powdered milk
Powder made from dried (dehydrated) milk solids. The low moisture allows for long shelf lifes and does not need to be kept refrigerated.

Packaging materials: sacks, bulk packaging, sticks

6.1.9 Cheese
Milk-based product, many different sorts.

Packaging materials: (semi) rigid plastic containers, flexible plastic containers

6.2 Relevant packaging and characteristics
This paragraph discusses the packaging materials which have been identified in the previous paragraph. Bulk cars are however not considered to be within the scope of this study.

6.2.1 Beverage cans
Mostly aluminium two-piece cans, although three piece can are sometimes also used.

6.2.2 Food cans
Mostly tin-plate three-piece cans, although two piece can are sometimes also used.

6.2.3 Cartons
A container, typically used for fluids, which is made from paperboard, (aluminium) and polyethylene.

6.2.4 Bottles
Glass bottles with crown cork or twist-off cap.

6.2.5 Cups
For portion sized coffee creamer etc.

6.2.6 Bulk packaging
Bulk packaging includes big bags for about 1000 kilograms of powder (flexible intermediate bulk containers), jerry cans and other forms of packag-

Figure 1: beverage can, food cans, cartons, glass bottles and cups

ing for business customers.

6.2.7 Sacks
There are several sacks in use within Friesland Foods. All sacks are used for powdered dairy products: whether they are lactose for pharmaceutical purposes or coffee creamer. Most sacks are meant for business-to-business and contain 25 kilograms, but other net weights are used. Some larger customers even require net weights which exactly match the ingredient batch size.

Roughly two kinds of sacks can be distinguished: sacks which have a barrier or not. Barrier sacks are used to extend the shelf-life by keeping oxygen out and in case of modified atmosphere packaging, keep the gasses in. Other, less sensitive powder products are packed in a liner without oxygen barriers. Often, these sacks are micro perforated to ease handling and palletizing. When these sacks are stacked, the weight of the stacked sacks will force air out of the head space, not only providing a less voluminous sack, but also making the powder behave more or less like a solid.

6.2.8 Sticks
For portion sized powder products.

6.2.9 Bag-in-box
Airtight container for fluids, plastic bag in a cardboard box.

6.2.10 Beakers
Used for liquids, generally aluminium seal.

6.2.11 Rigid plastic container
Mostly used for cheese.

6.2.12 Flexible plastic container
Mostly used for cheese or slices of cheese.

6.2.13 Sachettes
Foil based packaging, usually portion-sized.

6.2.14 Pouches
Foil based packaging, usually portion-sized.

Figure 2: jerry cans, sack with liner, sticks, beakers, bag-in-box, rigid plastic container, flexible plastic container, sachette and pouches

7. Leak detection techniques

In this chapter, various techniques which can be used for in-line leak testing are presented. Information on these techniques was acquired using market and patent research. More information about this research can be found in Chapter 8. A distinction has been made between both pressure based detection techniques and non-pressure based techniques. Pressure differences can be occurred in multiple ways and also measured in multiple ways. These are described in Chapter 7.1 and include proximity, force, compression, vacuum change, pressure change and acoustic techniques. All alternative methods are described in Chapter 7.2. These include gas, ultrasonic, visual, weight, x-ray and laser detection techniques. All techniques are described, relevant products which are suitable for the methods are given, the accuracy is estimated where possible (see "typical leak quantities" on the next page and other limitations are given in this chapter.

7.1 Pressure based

Pressure based methods either decrease the pressure in the product packaging in respect to the outside environment or increase the pressure. Changing could take place both by changing the pressure inside or outside of the packaging. The following matrix lists the pressure based methods and whether they are based upon increasing or decreasing the pressure, and whether these pressure changes are applied to either the inside or outside of the packaging:

	Pressure increase	Pressure decrease
Packaging	Proximity, Force, Compression	Pressure decrease
Environment	n/a	Vacuum change

Table 1: pressure, packaging, environment matrix

These methods are introduced in the next subparagraphs.

7.1.1 Proximity

Proximity technique is based on the lid deformation of food cans, beverage cans, glass jars and bottles with pop-button lids[17] that is caused by the internal pressure of the packaging. This deflection is being registered by using a continuous magnetic field, which monitors the distance to the metal lid. It does so by using Faradays law of induction[18], which gives the electromotive force in Volts, which is a function of the distance between the metal lid and the sensor. A continuous sample of this signal results in a merit value of the lid profile. Anomalies in the lid cause a lid profile outside the set boundaries, so the faulty packaging can be ejected out of the production line.

The use of this technique is limited to packaging which is sealed by a metal lid. Only this metal lid is checked for leaks and micro leaks should cause enough deformation within a short time period to be noticeable by this technique. Poor seal quality, where no leak has (yet) occurred is not detectable by this technique.

7.1.2 Force

Applicable for LN-2[19] (Nitrodoce Liquid Nitrogen) dosed, carbonated packaging. LN-2 is a filling technique, used for beverage containers[20]. The containers are led through two parallel belts which apply a force to the sidewalls of the container. A load cell measures the tension in the sidewalls caused by this force. When the tension is lower than a set critical value, the container is ejected.

Limited to LN-2 dosed beverage containers (including aluminium bottles, PET bottles etc.[21]). Accuracy is quite good, since carbonated beverage containers are used. The internal pressure quickly decreases because of the carbonation, even with small leaks. However, only actual leaks are detected, bad quality seals which are not (yet) leaking are not detected.

7.1.3 Compression

For use with plastic containers.[20] Comparable to force leak detection, but does not need internal compression. Plastic containers pass through two paralel belts, which compress the container. As a result, the head space of the container is compressed. A force measurement is taken when the system is released. When this force is under a critical value, the packaging is leak (or otherwise faulty, for example when its only half-filled) and ejected from the production line.

Limited to plastic containers and pouches. Possible to self-check by using a sensor when compression is just applied and another one after the pressure is nearly finished. Dual check is less sensitive to variables in production (fill levels etc.)[22].

7.1.4 Vacuum change

Vacuum change detection methods can be used for almost all packaging. The packaging is placed in a chamber (by a conveyer belt). Next, the air is evacuated out of the chamber. A sensor measures the internal pressure of the chamber. When pressure decreases too fast, a leak is present.

This technique is very universally applicable, even packaging which evacuated it self will less accurately give positive results. The method tends to be somewhat slow though, which is countered by being able to test multiple products at once or by using a caroussel. This will however give no definitive conclusion on what packaging is leak.

7.1.5 Pressure decrease

More or less the inverted version of the vacuum change method. Products where air is evacuated out of the packaging are checked for leaks by again placing the product in a chamber. The chamber is this time pressurised and monitored for pressure decrease. When a leak is present, the pressure will decrease. The longer the test period, the better accuracy is achieved.

7.1.6 Acoustic

Also known as TapTone[23]. This can be used for containers that do not show measurable lid deflection. It measures internal pressure or vacuum of packaging by using an acoustic signal. The signal is emitted by applying a tap to the top of each container. The resulting tone response frequency is directly related to the internal pressure. This frequency is compared to a base frequency and, when differing too much, the packaging is considered leak and removed from the production line.[24]

This technique is applicable to all containers which have a lid is (very little) deformed by internal or external pressure.

Typical leak quantities

In the field of leak detection, quantities are historically stated in terms of the number of millibar outflow from a one liter container in one second [mbar l/s]. The table below presents terms which are often used and their approximate value.

Leak size [mbar l/s]:	Trivial name:
10^{-2}	Watertight
10^{-3}	Vaportight
10^{-4}	Bacteria-tight
10^{-5}	Gasoline- and oiltight
10^{-6}	Virustight
10^{-8}	Heliumtight

Table 2: typical leak quantities

7.2 Non-pressure based

All detection techniques which are not based on pressure are listed in this paragraph.

7.2.1 Gas detection

This method is widely used and usable for many different kinds of (sealed) packaging. Before sealing the packaging, a tracer gas is inserted into the packaging. This gas could be either an air-native gas in a large intensity (such as carbon dioxide) or an alien gas, usually in a 1-10% intensity, such as hydrogen or helium. The packaging is then sealed and transferred to a leak test station. This test station is based around a highly sensitive sensor which can detect the inserted tracer gas. To speed up the process, it is conventional to insert the packaging in a vacuum chamber, where pressure differences will speed up the outflow rate of the tracer gas in case of a leak. When the sensor registers a value of tracer gas above a critical level, an ejector is used to withdraw the leak packaging from the production line.

This method can be used both in-line and offline and many suppliers offer leak detection solutions based on this technique. With this method, even very small micro perforation can be detected. Bad seal quality of non-leaking seals is not detectable. High costs and the addition of gasses to the product which do not add to the shelf-life of the product or otherwise does not make this technique attractive, but can sometimes be the only proper solution, since it can detect very small leaks.

7.2.2 Ultrasonic

Suitable for all kinds of seals. With or without the use of water as a medium, ultrasonic sound waves are transmitted onto the seal of the packaging. The reflected sound is an indicator of the seal quality.[25] Any foreign material (or air) trapped in the seal will cause more sound to be reflected and less sound to be transmitted through the seal. Systems using both one or two transducers are available on the market[26].

Limited to seals. It does not only detect leaks, but can give an indication of the general seal quality.

7.2.3 Visual

Applicable to semitransparent or transparent seals. Camera's take images of packaging on the production line, which are analyzed by computer for visual defects. Therefore, it can also detect other anomalies, such as a faulty print. However, it can only find leaks which are visible and big enough to detect.

7.2.4 Weight

Suitable for all kinds of packaging. When a packaging is leak and the contents of the packaging can escape, the weight is lessened. To some extend, this is measurable, meaning the packaging is leaking.

Very limited usability. Leaks may be located at the top of a packaging, where the contents will not get out. Leaks might be too small for the contents to escape the packaging, but big enough to let in air. Leaks might take place in the inner packaging (i.e. liner), which prevents the whole packaging from leaking, but is very unwanted. A significant amount of the contents needs to be escaped in a short time. Small leaks are hard to detect.

7.2.5 X-ray

Suitable for all kinds of packaging. This technique measures the fill level of the packaging. Analogue to the weight method, under filled packaging may indicate a leak.

Very limited usability. Leaks may be located at the top of a packaging, where the contents will not get out. Leaks might be too small for the contents to escape the packaging, but big enough to let in air. Leaks might take place in the inner packaging (i.e. liner), which prevents the whole packaging from leaking, but is very unwanted. A significant amount of the

> ## *Why are there no minimum detection numbers stated?*
>
> Minimum detectable leak size is very much dependant on the type of packaging, testing times etc. Technique A can be more accurate for a packaging than technique B, but for a different packaging, this might be visa versa. For more information, see Chapter 15.1

contents needs to be escaped in a short time. Small leaks are hard to detect.

7.2.6 Laser
Suitable for plastic foil and paper containers, which are either evacuated or pressurized. Similar to the acoustic technique, this technique is based on measuring the lid deflection. A laser beam is pinpointed at the lid and the refracting beam is analyzed.

Only suitable for pressurized or evacuated packaging which has a more or less flexible lid. This technique does not exclude cans explicitely, although the major manufacturer does not include cans in its description.

7.2.7 Ion Mobility Spectrometry
Suitable for all kinds of packaging. Using spectrometry, a 'fingerprint' of the air around a closed packaging is made[26]. This fingerprint is compared to fingerprints of individual packaging. When a leak is present, particles of the product (even a few parts per billion) will result in a different fingerprint. When these fingerprints do not match, the product can be ejected from the production line.

This testing method can also detect contaminations on the packaging (but not actually in the packaging with 100% in-line detection), such as cleaning fluid residus. This will also result in a different fingerprint and thus in rejection of the packaging.

This is apparently a fairly new technology, which is not yet proven on a industrial scale. Might become available in the near future for all kinds of packaging.

8. Supplier list

In this chapter suppliers of in-line leak detection devices are presented. The list is not intended to give a complete overview of the comperitors in the market, especially when vision techniques are concerned. This is because this technique relies on very much standard camera's which are combined with interpreting software. This market is relatively easy to enter.

The major suppliers for other techniques are quite complete: many companies resell products from one of these. These major suppliers are separately listed in the table. A key is also shown, which explains the abbreviations.

Key:	
GD	Gas detection
PR	PRoximity
US	UltraSonic
FS	Force
CO	COmpression
V	Vacuum change
P	Pressure decrease
W	Weight
X	X-ray
VI	VIsual detection
L	Laser
A	Acoustic

Table 3: abbreviation key

Name:	Web site:	Techniques:
Wilco AG	www.wilco.com	V, P, FS, US
Teledyne	www.taptone.com	CO, X, FS, L, A, PR
Leak Control	www.leakcontrol.nl	G
Dijkstra Vereenigde	www.dijkstra.net	A
Gullimex	www.gullimex.com	G
Witt	www.wittgas.com	G, V
Autonational	www.autonational.nl	V, P
Laco Technology	www.lacotech.com	G, VA
PTI inspection systems	www.ptiusa.com	V, US
Nolek	www.nolek.com	PR, G
PBI Dansensor	www.pbi-dansensor.com	G
Bonfiglioli	www.bonfiglioli.com	CO, V, P
Edixia	www.edixia.com	VI
DVC	www.oeminspectionmodules.nl	VI
Isotron	www.isotron.nl	VI
Simac Techniek	www.simac-masic.com	VI
ISRA Vision	www.isravision.com	VI
Bbull	www.bbull.com	P, V

Table 4: supplier list

9. Packaging - detection technique matching

On the next page, a table is presented where the in-line leakage detection techniques are listed horizontally and the packaging forms vertically. The resulting matrix shows whether or not a certain technique could be used for a specific packaging form. An O means it might be possible with in-line leakage detection machines offered on the market in the summer of 2008, whereas an X indicates it is most probable not.

The reason 'might be possible' is stated in the phrase above is that the applicability of many in-line leakage detection systems very much depends on the properties of the packaging and its production line. The packaging categories stated vertically are very broad, with a lot of variety within the category. To be able to give a good idea of what might be possible and what not, the table is given this form.

To overcome some of the major reasons why for example one carton might be appropriately tested by an in-line leakage detection technique and the other might not, footnotes have been added giving this information. Besides these packaging specific footnotes two general limitations why an in-line leakage detection method might not by suitable should always be kept in mind. These are the speed on the production line, which limits the testing time of the technique and the accuracy required. Sometimes these two factors also correlate: some pressure based methods gain higher accuracy when the test time is longer.

Other limitations to a technique and its applicability to certain packaging forms are stated in Chapter 7, where an introduction to these techniques is given, although this does not show the complete picture.

The table could therefore best been used as a starting point. One has a packaging where in-line leakage detection might be of interest and he wants to contact suppliers for quotations. At that point, it might be good to contact suppliers who alltogether cover all possible leak detection techniques for a packaging and meet with them to find out the limitations to such techniques, keeping in mind the specific packaging an in-line leakage detection system is looked after. From that point, quotations from different suppliers can be requested, well defining the requirements to the system and without ruling techniques which might be appropriate out.

New techniques (for example IMS) are being developed continuously and new ways of using existing techniques on a broader range of packaging are continuously developed. This table should therefore not be used as a definitive source for basing decisions on regarding in-line leak detection systems.

