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**COMBAT RATION  
ADVANCED MANUFACTURING  
TECHNOLOGY DEMONSTRATION  
(CRAMTD)**

**"Leak Detector Implementation"  
Short Term Project (STP) #75**

**FINAL TECHNICAL REPORT  
Results and Accomplishments (November 1995 through June 1996)  
Report No. CRAMTD STP #75 - FTR26.0  
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# 1.0 CRAMTD STP#75

## Results and Accomplishments

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### 1.1 Introduction and Background

There is currently a requirement for two 100% inspections, pre- and post retorting in each plant producing retorted MRE pouches, looking for cuts, holes, surface defects, and seal leaks. In spite of this significant investment in manpower for the inspection tasks, the final rate of rejection of lots is high (often 12 to 15 percent of which 4 to 7 percent is due to pouch abrasions and holes). Evidently the human inspection system is not as effective as it needs to be, allowing an excessive number of defects in the finished product lots, and lowering the probability of lot acceptance to an undesirable level. To increase the probability of lot acceptance, the defects ratio in the finished product lot has to be decreased. This can be accomplished by either decreasing the number of defects created by the process or by increasing the efficiency of the inspection system. For example, if the process produces 10 defects per 10,000 pouches and the inspection system has an efficiency of 50%, then the finished product lot will contain 5 defects per 10,000 pouches, and based on a 200 pouch sample size, this lot will have a 90% probability of being accepted. If the inspection efficiency can be increased to 80%, then the defect ratio in the finished product will be reduced to 2 per 10,000 pouches and, under the same sampling rule, the probability of lot acceptance will increase to 96 %. The same lot acceptability can be achieved with a 50% effective inspection system if the process can be improved to only produce 4 defects per 10,000 pouches.

The objectives of this project were: (1) Define the type of defects that are being produced by obtaining and analyzing the data that is being collected by the USDA and the AVI's. (2) Visit MRE production and assembly plants to determine the most likely cause of the leak defects. (3) Characterize/Optimize the performance of the ATC-3 Package Leak Detection System as a function of process and product parameters, as well as the type leaks most likely found. (4) Provide guidance, assistance, and consultation to the MRE industry in their task to identify the most desirable, economically and technically effective non-destructive MRE pouch leak detecting test equipment available for plant inspection. (5) Identify and evaluate competing leak detection systems and compare the performance against the ATC-3 tester.

This Short Term Project started November 1, 1995 based on technical and cost proposals, dated November 14, 1995 that were submitted to the DLA on November 15, 1995. Final approval for the project was received on January 11, 1996.

### 1.2 Results and Conclusions

The USDA and AVI inspection data for preformed pouches was obtained and analyzed. It was concluded that the placeable products generate the highest lot rejection rate during the USDA inspection (17.4%), and that the hot filled products are least likely to be rejected (9.8%).

It was also concluded that even though the lot rejection percentage is high, this does not necessarily mean that those rejected lots have a high number of defective pouches. Lot acceptance based on sample inspection is based on probability. The AVI data revealed that the majority of the defects found during the assembly process are either line cuts, leaking seals or punctures. It was estimated that on the average 1 per 20,000 pouches was identified to be defective during the assembly process.

CRAMTD had earlier acquired an Advanced Technology Concepts, Inc. Model ATC-3 leak tester. This STP quantifies baseline performance for this tester against which other leak testers can be compared. The performance of any tester is quantified in Type I and Type II errors. Type I error is the rejection of a non-defective pouch, Type II error is the acceptance of a defective pouch. The ATC-3 performance was quantified as: Type I error: 0% @ 70 F and @ 85 F and 11% @ 100 F, and Type II error: 22.2% for holes and 16.7% for slits, resulting in an average Type II error of 19.4%. It was concluded that the performance improves if the defects are larger and if the pouch is tested on both sides. Note: the test cycle was about 1 pouch per minute

A comparison was made against the human inspection system. At a rate of 7 seconds per inspection, the human performance to detect 600 micron holes could be quantified with a Type I error :6% and a Type II error: 55.6%.