Key:	
O	In-line leak detection might be possible for packaging form
X	In-line leak detection most probable not possible for packaging form

Table 5: Key for table x+1 (next page)

	Proximity	Force	Compression	Vacuum change	Pressure decrease	Acoustic	Gas detection	Ultrasonic	Visual	Weight[12]	X-ray	Laser	IMS[10]
Cans	O[1]	O[1]	X	O	X	O[6]	O[7]	X	O[9]	O	O	X	O
Cartons	X	X	X	O	X	X	O[4,7]	O[8]	X	O	O	X	O
Bottles	O[1]	O[1]	O[3]	O	O[5]	O[6]	O[7]	O[8]	O[9]	O	O	X	O
Cups	X	X	X	O	X	X	O[7]	O[8]	O[9]	O	O	X	O
Bulk packaging[12]	X	X	X	X	X	X	X	X	X	O	X	X	X
Sacks	X	X	X	O[4]	O[5]	X	O[4,7]	O[4,8]	O[9]	O	O[8]	X	O
Sticks	X	X	X	X	X	X	X	X	X	O	O	X	O
Bag-in-box	X	X	X	O[4]	O[5]	X	O[4,7]	O[8]	X	O	O	X	O
Beakers	O[1,2]	X	O	O	X	X	O[4,7]	O[8]	O[9]	O	O	X	O
Rigid plastic container	X	X	O	O	O[5]	X	O[7]	O[8]	O[9]	O	O	X	O
Flexible plastic container	X	X	O	O	O[5]	X	O[7]	O[8]	O[9]	O	O	O[5]	O
Foils[11]	X	X	X	X	X	X	X	X	X	O	X	X	O

Table 6: packaging / leak detection matrix

[1] internal pressure necessary
[2] metal lid necessary
[3] applicable when concerning deflectable (plastic) materials
[4] only limited air permeability allowed
[5] only applicable for evacuated products
[6] applicable for pressurized/evacuated packaging
[7] tracer gas necessary
[8] only seal is checked, only applicable on packaging with seal
[9] requires (partly) transparent material
[10] (too) new technology
[11] possibly no leak detection required
[12] big-bags are too large for most leak detection methods

10. Legislation

Leak detection is of course a useful tool to incorporate in the production line for quality assurance. Some products and packaging can benefit more from leak detection than others. This does not only raise the question where the main priorities lie for in-line leak detection, but also where leak detection and other forms of integrity testing are obliged. The results of the research on the latter are discussed in this chapter. It focuses on European and in particular Dutch legislation concerning leak detection of packaging. Also, some attention has been paid to possible future legislation concerning leak detection.

10.1 Present legislation

10.1.1 The General Food Law

On January 1st, 2005, the General Food Law was established by the European Union[27]. It discusses several general issues for the food industry. Article 30 is of relevance here: it obliges food companies to systematically check the safety of their products. This means a safety system which controls the entire process is obliged. This safety system should be based upon the HACCP, the Hazard Analysis and Critical Control Point[3] system. Of course, dairy products are usually assigned a more than moderate risk concerning safety, because they can be spoiled easily.

Dutch legislation concerning this product safety is mainly consistent in the form of the “Warenwetregeling Hygiëne van Levensmiddelen”[28]. This law is a hat rack for several specific legislation. Mainly the “Warenwetbesluit Bereiding en Behandeling van Levensmiddelen” is of relevance to leak detection. It deals with the ways stocking, treatment, packaging and transport of raw materials of food products should take place. It also discusses machines and materials which are used during the process. It also offers norms for the existence of micro-organisms in food products.

These legislations therefore vaguely hint to when leak detection might be important, although it does not oblige the use of leak detection in specific. The HACCP plays an important role here; leak detection could be used to eliminate treats which are appointed in HACCP studies of a certain product/packaging combination. The next paragraph elaborates on this.

10.1.2 HACCP

The HACCP is an analysis system and therefore does not offer any predetermined rules which should be adapted in the production process. Instead, a HACCP study identifies possible safety hazards which allow key actions, knows as Critical Control Points (CCPs) to eliminate or at least reduce the hazards which are identified. Leak detection can be a useful tool in certain stages of the production process to address these CCPs.

Products which are most likely to have CCPs identified which could benefit from leak detection are products which are packed using active packaging[30] or modified atmosphere packaging[31] (MAP). Modified atmosphere packaging has air in the head space replaced with an inert or semi-inert gas, to allow for longer shelf life. Inert gasses are gasses which are not under normal circumstances[32]. Nitrogen is often used for food packaging in this respect, because almost all bacteria and fungi require the presence of either oxygen or carbon dioxide, thus preventing the food from spoiling. The inert properties of a gas like nitrogen also make sure no change in the taste or smell of a product will occur, since a chemical reaction needs to take place for a smell or taste to send a signal to the brain. Products which are packed using MAP are therefore all critical in terms of spoiling, since MAP does come at a cost. In this kind of packaging, leak detection is most critical and will probably be present in HACCP studies. Other less critical packaging where pH and Aw values (a magnitude for water activity) come into play might also benefit from leak detection.

10.1.3 Products with leak detection related CCPs
No products have been identified which have leak detection related critical control points. This means no immediate action is required.

10.2 Possible future legislation
Although it has become clear from the previous paragraphs that no definite legislation, either national or European, is present up the date of publication and since no legislation on leak detection is in preparation at this point, future legislation might include leak detection and integrity testing in general.

Both clear legislation and Good Manufacturing Practices (GMPs) are already implemented for medical packaging. In particular packaging for sterilised products and medical devices are to be tested for integrity. There is a good possibility that in the near future this legislation could form the basis upon where new food product packaging laws could be put in place. This is especially likely for the earlier discussed active packaging, MAP types of packaging and for vacuum food packaging.

11. Packaging selection

The previous chapters have sketched which leak detection techniques are available for what product/packaging combinations. For some packaging/product combinations no proper in-line leak detection machines are available, whether they consist of ready-made or tailor-made solutions.

Almost all combinations come with less than perfect solutions, but some combinations have better solutions than other, aside from no proper solution at all. In the second part of this report, a (better) solution is sought after for one of these combinations. This chapter explains why sacks, and especially micro perforated sacks, have been selected.

To rationalise this decision a formula is used on all packaging which are listed in the table of Chapter 9. A ‘grade from one to ten is given to the availability and quality of the in-line leak detection techniques. Next, the number of operating companies which make use of each type of packaging is determined. These numbers are used in the following equation:

*(11 - quality and availability score) * number of CoOps*

This results in final scores between 1 and 70. The higher the final score, the more attractive it would be finding a solution for a specific packaging.

Packaging	Q/A score	OpCo #	Total score
Cans	8	5	15
Cartons	6	4	20
Bottles	9	3	6
Cups	6	3	15
Bulk packaging	?	?	?
Sacks	3	4	32
Sticks	2	2	18
Bag-in-box	6	1	5
Beakers	7	3	12
Rigid plastic containers	8	2	6
Flexible plastic containers	7	2	8
Foils	1	1	10

Table 7: packaging form selection table

At the time when sacks where chosen to further investigate, the table above was not yet complete. Therefore, the decision was not taken as formally as is hinted, but turned out to be pretty correct anyway.

The most problematic sacks are the ones which are micro perforated. Focus has been on these sacks micro perforated 25 kg sacks, keeping in mind that a concept might be developed which also covers other volume sacks and barrier sacks.

12. Sacks specifications and the packaging line

In Chapter 6 different packaging and properties of them have been briefly discussed. Now a choice has been made to develop an in-line leakage detection system concept for micro perforated sacks, more in-depth information about these sacks and the packaging line is needed.

This chapter provides this information about sacks and micro perforated sacks in particular. Information was gathered from corporate information systems and by interviews.

12.1 Products and packaging

Most products packed in 25 kg sacks have a relatively long shelf life, although some powders are packed in sacks which have shorter shelf lifes. These mostly consider the Omega-3 powders. All 25 kg sacks are used purely business-to-business. Alternatively, sacks with different content sizes are used. Big bags for about 1000 kg are sometimes used for bigger clients. Most powders are packed in 25 kg sacks, both at Friesland Foods Domo as well as Friesland Foods Kievit. It is expected that the amount of 25 kg sacks as a percentage of the total production output will only increase in the future (see Appendix B).

All sacks (micro perforated or barrier) consist of two parts: a plastic liner with a paper outer sack which are glued together. Both the liner as the paper outer sack are often multi layer materials. The dimensions and further specifications of a typical sacks are added in Appendix A3.

Micro perforation is added to sacks at the packaging manufacturer to ease palletizing (excess air will be pushed out of the sack) and to allow the sacks to become more compact. Also, powders tend to behave more stable, like solids, when no excess air in trapped inside the sacks.

12.2 The packaging line

In figure 3 a schematic view of the packaging line for micro perforated sacks is displayed. After the sack is opened, the first stage is filling the sack with the powder. Measuring equipment is used to test if the contents of the sack is within target, but is not drawn in the schematic. The next stage is the folding of the sack, which is done by a preform coming down to the sack. The amount of head space can be decided, within reasonable limits, by lowering this device further to decrease head space. The same way, by stopping this device at a higher point, more head space will be available in the sack.

The third phase on the production line is to cut off the excess liner and paper outer sack. In the fourth stage the seal is applied to the liner through the outer sack. In a fifth stage, a stitching is added to the sack, since the seal in the liner alone will not keep the outer sack closed. The final stage is the palletizing of the sacks.

12.3 Problems

Under normal circumstances, no leaks will occur. In practice, the circumstances are not as ideal so that no leaks will occur. Leaks bigger than the micro perforation in the sacks can be problematic, since powder can escape from the inner liner. This is not visually detectable, because the outer sack keeps the powder from being visible. The sacks are used in business-to-business environments, where sometimes the paper outer sack is removed before entering the clients production plant. This is because the paper outer sack is a potential source of contamination. This is prevented (often in HACCP guidelines) by removing the outer sack on forehand.

No intensive studies have been performed on the sources of leak related problems with sacks, but an interview (see Appendix B) came up with the following most common issues:

- The glue between the liner and the outer paper sack, or even between the different layers of the paper outer sack, is too weak or not available. When this is the case, the sack might be filled with powder in between the liner and the outer sack. When the sack is filled appropriately there still might occur problems when the liner is sealed: the liner might have lowered so that the seal cannot be applied completely. Both cases result in very severe leaks.
- During the production of the liner, air is blown through the liner so the sack will easily open. When this stage in the production of the sack has failed, the liner might be too sticky to open, again resulting in filling the sack between the liner and the outer sack.
- The bottom seal in the liner, which is provided by the packaging producer might not be at the right spot. The seal might have been moved to the top of the next liner, disallowing the liner (and indeed, the whole sack) to be filled

These issues are quite severe, but often not visually detectable from outside the sack. Here a leak detection system might be useful. Also smaller leaks might occur, but are less common. Usually these minor leaks occur in the seal, especially when the powder is at the sealing point, weakening the final seal or not disallowing the seal to be completed.

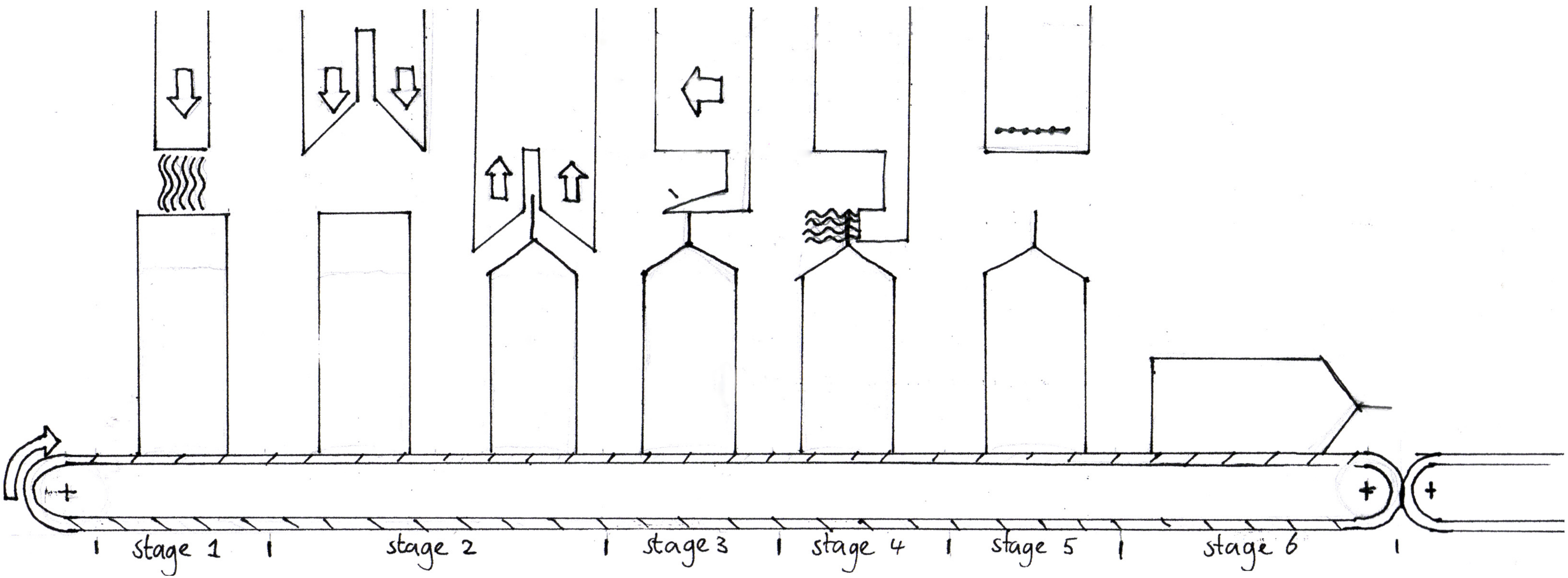

Figure 3: Schematic view of the production line for powder-filled sacks

13. Concepts

In this chapter, two concepts for 25 kg sacks which were generated are discussed: one concept based on X-ray and one concept based on applying a standardized force on the head space of the sack.

Priority has been given on the second concept, since applying X-ray is something that is also researched by suppliers as a possibility. Furthermore, the head space concept was more promising and could more easily be used for both barrier sacks and microperforated sacks, instead of just micro perforated sacks.

13.1 X-ray seal scan

Given the most common problems which are stated in the previous chapter (too little glue for good adhesive properties, too sticky liner to open liner, misplaced bottom seal), no real extensive leak detection might be necessary. When just the place where the seal should be is checked for integrity, these three problems might be overcome.

This technique might be unreliable, since wrinkles and the paper outer sack might have influence on the results of the test. When only very big leaks are considered, this concept might be a good solution for micro perforated sacks.

13.2 Head space force system

13.2.1 Workings of the concept

Figure 4 on the next page shows a schematic view of the concept. The concept is based on applying a standardized force to the head space which is available in the sack, and then monitoring how this force decreases over time, due to the outflow of air through the micro perforation (and through possible leaks).

The system is integrated on the production line by placing it on the conveyor belt just after the sewing of the sack and before the sack is pushed over to be palletized. Call out 1 shows a piece of the conveyor belt just after sewing. A sack is than transported onto conveyor belt 2, which halts for a few seconds when sack 3 is positioned between two halves of the pressure applying device, 4 and 5. Device 4 and 5 are shaped in such way only a force can be applied to the head of sack 3, in the area where no powder is blocking the way and only air is available.