### **1.3 Recommendations**

- Modifications to the ATC-3 made during the Preliminary Engineering (section 3.2.4) task indicate that performance can be significantly improved. Vacuum system modifications, for example, improved the cycle time to less than 10 seconds per pouch and extended application to pouches with less than 5 cc residual gas. It is therefore recommended that some additional engineering be included in any subsequent Leak Tester procurement.
- Alternate testers and/or ATC-3 modifications can best be compared using a standardized performance test protocol such as established during Phase Ia and described in TWP#115 (Appendix 4.7).
- Based on the performance obtained and expected in subsequent testers, it is recommended that a modified ATC-3 type of tester be implemented on the plant floor for leak defects.
- A follow-up project should be proposed which focuses on identifying specific causes for leaks and prevention. Such a protocol would build on prior surveys and employ leak testers to troubleshoot the production line.
- Highly successful preliminary results at measuring the amount of pouch residual gas (TWP #117, Appendix 4.9) using data readily available from the ATC-3 type of tests should be further evaluated. Multiple use of the "leak detector" would provide enhanced cost/benefit as well as provide a non-destructive test for an important product specification.

## 2.0 Program Management

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STP#75 is a single-phase work activity, consisting of two components, Phase Ia and Ib. The two components have the following general objectives:

### 2.1 Phase Ia: Defect and Baseline Characterization

This phase will focus on defining the nature of leak defects as observed at the MRE producer sites and determining the performance of the ATC-3 leak tester as a baseline leak detector.

### 2.2 Phase Ib: Leak Detector Procurement

This phase is aimed at supporting MRE producers in evaluating alternate leak detection systems and definition of equipment procurement strategy. The evaluation of alternate leak detection systems includes staying abreast of developments and improvements to leak detection equipment used in other industries.

The work activity and status are illustrated on the attached figure 1, CRAMTD STP#75 "Leak Detector Implementation," Time and Event Milestones (Appendix 4.1).

### 2.3 Summary of STP Accomplishments

- USDA and AVI pouch inspection data was obtained and analyzed. The entrée types expected to show the greatest growth in production also have the greatest incidence of holes, abrasions, and residual gas defects.
- Baseline performance for a vacuum/pouch deflection method leak detector (ATC-3) was established and based on improvements identified during a preliminary engineering design phase it was concluded that production scale testing is feasible.
- Two MRE production facilities were visited and although inspection times and methods used by the producers varied, parameters were established to characterize human inspection.
- Measured human inspection efficiency at the CRAMTD demonstration line. The human inspectors, albeit with no prior on-the-job experience, were only able to identify appropriately 50% of the defects while rejecting 6% of the non-defective pouches.

## 3.0 Short Term Project Activities

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### 3.1 STP Phase Ia Task

#### 3.1.1 Install ATC-3 Leak Tester and Establish Baseline (Task 4.2.1.1)

The ATC-3 tester, which was procured from Applied Technology Concepts, Inc. (Tawaco, NJ) under STP#21, was installed in the CRAMTD Quality Control Lab and integrated into the

CRAMTD computer network. This leak tester had been identified during STP #21 as best capable of flexible pouch leak detection and also it employees technologies, vacuum method along with pouch deflection, most amenable to cost effective scale-up to production line speeds. As such, the ATC-3 provided a reasonable machine with which to establish baseline performance and a standardized testing protocol. Further, the ATC-3 was itself a candidate for use in a production leak detection application.

Preliminary tests were first performed to study the repeatability and the sensitivity of the tester to various process and product variables. Based on this preliminary study, improvements were implemented such as the addition of a pre-loaded spring to the expansion sensor, special plates on both sides of the pouch to equalize the pressure and allow flow out of the pouch, a drawer insert to minimize the cavity size, increasing the stroke length of the deflection sensor, and adding a manometer to check the calibration of the vacuum sensor.

The modification to the expansion sensor (pre-loaded spring and stroke adjustment) was done to create a small pressure differential over the pouch defect, forcing the gas or fluid through the defect, out of the pouch. Plates were added to the system to distribute the force of the expansion sensor over the entire pouch. These plates were covered with a special TEFLON mesh, preventing the plates from sealing the defect of the pouch and preventing any flow through the defect. The pre-load of the spring was about 0.5 lb f at the beginning of the expansion range to 2.5 lb f at the end of the range. Assuming that the pouch surface area in contact with this sensor is about 25 square inch, this created a pressure differential ranging from 0.02 to 0.1 psi between the inside and the outside of the pouch. Due to the design limitation of the instrument, we were not able to test a stronger spring. A stronger spring might improve the capability of the tester to detect smaller holes or holes in pouches that contain products which are more viscose in nature, or detect holes in a shorter time period.