On device 4 and 5 are placed grating 6 and 7, which will allow air to flow out through the micro perforation and through possible leaks, without blocking it, like a solid would. Device 6 and 7 are than moving towards each other, effectively pressurizing the sack until a predefined force is registered by force sensor 8. From that point, devices 4 and 5 keep a fixed position and measurement will start.

After a fixed time period, measurement is stopped and the decrease of force over time is analyzed by computer 9, which depending on the slope of the line decides whether the sack has passed or failed the test. After this, conveyor belt 2 will transport sack 3 onto the continuously moving conveyor belt 10. Here, ejector 11 is placed, which by using ejector rod 12 will either push a failed sack out of the production line into ejection box 14 or let sack 13 continue to move along conveyor belt 10 to conveyor belt 15, which leads to the palletizing station.

The palletizing process might improve slightly, since the pressure applied to the head space will draw air out. Less air in the sack in turn will make the powder behave more like a solid, which eases palletizing. It is questionable if enough air is pushed out to have a real effect on palletizing. The concept does not only test for leaks, but also applies pressure to the

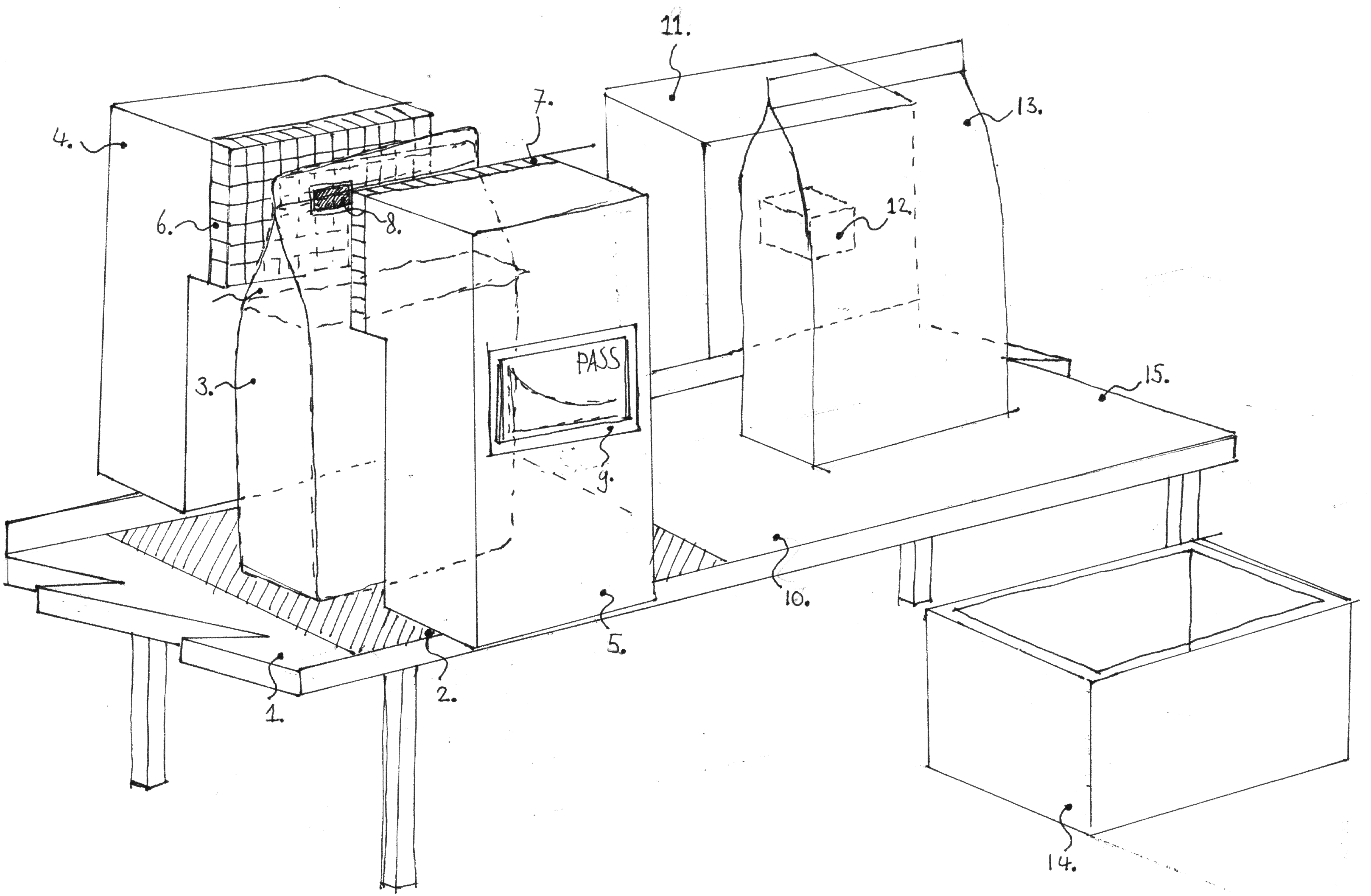

Figure 4: Workings of the head space pressure concept

sacks, effectively testing for weak seals too.

The concept requires the production line to run sequential instead of continious. This might be overcome using a variation as described in Chapter 13.2.2 or might not be a problem at all, since filling of the sacks will often take place sequential anyway.

13.2.2 Variations of the concept

Variations of this concept might be considered. For example, devices 4 and 5 might not stop at a predefined force level, but at a predefined distance from each other. This might however introduce new problems when head space differs much between sacks.

Another alternative is replacing the pressure devices 4 and 5 by two belts compressing the head space of the sack, more or less like was explained for the compression technique in Chapter 7.1.3. Two sensors, at the start and end of these belt, could register how the force would decrease over time and use this information to decide whether or not to let the sack pass or fail.

This alternative would not require the sack to stop moving on the conveyor belt, but might introduce new problems regarding accuracy for example. It does however offer more freedom when a longer measuring time is required than is available with the proposed system.

14. Proof of concept

To find out if the concept can work in practice, some critical points of the concept have been appointed. When the concept fails completely on one of these points, it will be near-impossible to create a machine based on this concept that can be used in a production environment. Tests are performed on both micro perforated and barrier sacks.

In this chapter these critical points are described, a test environment is proposed for each of these critical control points and finally the outcome of the tests is given. Conclusions about the testing are formulated in the next chapter.

14.1 Head space

14.1.1 Critical point

To use the concept, a certain amount of head space needs to be present in both the barrier and micro perforated sacks to be able to get a correct measurement. Barrier sacks will only require a very small amount of gas (like air or other gasses which have been inserted in the sacks for Modified Atmosphere Packaging) to get a correct measurement.

Micro perforated sacks on the other hand will lose some of their head space over time, especially when pressure is applied to the packaging during leak testing. It is therefore crucial for the concept that the amount of head space required during testing does not exceed the head space that is currently available in the micro perforated sacks, or at least not by too much.

However, it remains unsure how much head space is actually required for a correct measurement. Therefore, a test is proposed where the outflow of the micro perforated sacks can be determined in a very rough manner.

14.1.2 Test setup

A micro perforated bag is fully filled with air and then sealed completely. The sack is then placed under the test bank of a compression machine, making sure the micro perforation is not blocked. The machine is setup to apply a preload of 1000N. After that, the compression bank lowers the compression plate until half of the distance of just after the preload is present between the plates. A speed of 5 mm/min has been used. The force occurring from the compression should at the end of the test be at least 1000N, the starting point of the test.

This test not from optimal, but due to the software of the compression test bench this is best way to perform this test in a short time. Ideally, the force was kept constant and the distance between the plates of the compression bank should be the dependant variable. It is further-

Key values used in this chapter

The table on the right sums up all hole sizes and the terms used for them in this chapter. Hole area is used as a unit instead of the [mbar l/s] used in Chapter 7. This is because for micro perforated sacks the outflow is not important, the individual holes should just not be big enough to allow product to move out.

Device:	Hole diameter: (10^{-6} m)	Hole area: (10^{-8} m^2)
Factory-made hole in microperforated sack	140	1,54
Total of hole size in microperforated sack	24 x 140	37,0
Injection needle	600	28,27
Sewing needle (cold)	260	5,31
Sewing needle (hot)	800	50,26

Table 8: key figures used in this chapter

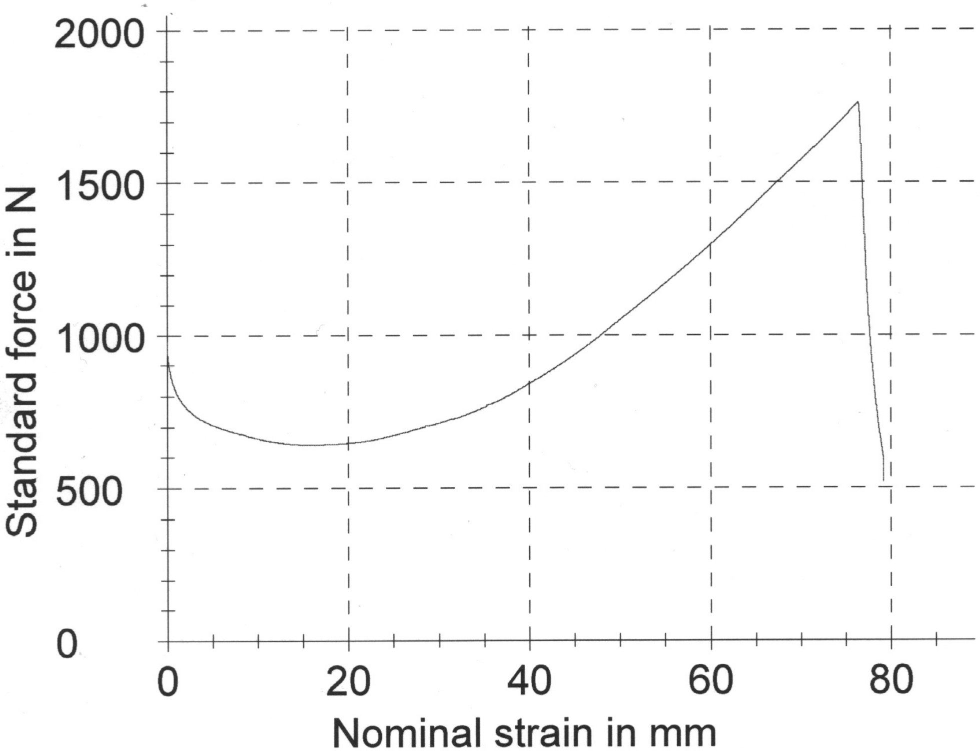

Figure 5: Force / strain graph for determining outflow rate

more very difficult to determine the volume of the sack after filling, for example in a water bath, since the micro perforation will ensure a continuous deflation of the sack. To overcome these problems, a broad margin has been used on the values which calculate the outflow and the worst-case scenario figures where chosen.

14.1.3 Test outcome

Figure 5 shows the force occurring from the compression as a function of the distance between the plates of the compression test bank. At a distance of zero mm a preload force of 1000N is present. During the first 15 mm lowering of the compression plate the force decreases, because of the settling of the sack. Thereafter, the force continuously increases over time, until about 1750N. At that point, the force causes the sealing of the sack to burst, resulting in a immediate drop of the force.

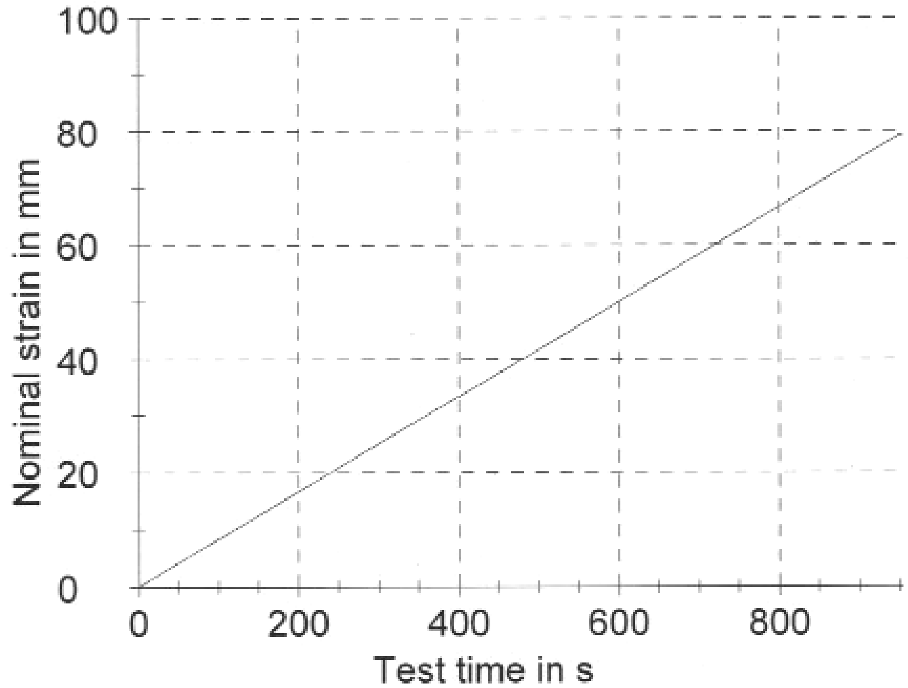

Figure 6: Strain / test time graph for determining outflow rate

Figure 6 shows the distance of the plates as a function of the test time. From this graph, it can be observed that the sack has lasted a little more than 900 seconds before the burst occurs. Considering the distance between the plates was a little more than 200 mm at the start of the test (at a preload of 1000N), the sack is compressed (and deflated) to:

*((200 - 75) / 200) * 100% = 62.5%*

Which means a 37.5% compression rate before bursting. At this point, the force is well beyond the initial force of 1000N. The contents of the bag is 50 liter (+/- 25%), meaning the volume of the bag is between 37,5 and 62.5 liters. Taking the worst case scenario, 62.5 / 2 = 31,25 liter air has escaped from the sack.

The outflow rate can then be calculated as follows:

outflow = volume decrease / time = 31,25 / 900 = 0,03472 l/s

Considering a measuring time of about 15 seconds will be necessary to accurately measure for leaks, a total of 15 * 0,03472 = 0,5 l will escape during measuring. This is, in the worst case scenario, the least amount of head space which is required for micro perforated sacks. This is well within reach of the actual head space which is present during the current filling process of the sacks.

The slow outflow rate also has a negative side: easing palletizing (see Chapter 13) will probably not happen with this outflow rate.

Figure 7: Test bank setup

14.2 Leak variance

14.2.1 Critical point

The next critical control point which is tested is whether or not a substantial leak can be detected. To be able to determine what a substantial leak is, the problems which have been described in Chapter 12 should at least be accounted for. Therefore, a small leak should be made in the liner of known size. Additional same-sized leaks should be made until a significant difference can be witnessed. Therefore, first a method to determine a standard leak size is developed.

14.2.2 Puncture devices

To be able to create same-sized leaks every time, a puncture device should be used which as sufficiently sharp to create nice, clean edges. Furthermore, it should eventually become cylindrical, so the hole size is not depending on how far the puncture device is inserted in the liner.

Figure 8: Injection needle and sack under the compression bank

The smallest device which meets these demands which was available is a very thin sewing needle. For bigger holes, an injection needle was available (see Figure 8). To determine the hole size, a microscope was used. The microscope was also used to check if smaller hole sizes could be achieved by pre-heating the needle.

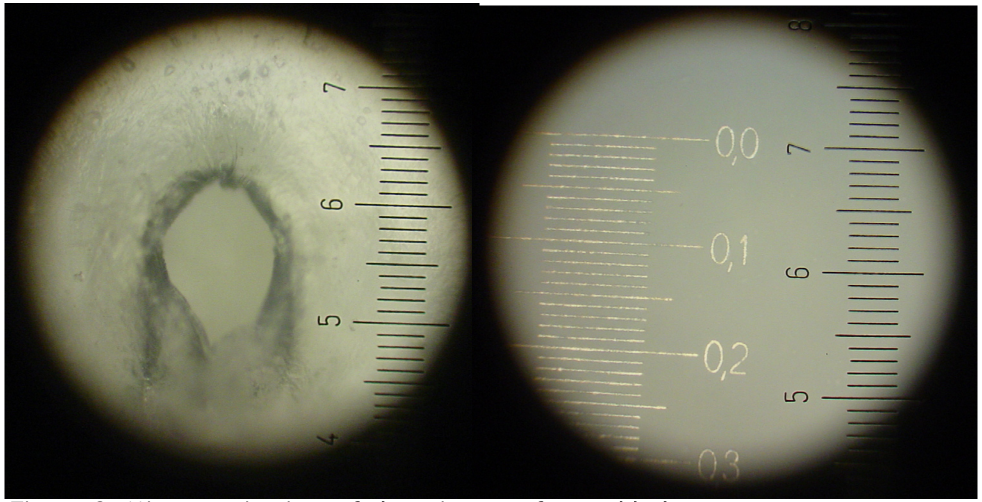

Figure 9: Microscopic view of the micro perforated hole

Figure 9 shows the hole which is introduced in the sacks by the sack manufacturer. The diameter of the hole is about 1.1 units, which corresponds to about 0,14 mm or 140 microns (see conversion picture on the right). This value was measured so the holes which are created later could be compared to the value of the micro perforation already present.

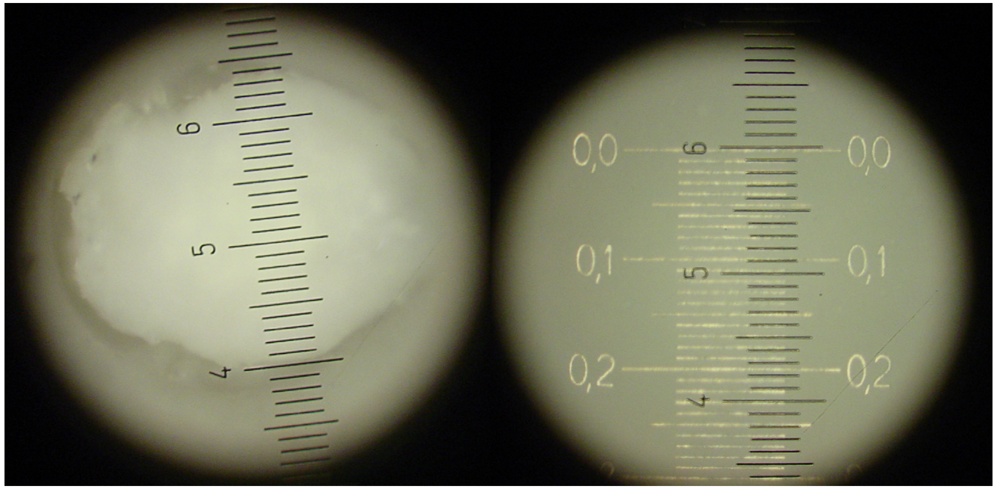

Figure 10: Hole punched through with a cold sewing needle

Figure 10 shows the hole which was created using the cold sewing needle. The diameter of this hole is about 0,26 mm or 260 microns. The hole quality is very much comparable to the holes of the micro perforation already present in the liners. The injection needle pretty much gave the same results, but larger. The average hole created by the injection needle was approximately 0.60 millimeters or 600 microns.

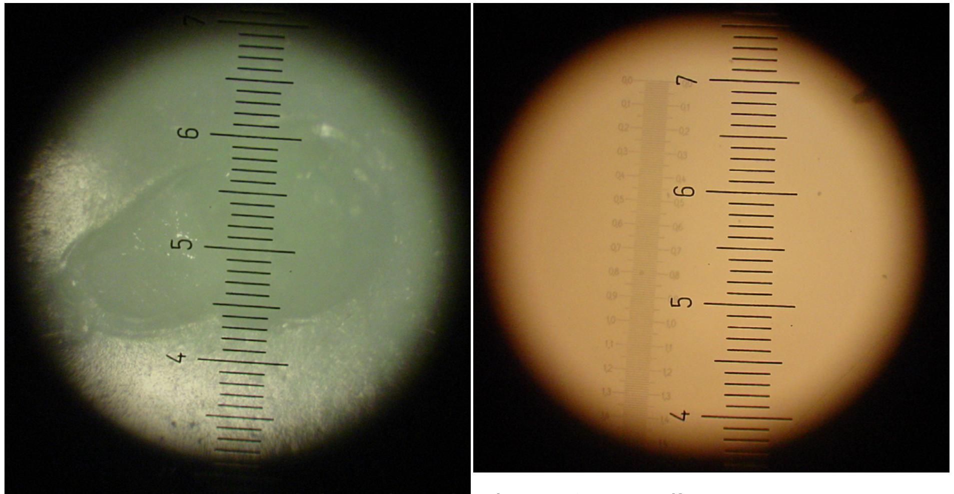

Figure 11: Hole punched through with a hot swing needle

Figure 11 shows what happens when the needle is heated (using a small gas burner. In theory, the heating would result in a smaller, neater hole. Instead, due to unsteady hand and melting of the liner around the heated sewing needle, the resulting hole is much lower. The edges are neater, but the general form is much less like a circle than with the cold needle. The resulting hole is also a lot bigger than the hole created with the cool needle (see the scale on the right of figure 11).

Since the micro perforation in the micro perforated sacks is already 140 microns per hole, the 600 micron injection needle is best suited to puncture the micro perforated sacks. For the barrier sacks, the smallest puncture device was chosen: the cold sewing needle.

14.2.3 Test setup

An air filled, sealed barrier sack is placed under the compression bank (see figure 9). A force of 1000N is applied to the sack. After the sack has settled, meaning the force will become more or less stable, a 260 micron hole is punctured in the sack. The test is repeated five times.

14.2.4 Test results
Figure 12 shows that all five sacks have settled after about 120 seconds. Thereafter, the sack is punctured. Due to the sewing needle not being perfectly cylindrical over its lengths, the length which the needle is punctured impacts the hole size. Therefore slight variations between the sacks are present. A clear buckling is present at the point of punctuation and the slope of the line is clearly more downward.

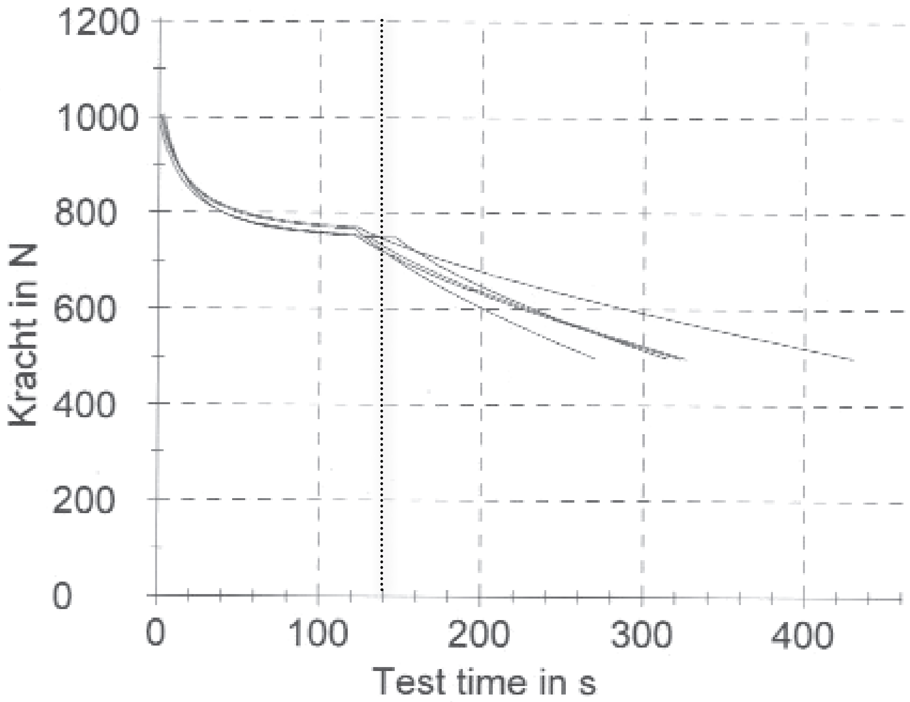

Figure 12: 5 barrier sacks punched through with an injection needle after 120s

14.3 Accuracy testing barrier sack
14.3.1 Critical point
It has become clear in the previous test that there is indeed a significant difference in force to be witnessed when a sack is made leak. However, there also seems to be quite a long settling time before the force becomes stable. Therefore, the next critical point to be tested is whether or not a difference can be measured during a reasonable time in a production environment. Also tested is whether or not the applied compression force plays a role in the accuracy and/or the settling time of the sack.

14.3.2 Test setup
A air filled, sealed and intact barrier sack is placed under the compression bank and a load force of 1000N is applied. During 300 seconds, the decrease in force is measured. This is repeated for sacks with 1,2 and 3 holes of 260 micron.

To test what the influence of the magnitude of the load force is, this whole test is repeated with a 2000N preload. During this test, also 1,2 and 3 holes of 260 micron where used and the test was aborted when 300 seconds had been reached.

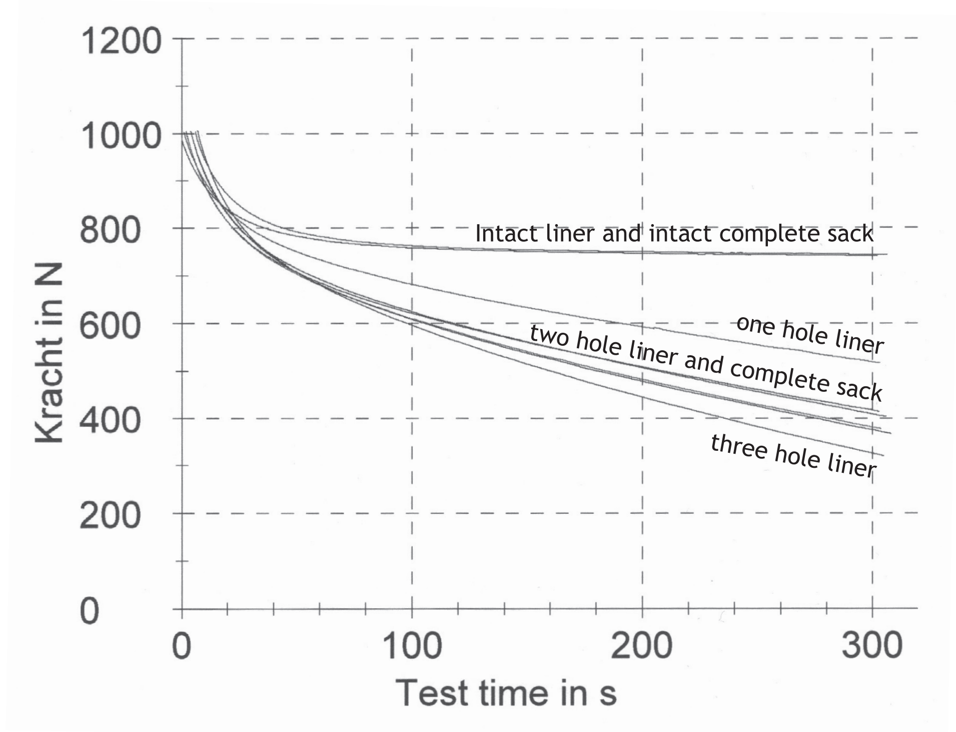

Figure 13: Leak barrier sacks under 1000N preload

14.3.3 Test outcome
Figure 13 shows that there is indeed a measurable difference between the intact sack and the sacks with 1,2 or 3 holes. In the graph, not all lines start off at exactly the same point, giving a somewhat distorted view.

However, it is clear that at about 40 seconds a very much measurable difference is present. The difference between no holes and one hole is greater than the difference between one and two holes. In figure 14 the results for the same test using a preload of 2000N are presented.

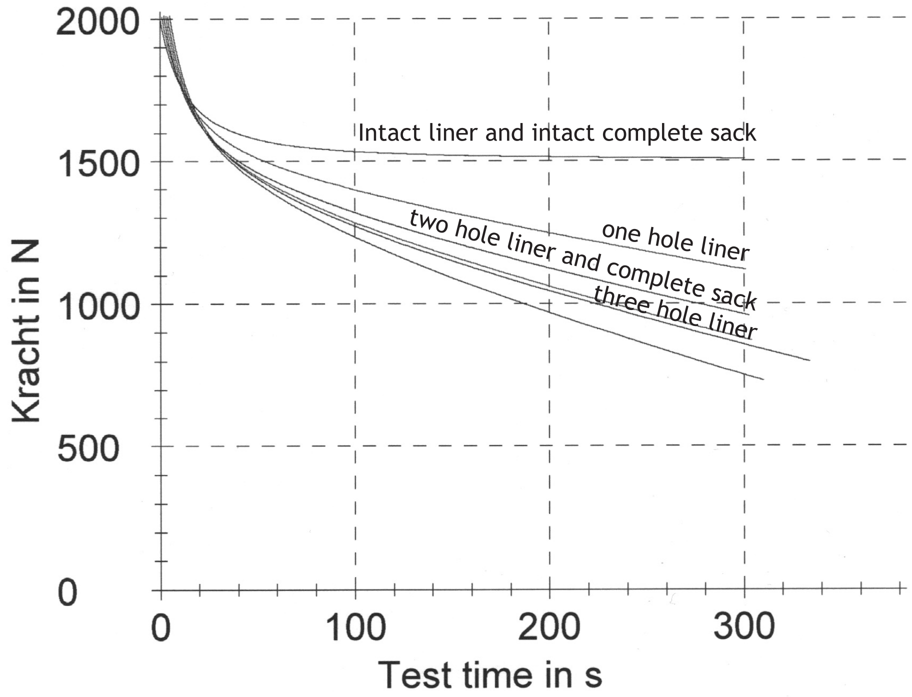

Figure 14: Leak barrier sacks under 2000N preload

Because the test was carried out using only the liner and not the complete liner in the sack, during this test also a complete sack including the paper outer sack was tested under the same circumstances, without any holes and with two holes. The top two, colliding lines in figure 11 show that this does not make any difference for the intact sack. The second and third to last lines show that the same can be said about the three hole sack.