After the above described modifications were implemented, an experimental designed study was executed to document the baseline performance of the ATC-3 tester as a function of various process and product parameters. Results of this study are documented in Technical Working Paper #115 (attached as Appendix 4.7). Within the range of the parameters, the overall performance of the ATC-3 was quantified with a Type I error = 11% and a Type II error = 19.4%. Type I error is the rejection of a pouch that is not defective and Type II errors are accepting a pouch that is defective. However, it should be noted that the main reason for the Type I error were the experiments with product temperature at 100 F. It was hypothesized that the cooling effect of the pouch during the test cycle resulted in a drop in expansion, which was then detected by the system as a leaking pouch. Excluding the results from the experiments at 100 F product temperature, the Type I error dropped to 0%. This phenomena causes however some concern as the temperature of pouches in a production environment after retorting might vary from 70 to 110 F. Variation in product temperature is caused by the location of the pouch in the retort process and the duration between the retort process and the testing time. Further work in this area is warranted to identify how the effects of elevated product temperatures can be compensated to reduce the Type I error.

The Type II errors were a function of the defect size and the location of the defect. Clearly, the leak detection Type II error becomes smaller as the hole size increases. For example, Type II error is only 10.2% if the defect size is (hole) 600 micron or (slit) 1/8" or larger. Type II error can also be cut in half if the pouch is tested on two sides and the pouch failure algorithm is based on a leak in any of the two tests.

It should be noted that the ATC-3 tester relies on the existence of residual gas inside the pouch, and will have a problem when residual gas amounts are in the range of 0 to 3 cc. The experiments for base line performance used residual gas levels ranging from 5 cc to 25 cc.

It should be reiterated that the above performance test was done to develop a bench mark performance point against which other leak testers can be compared.

While conducting the above experiments, the ability of the ATC-3 tester to predict the amount of residual gas that is inside the pouch was also evaluated. An analysis of this preliminary feasibility study is documented as TWP#117 (attached as Appendix 4.9).

### 3.1.2 Analysis of USDA/AVI Data (Task 4.2.1.2)

As has been reported at R&DA meetings (Table 1), the three main causes for lot rejection are: Abrasions/Holes, Bad/Weak Seals, and Residual Gas.

Table 1		
Defect	MRE_14	MRE_15
Abrasions/Holes	5.7%	4.1%
Bad/Weak Seals	2.5%	2.5%
Residual Gas	1.9%	1.5%

However, the R&DA data does not distinguish between holes and abrasions nor does the data identify if defects are product specific.

Therefore, additional analysis was preformed, using USDA inspection data on lots produced in 1994 and 1995. A total of 2426 lots were considered for this analysis. Of these lots, 13.6% of the lots were rejected, during the first inspection. Of this, 3.6% was due to holes, 1.9% due to abrasions, 2.4% due to seal defects and 2.0% due to residual gas defects. These lots were then divided in the four classes of products as identified in MIL-P-44073:

- Class 1 are the meat, poultry, and fish with sauce and gravy type products (967 lots).
- Class 2 are the vegetables with sauce type products (408 lots).
- Class 3 are the meat and poultry in loaf, slice or solid form type products (592 lots).
- Class 4 are the fruit type products (459 lots).

The defect data for each class product was analyzed and is shown in Table #2. Clearly, the Class 3 type products produced the highest percentage holes (5.6%), abrasions (4.7%), and residual gas type defects (3.4%). Class 4 type products showed the least amount of holes (0.7%) and abrasions (0.9%). There can be two reasons why Class 4 type products generate less "hole" and abrasion type defects. First the product is "hot" filled and does not require a sterilization

process, and are therefore handled less. Second, these type products are typically low in viscosity and would more likely leak product fluids through the defect than products that do not contain liquids or contain liquids with high viscosity. The reason why placeable products generate more “hole” type defects might be due to the more distinct shape of these products and stressing the film around these shapes if packed with low residual gas.