In figure 13 the graphs are again somewhat distorted, but this time somewhat less. A clear difference is present at about 30 seconds, but one could imagine that at about 20 seconds a result might also be measurable. Again, a greater difference between no holes and one hole exists than between one and two holes.

14.4 Sack Fmax

14.4.1 Critical point

From the test explained in 14.3 one could conclude that there might be a positive change in settling time and / or the slope of the lines when the initial load force is increased. There is of course a maximum to increasing this load force. Therefore, the maximum load, the Fmax, is determined. This is the points where the sack tears.

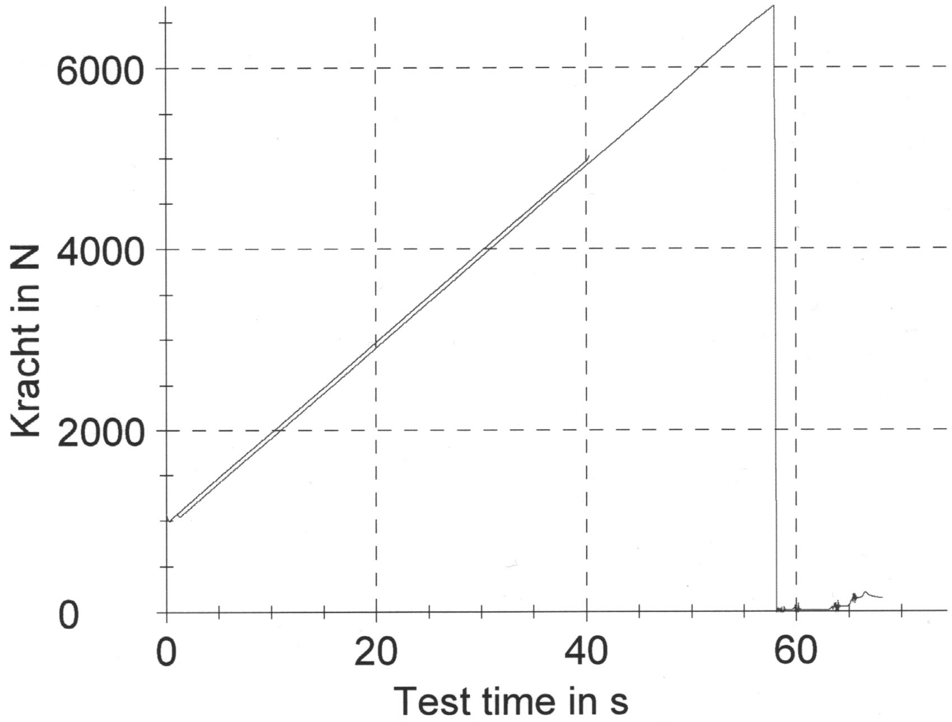

Figure 15: Micro perforated sack Fmax

14.4.2 Test setup

To determine the Fmax, both the micro perforated sack and the barrier sack have been fully filled with air and the fully sealed. No leaks have been made in these sacks. A preload of 1000N is applied to both sacks and 50 N per second is added to this preload, until a the sack bursts.

14.4.3 Test results

Figure 16 shows the results of the barrier sack and figure 15

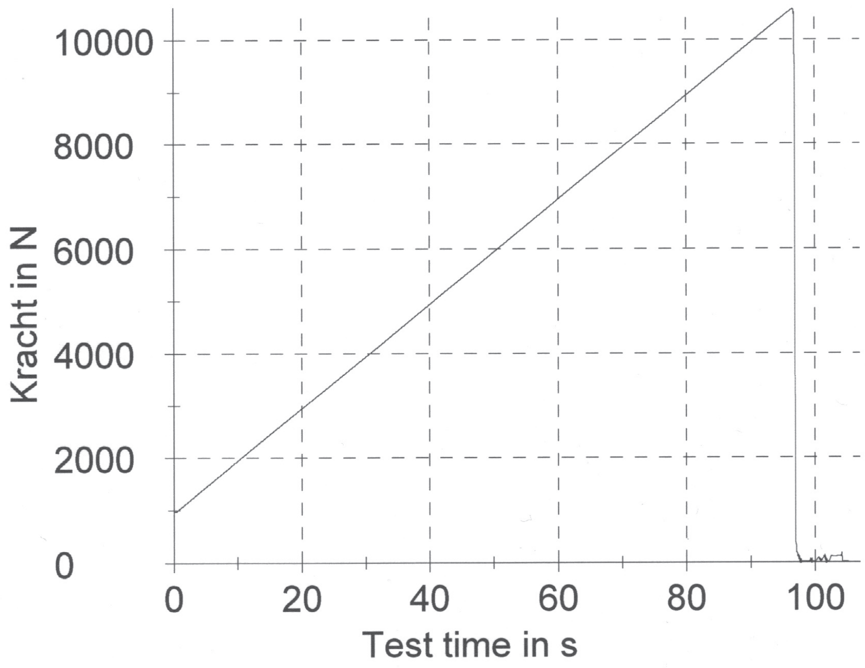

Figure 16: Barrier sack Fmax

shows the results of the micro perforated bag. The barrier sack bursts at about 10500N and the micro perforated sack at about 6500N. This shows that there clearly is some margin when a force of 2000N is used.

14.5 Accuracy testing micro perforated sack

14.5.1 Critical point

Like the barrier sack (Chapter 14.3), also the accuracy of the leak size of micro perforated sacks was put to the test. Because many 14 micron holes are already present in the liner and since the leak problems identified in Chapter 12 are quite severe, it was decided to test whether one or more 60 micron holes could be detected within a reasonable time.

14.5.2 Test setup

The test setup is identical to Chapter 14.3 (1000N preload).

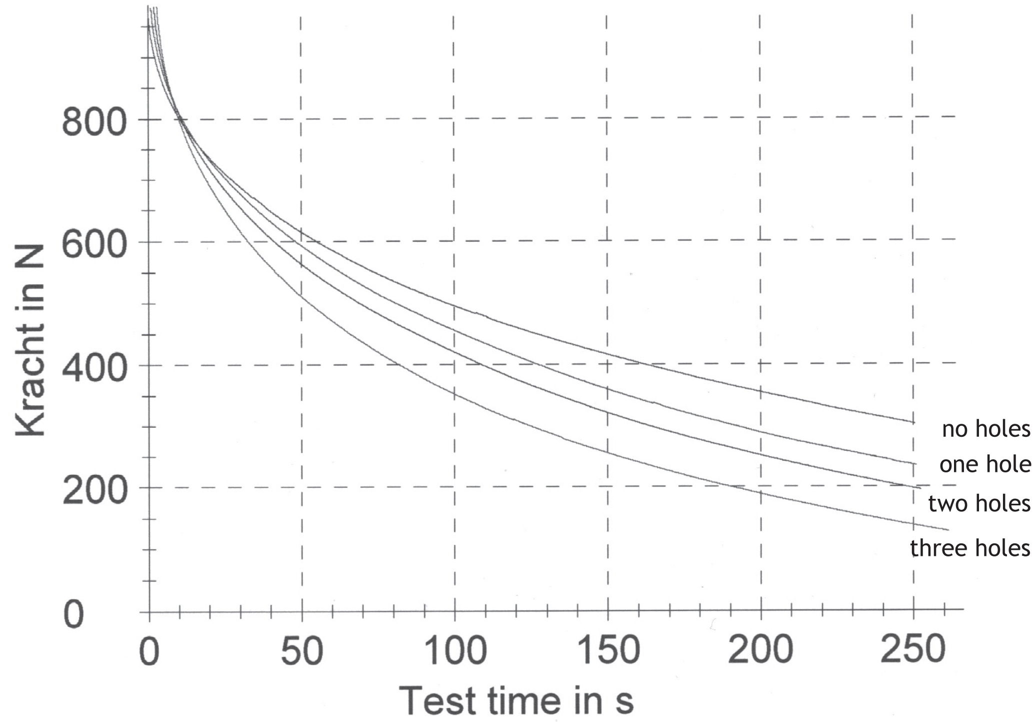

Figure 17: leak micro perforated sacks under 1000N preload

14.5.3 Test results

Just as with the barrier sacks, a difference between no holes, one, two and three holes can clearly be seen. After about 25 seconds the difference manifests itself, due to the settling time which incurs quite a big downward slope (see Figure 17).

15. Conclusions and recommendations

In this chapter the conclusions and recommendations of both the research phase as well as the concept development phase are discussed.

15.1 Market research

In Chapter 9 a table was presented, linking in-line leak detection techniques with packaging forms. A lot of remarks has to be put under the table, since many techniques demand specific properties from the packaging to be able to work properly. There is a great difference in the minimum leak size which could be detected.

The figures which are given are very unspecific. This is because almost all the information which was gathered had suppliers of leak detection systems as a source. No literature was available to check the claims. Especially claims on minimum detectable leak size are often only the case under perfect conditions. This table should therefore be used as a first guide to which leak detection techniques might be appropriate for a kind of packaging. It cannot provide much more information than this starting point, since a great many of variables should be taken into account when considering which technique to choose. This starting point however is valuable, since when quotations on a leak detection technique are asked for, one should not limit itself to one kind of leak detection technique. It is useful to ask for quotations from different companies which offer different techniques which might be used for in-line leak detection.

Alternatives to in-line leakage detection systems should also be considered. Might off-line detection be good enough in a particular situation?

In Chapter 11 a priority mark has been given to each packaging type, depending on the number of available techniques, the quality of these techniques and the number of operating companies which might benefit from a new concept. This has lead to choosing sacks (and especially micro perforated sacks) as the subject to focus the design phase on.

15.2 Concept feasibility

15.2.1 Head space availability

The total amount of head space which is required for a micro perforated 25 kg bag turns out to be about 0.5 liter. This value is probably even lower, since worst case scenario values have been used on values with large tolerances. No proper equipment was available to easily and precise estimate the total volume of air inside the bag. Another reason this value is probably lower, is because the load force could not be kept constant while testing. The load, which started at 1000N increased up to a final value of about 1750N. This higher load would increase stress on the liner, causing deformations which makes the outflow rate of air seem higher than is actually happening.

Despite this pessimistic calculation, a value of about 0,5 liter of total head space required for measuring is very much achievable. The present amount of head space is estimated to be anywhere between 4 and 8 liters.

15.2.2 Leak variance

Observance under a microscope shows that the tested sacks have a micro perforation which is close to a circle form with a 140 micron diameter. However, different types of micro perforated sacks on the market have different sizes (and forms?) of micro perforation.

The test made it clear that different slopes occur when even a small leak is present in the sacks. For barrier sacks, even when only one 260 micron hole was punched through the liner, a clear difference in force could be witnessed.

The test did however also show that quite large settling times are required before the force reaches a stable value. In the case of barrier sacks, about 2 minutes is needed. Micro perforated sacks never reach a stable value, since air is constantly leaking out. Given the small time there is available on the production line, this might prove problematic for the feasibility of the concept.

15.2.3 Leak accuracy barrier sacks

The previous test has showed settling time might be problematic. A follow-up test was performed to see which accuracy could be achievable for barrier sacks. It turns out that about 40 seconds are needed before a clear difference between a non-leaking sack and a leaking sack could be measured under a load of 1000N.

A second test with a higher load (2000N) show that better results are achievable. A test time of about 20 seconds seems possible to detect the sack with one extra hole of 600 micron. When more substantial leaks are present, the test time might drop a little, but not by much.

15.2.4 Fmax

The previous test indicates that there might be a positive connection between the load size and the required measuring time. The load is however bounded to a few specifications, of which one is the maximal load which can be applied before a burst occurs.

The test results show that this value is about 10500N for barrier sacks and 6500N for micro perforation sacks. This mean that the load might even be set higher than the 2000N used in the previous test. The fail point of the sacks seem to be just before the seal, here the stress in the liner is most high. The seal itself seems to be properly strong.

15.2.5 Leak accuracy micro perforated sacks

The results for the micro perforated sack are quite comparable to the results of the barrier sack. In about 25 seconds a measurement can be done which can scout one 600 micron hole extra in a micro perforated sack.

In the production environment, most micro perforations will probably be blocked by the powder substance inside, which will make the impact in the graph of a leak more visible.

15.2.6 General recommendations

Testing proved the concept is almost certainly feasible for micro perforated sacks where large leaks due to filling failures (described in Chapter 12) are present. When really large leaks are present, the force might not even be able to reach the target (for instance 1000N). Therefore, a safety feature should be incorporated in the system which rejects the sack when the load force cannot reach the target load in a certain time or when a certain distance between pressure plates has been reached, without the load force reaching its target.

The applicability for barrier sacks, where small leaks will probably be problematic is less sure. The testing time including the settling time of two minutes will probably be too large when really small leaks need to be detected. If small leaks are less critical however, or when test time are allowed to be a lot longer, this concept might be a valuable alternative to gas detection methods that are now available and relatively expensive. Tests where parameters such as the allowed test time and leak size are defined should be done to more precisely determine the feasibility of this concept for barrier sacks. Big leaks, for example due to the filling failures which were explained in Chapter 12 for microperforated sacks, should also be relatively easy to discover in barrier sacks.

The laboratory tests might not be accurate for production environments. Micro perforation or even leaks might be blocked by the testing equipment or the powder substance inside, which might result in false positives or misses. It might also have an impact on the accuracy of the tests, requiring longer test times. Also, multiple small leaks where no substance can leak through will in a production environment probably be rejected. This will however not be very common, since under normal conditions leaks besides the standardized micro perforation will not occur. Multiple small leaks will therefore still indicate something is wrong in the production process, although the specific sack might not need to be rejected.

Further research on the feasibility of the concept should also include research on the exact failures which cause the leaks and how many times they occur. This research can provide insight in the limitations of the proposed concept. It is not clear for example if sacks which have been filled inbetween the outher sack and the liner and then properly sealed can be detected. The liner might not be leak, although a filling problem is present. One might predict that in the process of filling in this case, the liner will move down, making a seal impossible and therefore making the failure detectable. This prediction should however be thouroughly tested. Another point which needs special attention is what happens if a leak is present, but where air cannot escape due to the product blocking it. For micro perforated sacks, this might be far less a problem than for barrier sacks. Again, this should be tested properly.

There are some options which might improve the results which have not been tested. Only one kind of micro perforated sack has been tested, but there are more sacks available on the market with different hole sizes and different number of holes. To reduce settling times, a preload might be put on the sack. The position of the sack during the tests has been carefully chosen so the micro perforation would not be blocked by the testing equipment. One could also use a grid like component to apply the force to the sack, so possible leaks and micro perforation will not be blocked.

Because the concept applies a pressure on the sack, not only leaks can be discovered, but also weak seals which could become leak during for example transportation can be discovered: when they are pressurised they will break and will be detected as a leaking sack and removed from the production line.

15.2.7 Overall concept conclusions

The concept seems feasible for the products which it was designed for: micro perforated sacks. Relatively small leaks can be detected, but detection of smaller leaks requires a longer testing time, which might not always be an option. Therefore, the concept might not always be feasible for barrier sacks. Settling time is relatively long. A fair balance between testing time and hole size detection limit should always been sought with this concept.

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17. List of figures

18. Appendices

friesland foods

Specificaties verpakkingen	**VOA**	**T482004**
	Status	Draft
Supply Specifications	Date	27-02-2007

Product	:	Bag 25 kg (Pinch bag closure) 3 Ply
Supplier	:	Bischof & Klein 402429
Order dimensions (mm)	:	580x960x170
Location	:	PUB
Quality	:	Kraftsackpaper, SCL paper and a PE / EVOH / PE liner
Linked specifications	:	**VOA C482001 / M132002 / D339**
Pallet size (l x w mm)	:	1200 x 1000 (CP1)
Clustering (quantity)	:	15
Quantity/pallet	:	2000
Weight/pallet (kg Net)	:	682
Stacking pattern	:	Bundles of approx. 15 pcs.
Overhang	:	None
Covering	:	Pallet
Wrapping	:	2 x belt
Storage conditions	:	Between 15-25°C and 40-60%RH (B+K storage instructions)
Shelf life	:	Max. 1 year After 1 year the processing unit will decide whether the material is still usable

Cause: New
Author: M. Molman

Note

Printing, number, prize and delivery time in consultation of the concerned purchase department.
Entirely or partially not meeting up to these specifications can cause rejection and return of the total supply. Deviation which cause in to problems in use or not sellable products lead to rejection. The supplied material is produced of raw materials, which meet up with the Dutch packaging and durable article resolution. Modifications in composition and or the production process can only be made after written permission of the buyer. The purchase conditions are undiminished in use on all our transactions.

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Specificaties verpakkingen

Material Specifications

VOA	**M132001**
Status	DRAFT
Date	27-02-2007

General data

Product	Bag 2 Ply
Quality	Kraftsackpaper 120 g/m^2 & 70 g/m^2, bottom 100 g/m^2 Liner PE / EVOH / PE
Supplier	Bischof & Klein

Material data

Layer	Unit	Value	Tolerance (%)	Remarks
Krafsackpaper				
Outer ply	g/m^2	120	± 4	D-FDC paper, brown
Inner ply	g/m^2	70	± 4	Krafsackpaper, brown
Bottom	g/m^2	100	± 4	Elastic Kraftsackpaper, brown
Liner	µm	80	± 5	
PE	µm	38	± 5	
EVOH	µm	5	± 5	
PE	µm	37	± 5	

Physical and chemical properties outer ply

Aspects	Unit	Value	Tolerance (%)	Method
Weight	g/m^2	120	± 4	ISO 536
TEA value	J	280	Min.	ISO 1924/2
Air porosity	s/100 ml	18	Max. 45	ISO 5636

Physical and chemical properties inner ply

Aspects	Unit	Value	Tolerance (%)	Method
Weight	g/m^2	70	± 4	ISO 536
TEA value	J	85	Min.	ISO 1924/2
Air porosity	s/100 ml	17		ISO 5636

Cause: New
Author: M. Molman

Note

Printing, number, prize and delivery time in consultation of the concerned purchase department.
Entirely or partially not meeting up to these specifications can cause rejection and return of the total supply. Deviation which cause in to problems in use or not sellable products lead to rejection. The supplied material is produced of raw materials, which meet up with the Dutch packaging and durable article resolution. Modifications in composition and or the production process can only be made after written permission of the buyer. The purchase conditions are undiminished in use on all our transactions.

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friesland foods

Specificaties verpakkingen	VOA	M132001
	Status	DRAFT
Material Specifications	Date	27-02-2007

Physical and chemical properties bottom

Aspects	Unit	Value	Tolerance (%)	Method
Weight	g/m^2	100	± 4	ISO 536

Physical- en chemical properties liner

Parameter	Unit	Norm	Tolerance (%)	Method
Thickness	µm	80	± 12	
Moisture barrier H_2O	g/m^2.24h	0,8		ASTM F 1249 (23°C / 85% RH)
Permeability O_2	ml/(24h.bar.m2) 23°C, 50% RV	3	Max.	DIN 53380/3

Additional requirements

- The hotmelt is not allowed to damage the liner when the bag and the liner are separated.

Cause: New
Author: M. Molman

Note

Printing, number, prize and delivery time in consultation of the concerned purchase department.
Entirely or partially not meeting up to these specifications can cause rejection and return of the total supply. Deviation which cause in to problems in use or not sellable products lead to rejection. The supplied material is produced of raw materials, which meet up with the Dutch packaging and durable article resolution. Modifications in composition and or the production process can only be made after written permission of the buyer. The purchase conditions are undiminished in use on all our transactions.

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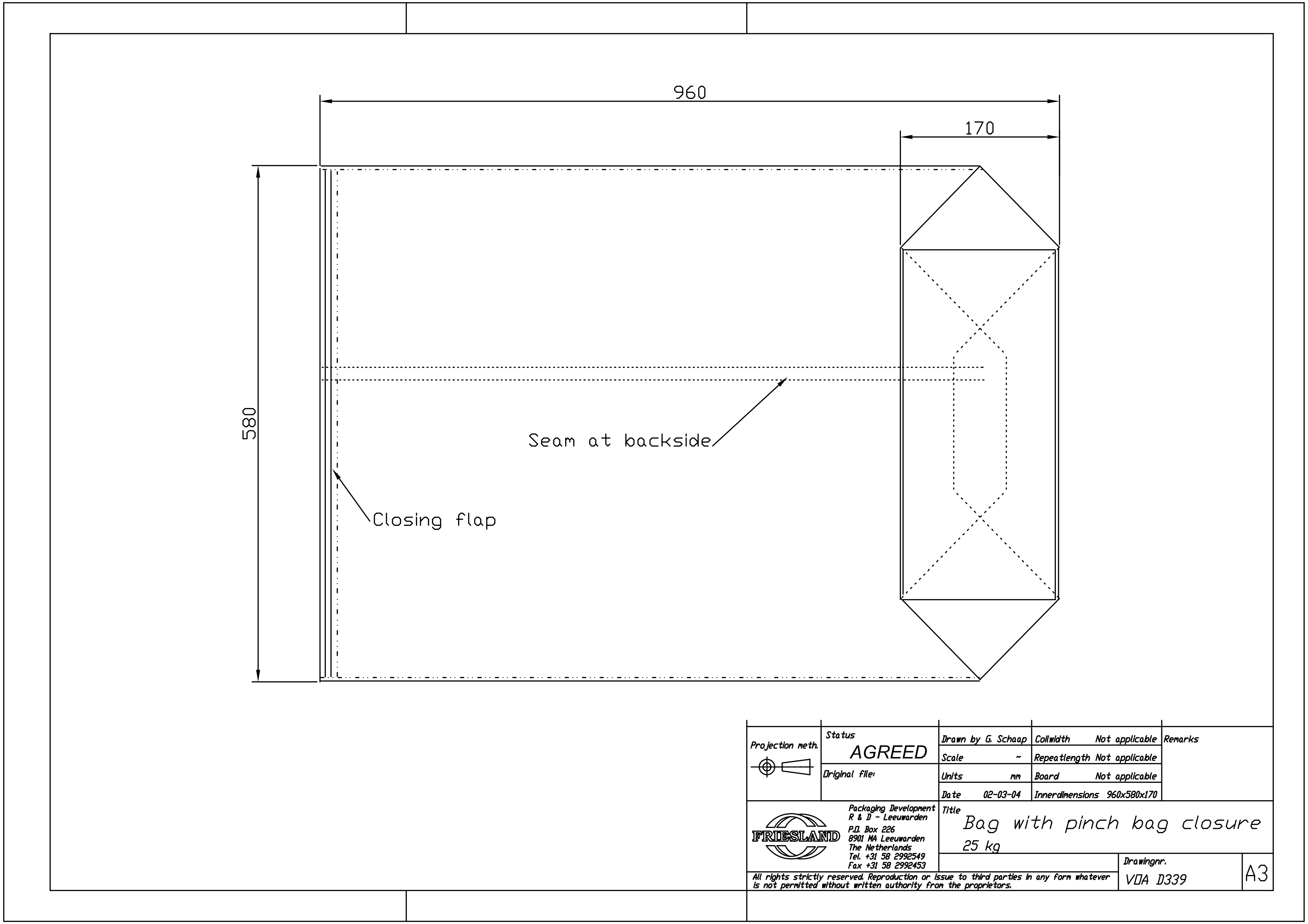

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Projection meth.
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Scale ~
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Date 02-03-04
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Repeatlength Not applicable
Board Not applicable
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Remarks
FRIESLAND
Packaging Development
R & D - Leeuwarden
P.O. Box 226
8901 MA Leeuwarden
The Netherlands
Tel. +31 58 2992549
Fax +31 58 2992453
Title
Bag with pinch bag closure
25 kg
Drawingnr.
VOA D339
A3
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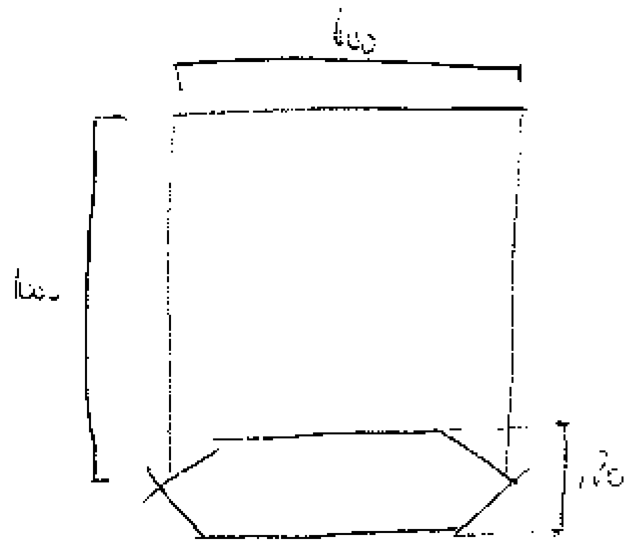
B

Verslag gesprek Domo/Kievit 7 april 2008

Locatie: Friesland Foods Kievit
Datum: 7 april 2008, 14:00
Aanwezig: Wietse van der Veen namens R&D Leeuwarden, Afke Fokma namens Friesland Foods DOMO (nader te noemen: Domo), Bastienne Peelen namens Friesland Foods Kievit (nader te noemen: Kievit), Stephan Domburg

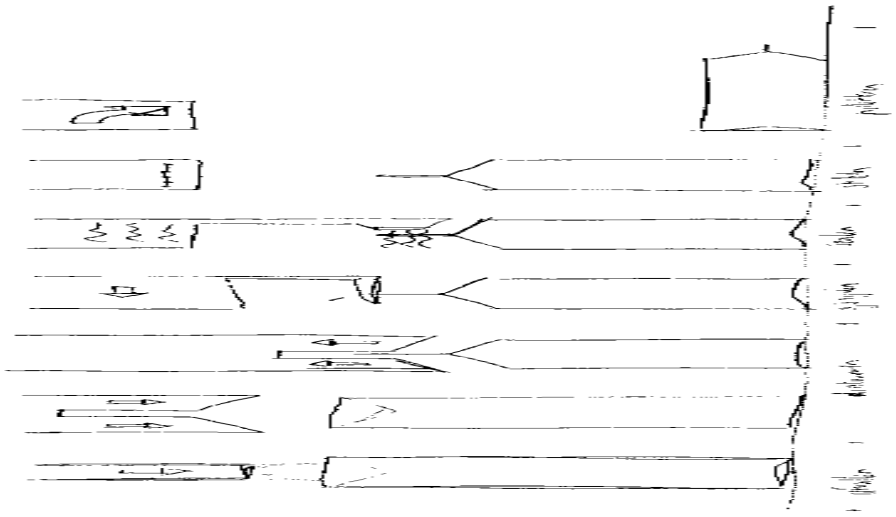
Aanleiding
Door zowel Domo als Kievit is aangegeven dat er interesse op het gebied van in-line lekdetectiemethoden bestaat. In dit gesprek is getracht dit onderwerp uit te diepen en precieze verwachtingen nader te definiëren. Daar zowel Domo als Kievit zich voornamelijk op het gebied van poeders voor professioneel gebruik bevinden, is besloten het gesprek met deze werkmaatschappijen te combineren.

Product en verpakking
Voor de beide werkmaatschappijen gaat het voornamelijk om poeders met relatief lange houdbaarheid voor professioneel (business-to-business) gebruik. Daarnaast worden ook poeders (vnl. Omega-3) met een beperktere houdbaarheid geproduceerd. Al deze poeders worden verpakt in kunststof zakken (liners) met papieren wikkel in diverse maathoeveelheden. Het gros hiervan bestaat uit 25 kg-zakken. Het vermoeden wordt uitgesproken dat in de toekomst het gebruik van deze zakken toe zal nemen. Globale (platte) afmetingen zijn in de figuur weergegeven.



Naast zakken wordt er tevens gebruik gemaakt van zogenaamde ‘big-bags’. Deze zijn vergelijkbaar met afvalzakken zoals deze in de bouw gebruikt worden en zijn bedoeld voor zeer grote hoeveelheden (+/- 1000 kg)

Verpakkingslijn
Onderstaand figuur geeft schematisch de stappen in de verpakkingslijn weer, die gelden voor de (25 kg) zakken. De throughput van de lijn is 8 zakken per minuut. Vóór het paletteren is voldoende plaats in de productie om een lekdetectiesysteem in te zetten.



Problemen
De liners worden voorzien van microperforatie, behalve voor beperkt houdbare poeders, waardoor overtollige lucht gemakkelijk uit de zakken kan verdwijnen, hetgeen paletteren vergemakkelijkt en er een compacter geheel ontstaat. Ook heeft het poeder op deze manier meer de neiging zich te gedragen als een vaste stof.

Toch is lekdetectie ook bij deze zakken een issue. Door lekken kan poeder uit de zakken verdwijnen. Dit is uiteraard niet de bedoeling en leidt ook tot problemen bij klanten die de papieren omverpakking verwijderen alvorens deze in hun eigen productie in te voeren. Vaak worden lekken niet eerder opgemerkt, omdat de omverpakking lekken in de liner verhult.

Een ander veelvoorkomende oorzaak van deze lekken bestaat enerzijds uit het foutief vullen van de zakken, dat wil zeggen vullen tussen de liner en de papieren omverpakking in en anderszijds een veelvoorkomend probleem dat poeder ter hoogte van de seal ervoor zorgt dat de seal niet goed dicht.

Mogelijke oplossingen
Naar aanleiding van de nog in uitvoering zijnde marktanalyse is door Stephan aangedragen dat een oplossing mogelijk kan liggen in lekdetectie doormiddel van een systeem gebaseerd op druk. Wanneer met behulp van bijvoorbeeld een roller de druk van de aanwezige lucht in de zak bepaald kan worden en eventueel ook de afname in druk als gevolg van gebruik van de roller, kan bepaald worden of er meer lekken aanwezig zijn dan de bewust aangebrachte lekken. Hiervoor zal een drempelwaarde ingesteld moeten worden, die zakken die deze waarde overstijgen uit de productielijn verwijderd (d.m.v. een zogenaamde ‘rejector’). Dit wordt als serieuze optie gezien. Een test zal uitgevoerd moeten worden naar de effectiviteit van deze mogelijke oplossing.

Afspraken
Wanneer het onderzoek van Stephan zich in een verder stadium bevindt, zal contact opgenomen worden om het e.e.a. af te stemmen.