	<b>Lots Produced</b>	<b>Lots Failed</b>	<b>% Hole</b>	<b>% Abrasions</b>	<b>% Seal Defects</b>	<b>% Residual Gas Defects</b>	<b>% Total Lot Rejection</b>
Class 1	967	130	3.9%	1.2%	2.7%	2.0%	13.4%
Class 2	408	53	3.2%	0.5%	2.5%	0.7%	13.0%
Class 3	592	103	5.6%	4.7%	2.4%	3.4%	17.4%
Class 4	459	45	0.7%	0.9%	1.7%	1.5%	9.8%
Total	2426	331	3.6%	1.9%	2.4%	2.0%	13.6%

Even though the above data indicates some problem areas, the above should be put in perspective. Lots which contain a critical defect such as a “hole” type defect at a ratio of 2 per 10,000 pouches have a 4% chance to be rejected during the USDA inspection. Even though the occurrence of lot rejection due to holes appears to be substantial, the occurrence of a hole is rather small. Also, the lots that failed the USDA inspection might not be any worse in quality than the lots that passed the inspection process. It is very difficult to sort out the defects unless they are gross defects. The key to improve the quality of the MRE lots is the identification of the defect source(s) and eliminating these rather than sorting defects out of the process.

A data set from the AVI 1995 defect database was also analyzed. A total of 922 defects distributed over 354 lots from 9 producers was recorded. The three major defect categories were either line cuts (35%), leaking seals (32%) or punctures (27%). If we assume that the average lot size is about 50,000 pouches then we can say that the AVI found on the average 1 defective pouch per 20,000 pouches.

The AVI also records the location of the defect on the pouch. For this purpose the pouch is divided into a grid (40 grid locations on either side of the pouch). An analysis was performed to identify if certain defects occur in specific locations. As expected the two top corners of the pouch seal were most prone to a leaking seal defect. This could be due to seal whipping, in which product residues might be whipped into the corners of the seal. Line cuts were spread over the pouch with a slightly higher occurrence in the lower half of the pouch. Also, the holes were spread over the pouch with a slightly higher occurrence in the two top corners of the pouch.

In addition to reviewing inspection data, we also conducted a literature search to obtain any updated information in the area of leak testing. The results of this literature search are documented in the Appendix 4.6.

### **3.1.3 Visit MRE Producer Sites (Task 4.2.1.3)**

Two plant visits were made to study the MRE inspection procedures. In each plant, the pouches were inspected 100% after the retort process. Inspection times and methods however varied. Based on these observations, parameters for task 4.2.1.4 were selected.

### **3.1.4 Human Inspection Characterization (Task 4.2.1.4)**

The human inspection was characterized during trials at the CRAMTD demonstration line by studying the inspection efficiency as a function of various environmental factors such as inspection rate and lighting. Even though these inspectors had no on-the-job experience, they were briefly trained on the type defects that needed to be identified (600 micron hole). In the best situation, the human inspector was only able to identify approximately 50% of the defects that were presented to him. In addition, the human inspector sorted out about 6% of the pouches that were not defective. The results of this effort are documented in TWP#116 (Appendix 4.8)

Based on the results of this study, it is clear that human inspection has great difficulty in identifying the small defects (600 micron) within a reasonable time period at a reasonable rate. It was also concluded in the report that the preferred method of environmental light is **a broad spectrum table light and not magnifying glasses**. The main problem with magnifying glasses was that the area of vision was too limited, forcing the inspector to move the pouch in front of the glass rather than moving his eyes over the surface of the pouch.

It was clearly demonstrated that the inspection efficiency increased as the allowable inspection time per pouch increased.

## **3.2 STP Phase Ib Task**

### **3.2.1 Monitoring and Evaluation (Task 4.2.2.1)**

Contacts with Applied Technology Concepts (ATC-3) and Packaging Technologies & Inspection (PTI) were maintained. No new developments have been uncovered in vacuum/leak detection technology.

Met with Multivac to discuss the Pack Check (PBI Dansensor, Denmark) Leak Detector (see Appendix 4.10). The unit is designed for laboratory use and is based on a fast/sensitive CO<sub>2</sub> sensor. After review of the technology for potential implementation within the MRE manufacturing process, it was concluded that the unit cannot be integrated for on-line 100% inspection for a number of reasons:

1. CO<sub>2</sub> gas injection would be required on packaging lines, an expensive modification for vertical pouch sealers.
2. CO<sub>2</sub> would escape from pouches during retort, making most leaking pouches indistinguishable from non-leakers.
3. The CO<sub>2</sub> method has limitations similar to other vacuum methods with liquid plugging small holes.

4. The CO<sub>2</sub> sensor based system is much more expensive than other methods for on-line testing.

### **3.2.2 Industry Assistance (Task 4.2.2.2)**

Based on benchtop results aimed at 100% on-line pouch testing (see Section 3.2.4) we are proceeding with development of equipment specifications in support of MRE Producers for the DPSC Leak Detection Initiative.

### **3.2.3 Preliminary Equipment Recommendation (Task 4.2.2.3)**

The accuracy results of the ATC-3 Leak Tester compiled in Phase Ia for plain pouches vis-a-vis the human inspector are encouraging. For the vacuum leak test system to become feasible for production line operation, reduction of both the test cycle time (40 seconds per pouch) and the rate of Type 1 errors are needed.

The remainder of this project performed tests with the ATC-3 unit specifically focussed on;

1. modifications to improve the vacuum system,
2. modifications to detection system; leveling plates, expansion restraints and force sensing,
3. simplified analysis method (less computation intensive algorithms),
4. feasibility of in carton testing pouches.

### **3.2.4 Preliminary Engineering (Task 4.2.2.4)**

The vacuum system was modified with a larger solenoid valve, larger tubing and replacing the internal venturi vacuum pump with the high capacity pilot plant pump used by the Demo Site packaging lines. Other modifications were made to reduce the internal volume of the vacuum chamber; inserts were fabricated for the leak tester drawer and sensor cover. Several small chamber leaks were repaired. The impact of these changes greatly improved the leak tester cycle performance to less than 10 seconds per pouch and increased the vacuum level by 10%. Pouches with very low residual gas (less than 5cc) were successfully tested with this new arrangement (see Appendix 4.2). It appears that the improved vacuum pressure improves pouch response, however further testing with this configuration will be needed to determine whether sensitivity and accuracy has benefited.

Pouch expansion with the higher vacuum caused some problems for the LVDT displacement sensor which has a limited range of motion. Springs were placed on the sensor to resist pouch expansion and keep pouch response within range of the sensor. Springs with a rigid plate on top of the pouch produced very reproducible pouch expansion. The problem with Type I errors of warm pouches (100F), where apparent pouch deflation occurred, thought to be a cooling effect during unrestrained expansion, was no longer observed. Limited pouch expansion will increase the pressure difference during testing, which should reduce plugging and help improve detection of small holes. A load cell may provide the best solution for sensing pouch expansion.

The ATC-3 unit uses a combination of analyses of pouch expansion and vacuum pressure to make a determination of whether to accept. This approach may be more suitable for micron sized defects and rigid packaging with headspace. The data collected on MRE pouches with the modified vacuum system suggest that defective pouches can be identified by one of two characteristics that can be easily programmed;

1. insufficient expansion - the maximum or the final expansion below an established threshold, and
2. deflation - the final expansion falling below the maximum expansion.

Examples of these pouch responses are shown in Figure 3 (Appendix 4.3). This analysis method significantly reduces computational requirements compared to the standard ATC-3 and has the benefit of less costly processors, simpler software (easier to program, faster debugging), easier for plant operators to set up and calibrate. Additional tests will be needed to show tester accuracy using this simplified analysis method.

Pouches were tested in the ATC-3 unit packaged in the protective cardboard carton to determine whether leaking pouches could be detected. The data, Figure 4 (Appendix 4.4), shows that the carton has little effect on the final pouch response. We believe that air within the carton escapes through the end flaps as seen on Figure 4 (Appendix 4.4) by an initial expansion-deflation. Testing in-carton has several benefits; cartoned pouches are easier to handle with automatic machinery, leaks are unlikely to happen after the pouch is sealed in the protective carton, and leak testing can be done after production or at the MRE meal assembly operation.

### **3.2.5 Specifications and Drawings (Task 4.2.2.5)**

A preliminary machine design was developed based on a multiple unit ATC-3 leak tester. A sketch of this concept located after the cartoning operation is shown in Figure 5 (Appendix 4.5). Further engineering is needed to determine suitability of integrating the leak detection system with existing equipment. This design assumes a vacuum test of 6-8 seconds and a production rate of 100 pouches per minute.

### **3.2.6 Economic Analysis (Task 4.2.2.6)**

An equipment cost estimate was made for the preliminary machine design. The costs have been identified as follows:

Controls	\$10,000
Materials Handling/Chamber	50-75,000
Integration/Installation	10,000
Detection System	<u>25,000</u>
Total	\$125-150,000

Based on an equipment investment of \$150,000, the annual cost savings required to justify the capital investment would be \$36,600/year. This calculation is based on a 5 year period at an interest rate of 7%. Since the investment could be made by the government, there are a number

of ways the benefit may be realized: reduced number of pouches scrapped in the field, reduced inventory on-hand, lower costs on pouches from savings at processor (labor, scrap, rework).