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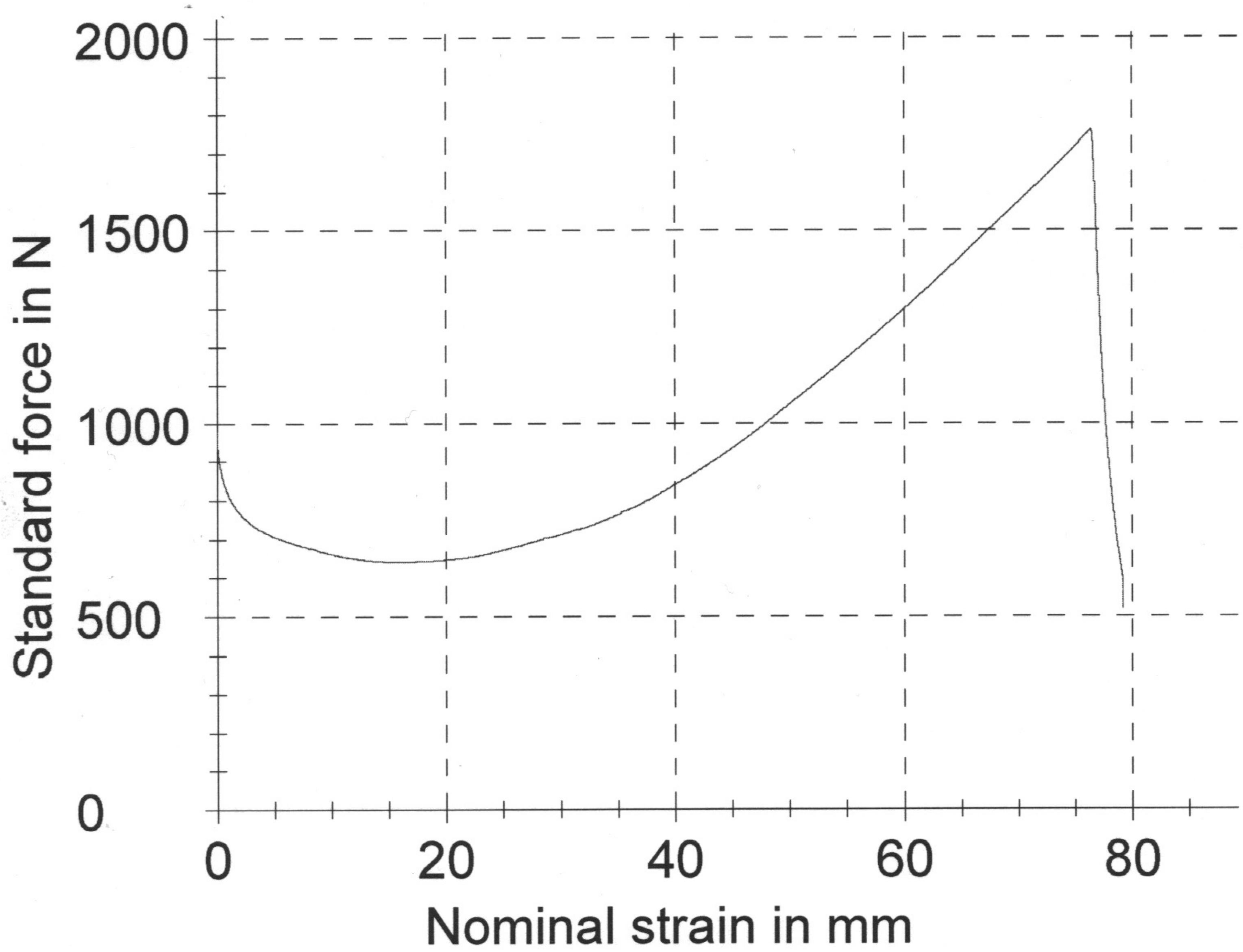
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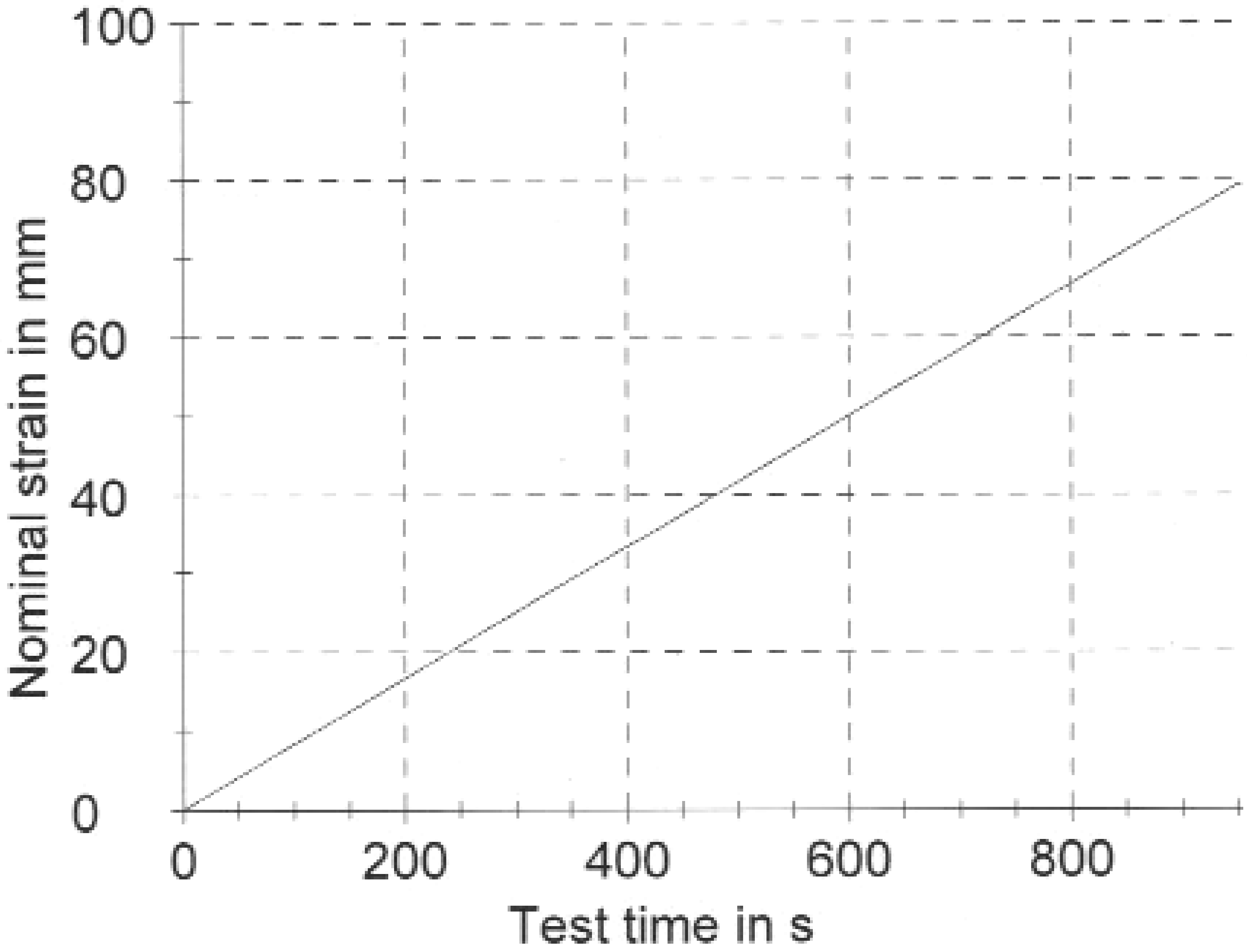
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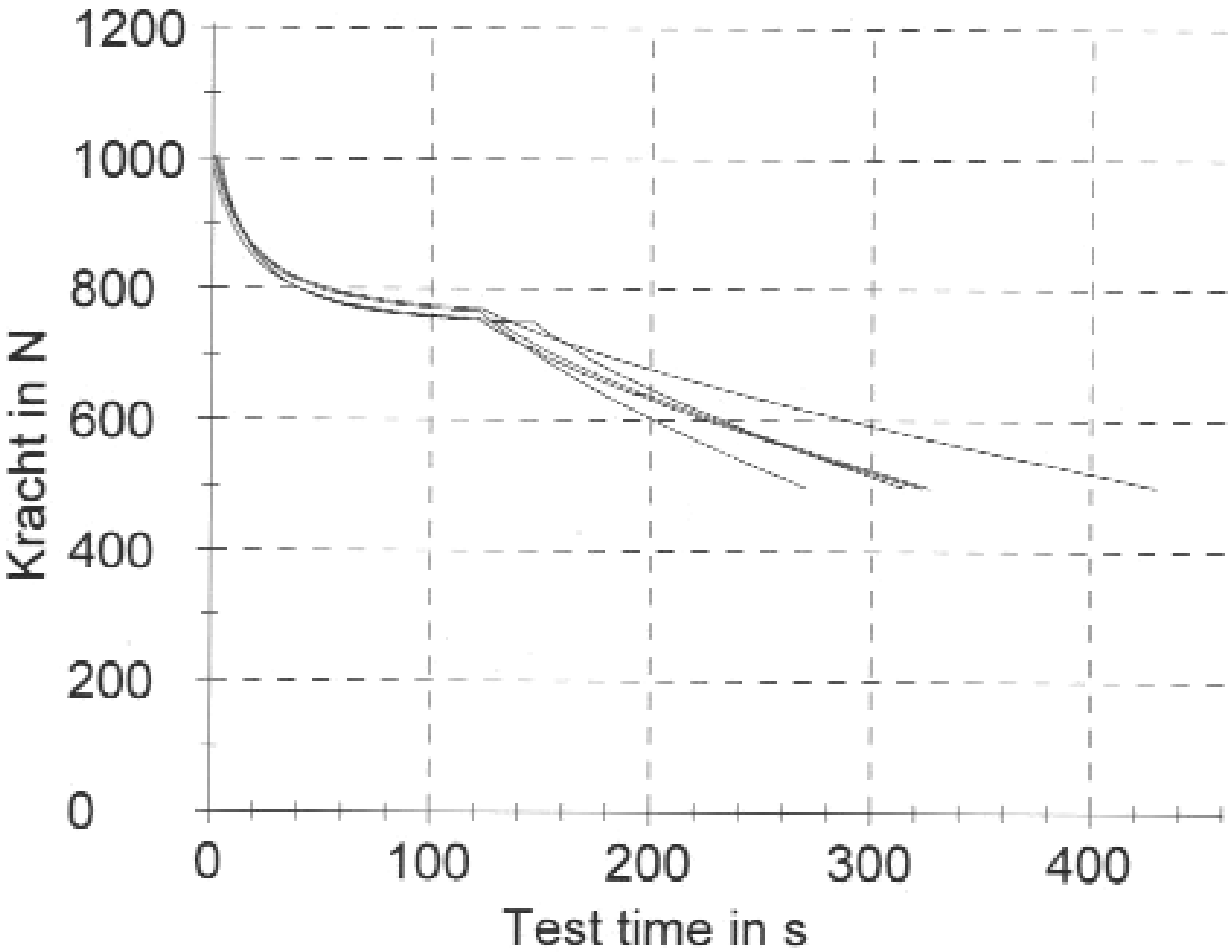

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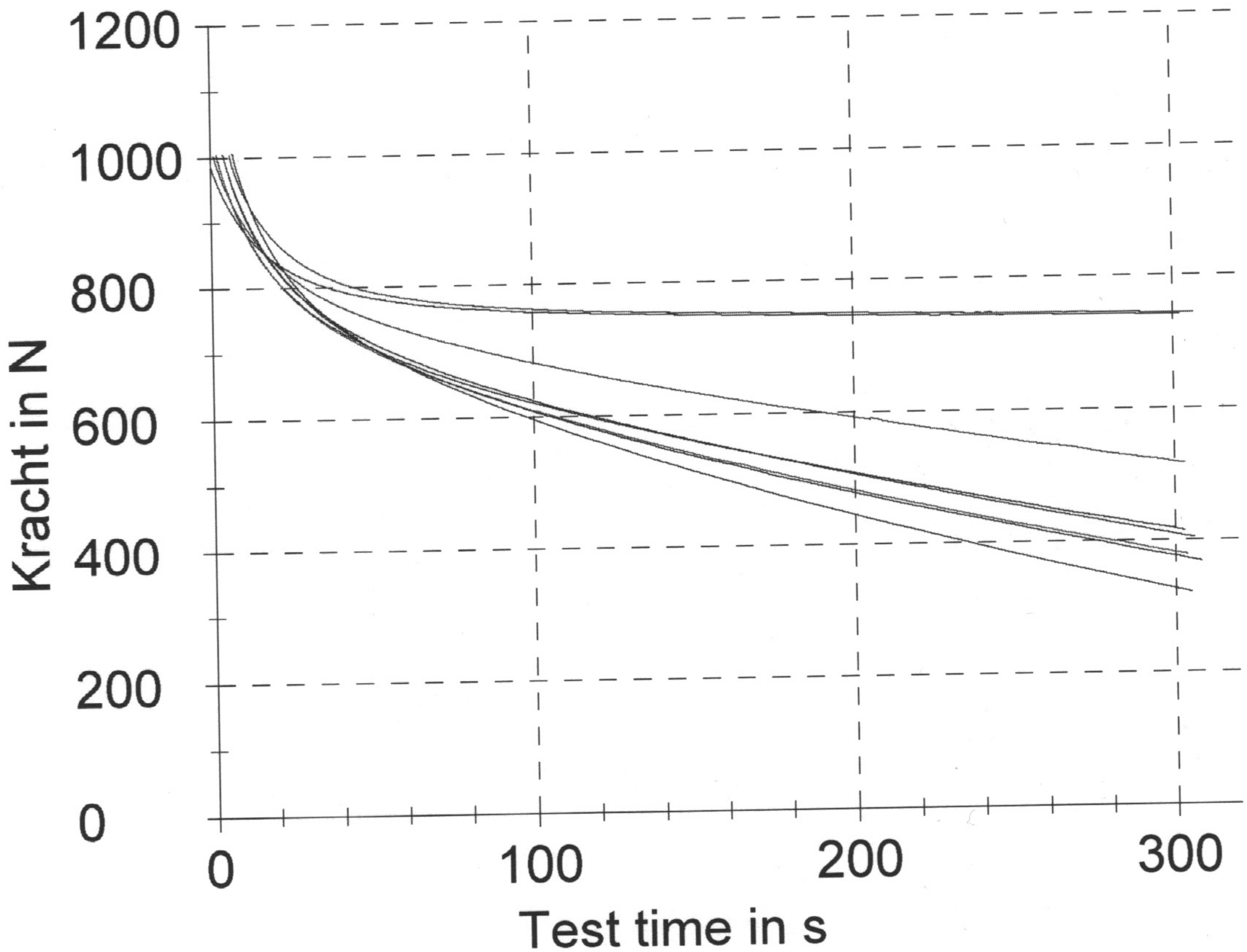
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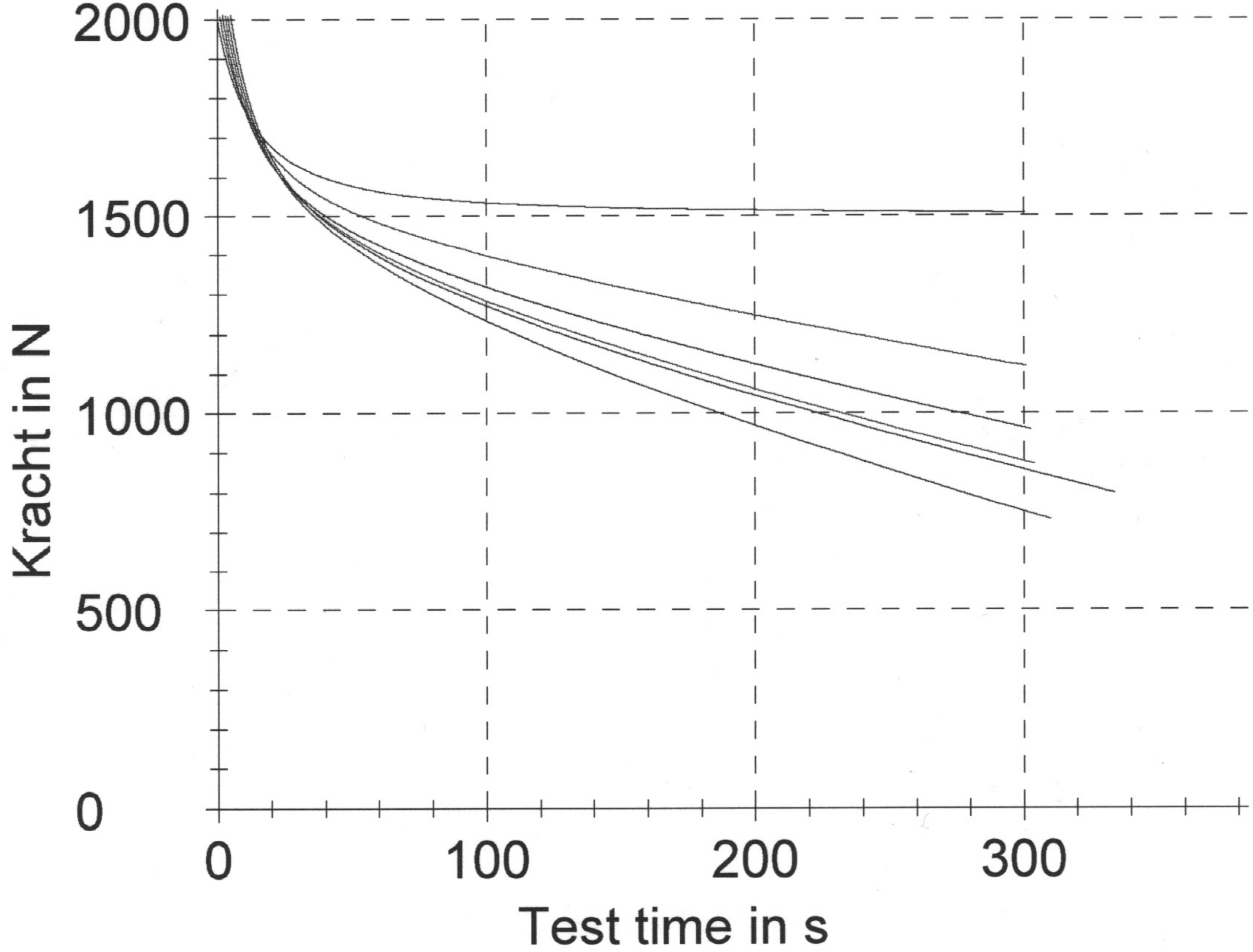
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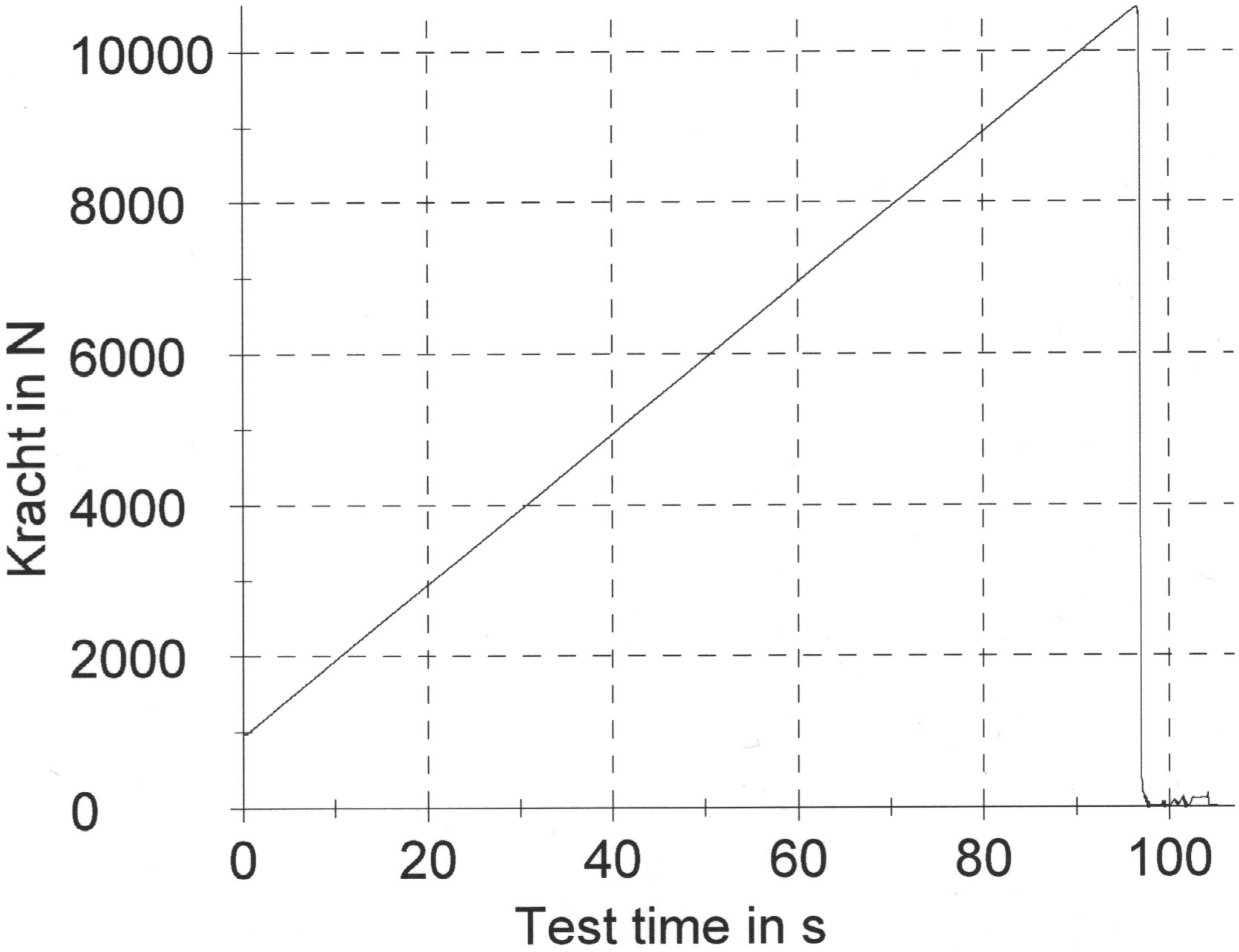
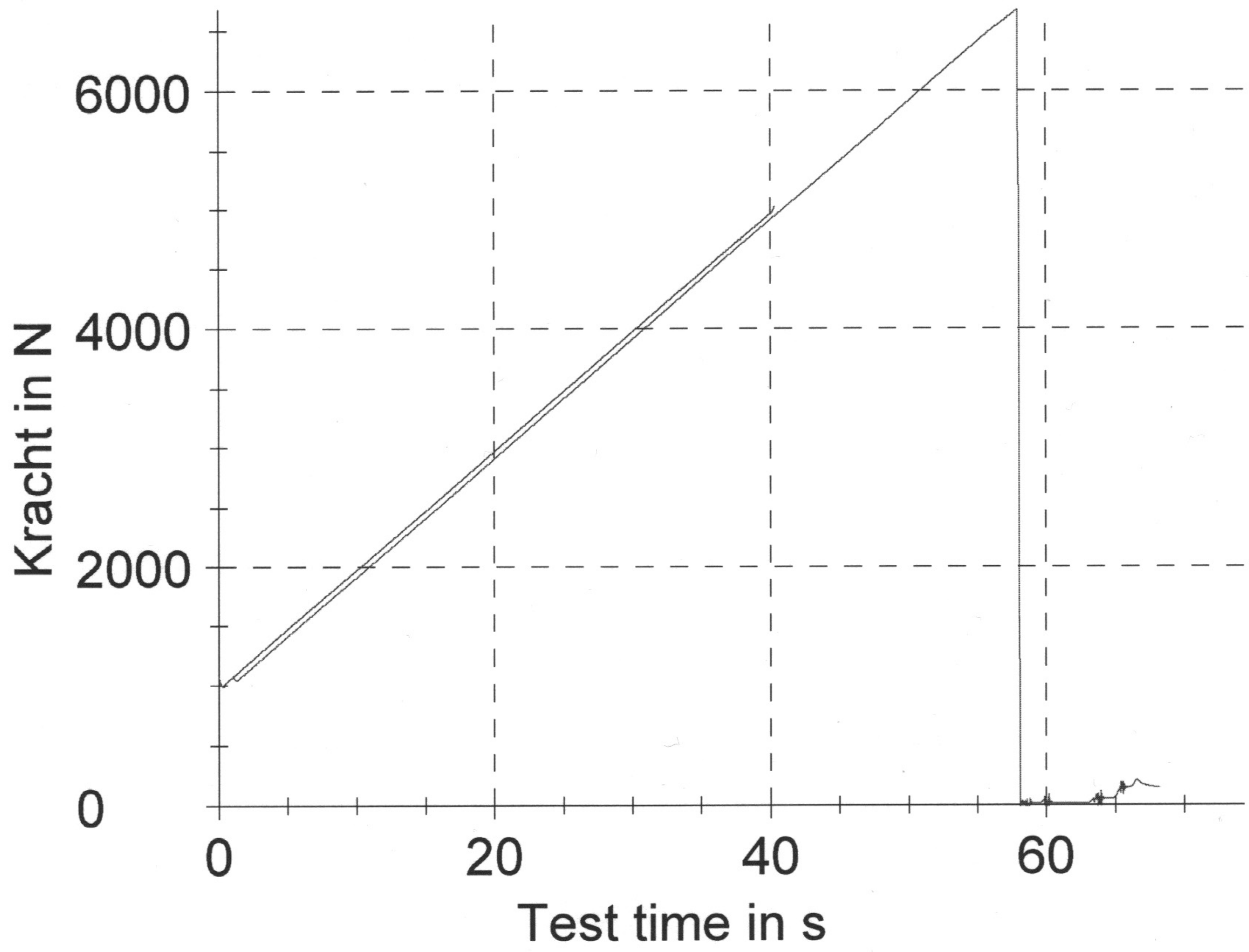
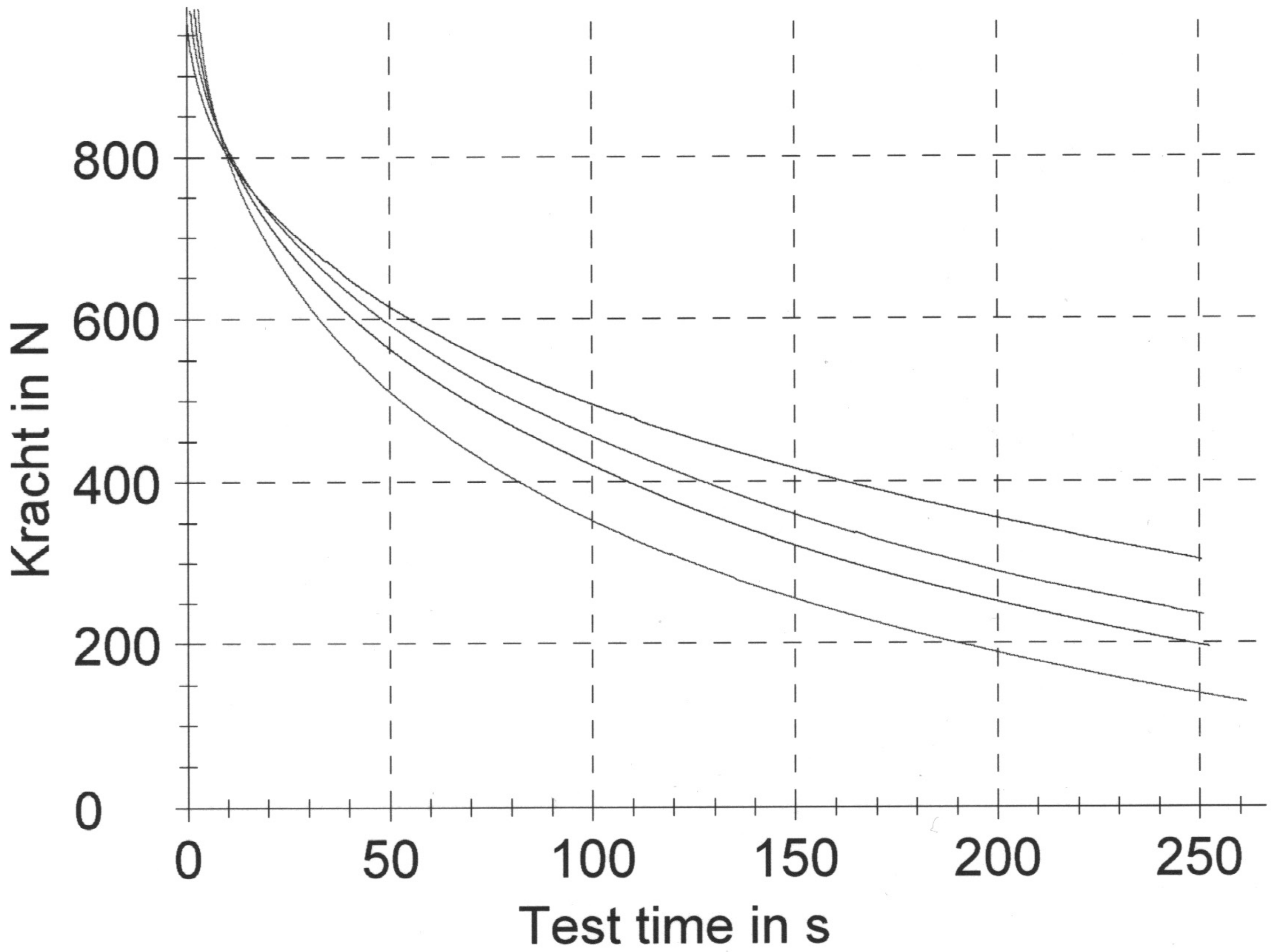
300
Test time in s



10000
8000
6000
4000
2000
0
Kracht in N
0
20
40
60
80
100
Test time in s


6000
4000
2000
0
Kracht in N
0
20
40
60
Test time in s



Kracht in N
800
600
400
200
0
0
50
100
150
200
250
Test time in s