## 4.0 Appendix

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- 4.1 Figure I CRAMTD STP#75 Time and Event Milestones
- 4.2 Figure 2: ATC-3 Vacuum Modifications
- 4.3 Figure 3: Pouch Leak Test Response Pouch Tested In-Carton
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**Figure 1 - CRAMTD Candidate Short Term Project #75  
Leak Detector Implementation  
Program Plan and Schedule**

Task Name	Reference	1995					1996							
		Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun				
Phase Ia - Defect and Baseline														
Install ATC-3 and Establish Baseline	4.2.1.1													
Analysis of USDA/AVI	4.2.1.2													
Visit MRE Producer Sites	4.2.1.3													
Human Inspection Characterization	4.2.1.4													
Phase Ib - Leak Detector Procurements														
Monitoring and Evaluation	4.2.2.1													
Industry Assistance	4.2.2.2													
Preliminary Equip. Recommendation	4.2.2.3													
Preliminary Engineering	4.2.2.4													
Specifications and Drawings	4.2.2.5													
Economic Analysis	4.2.2.6													
Final Technical Report	4.2.2.7													

### ATC-3 Vacuum Modifications

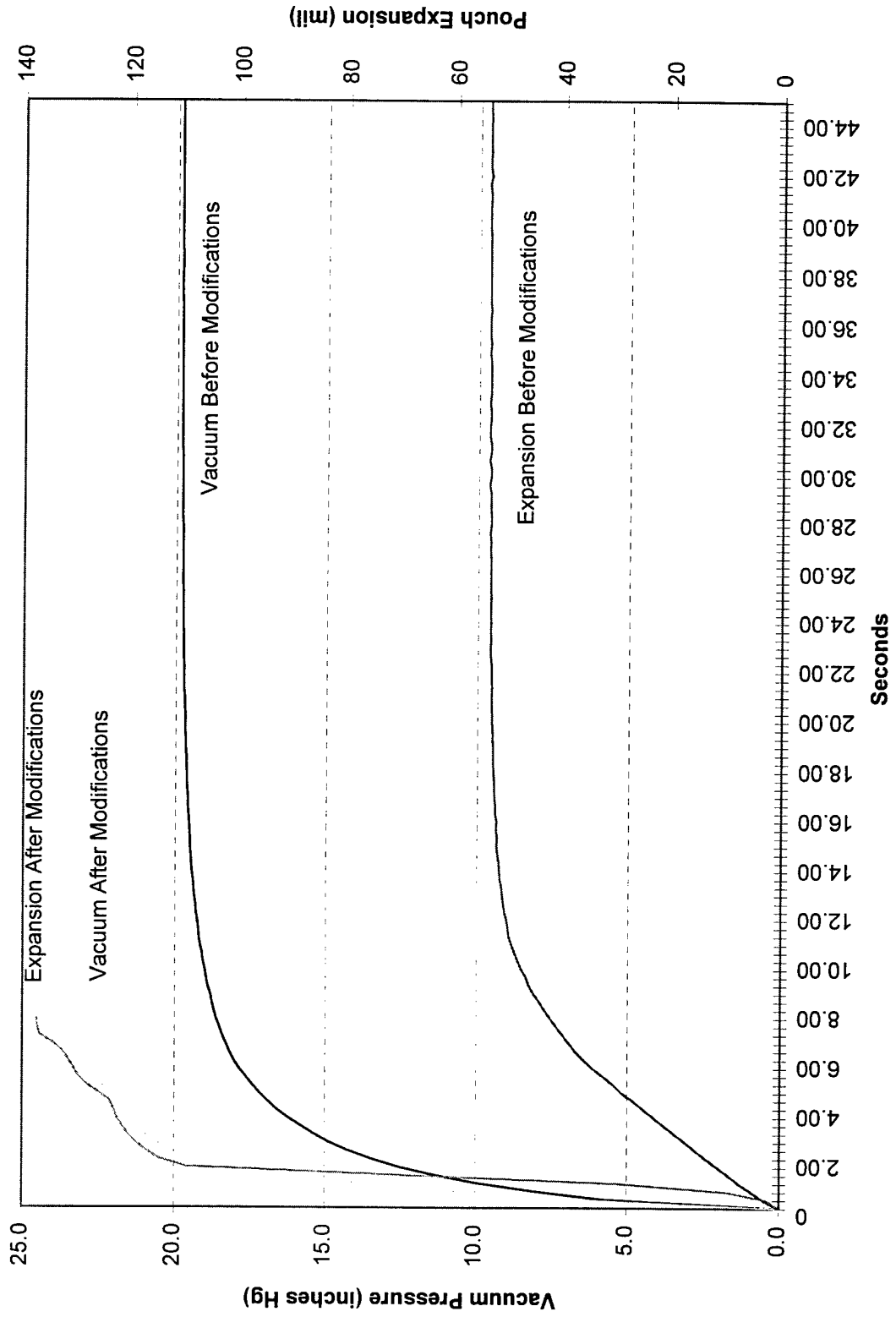


Chart2

**Pouch Leak Test Response  
Pouch Tested In-Carton**

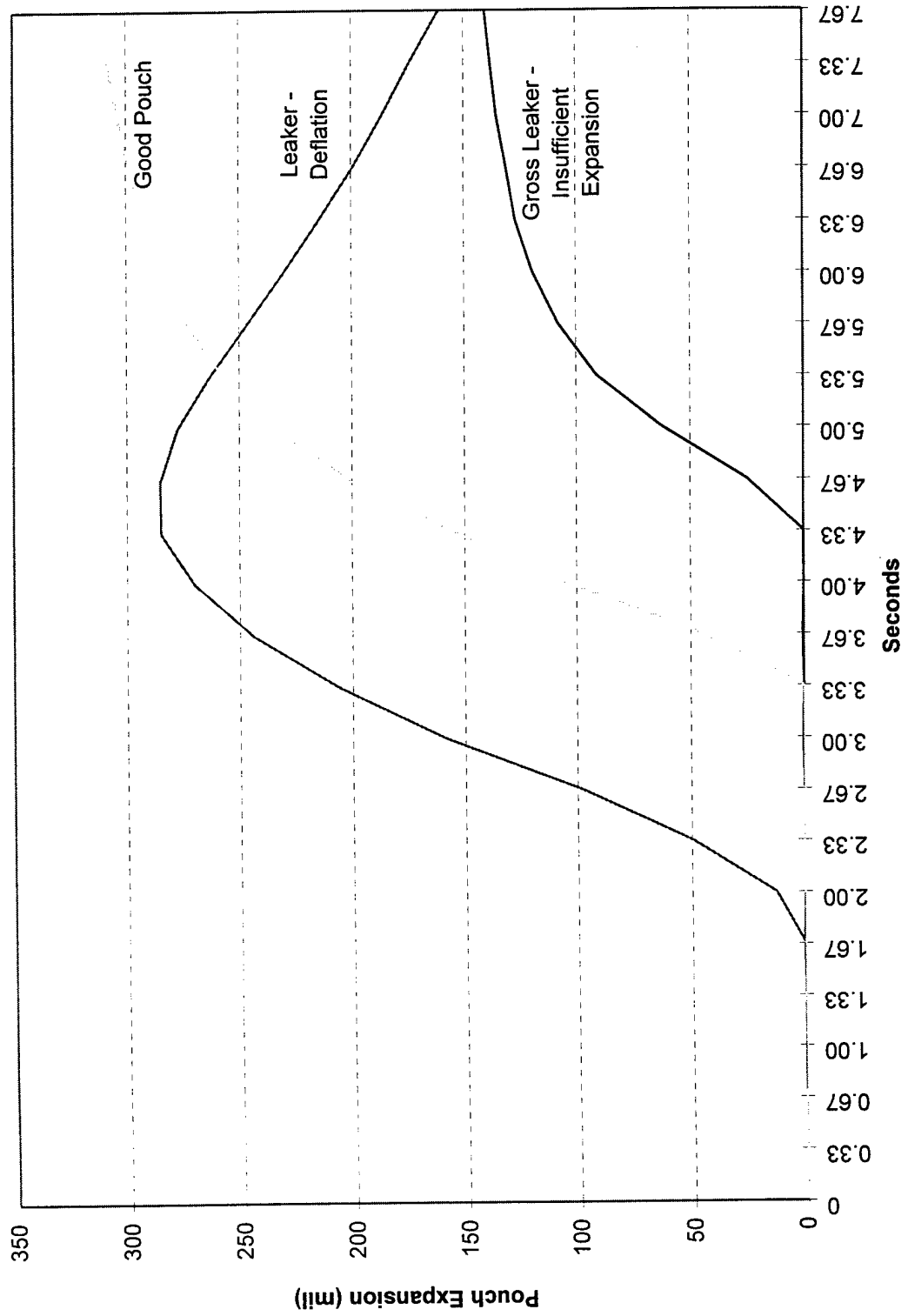
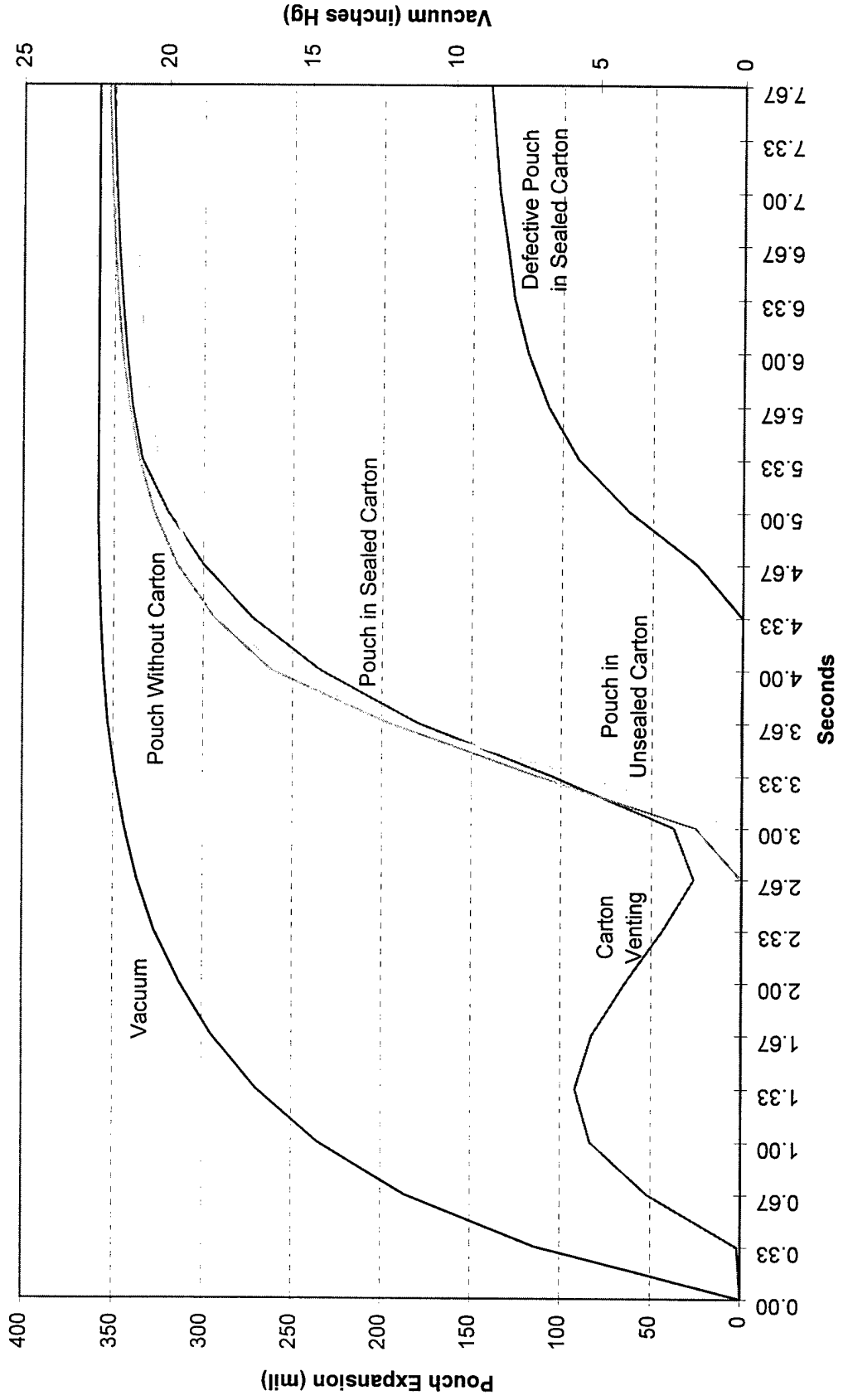
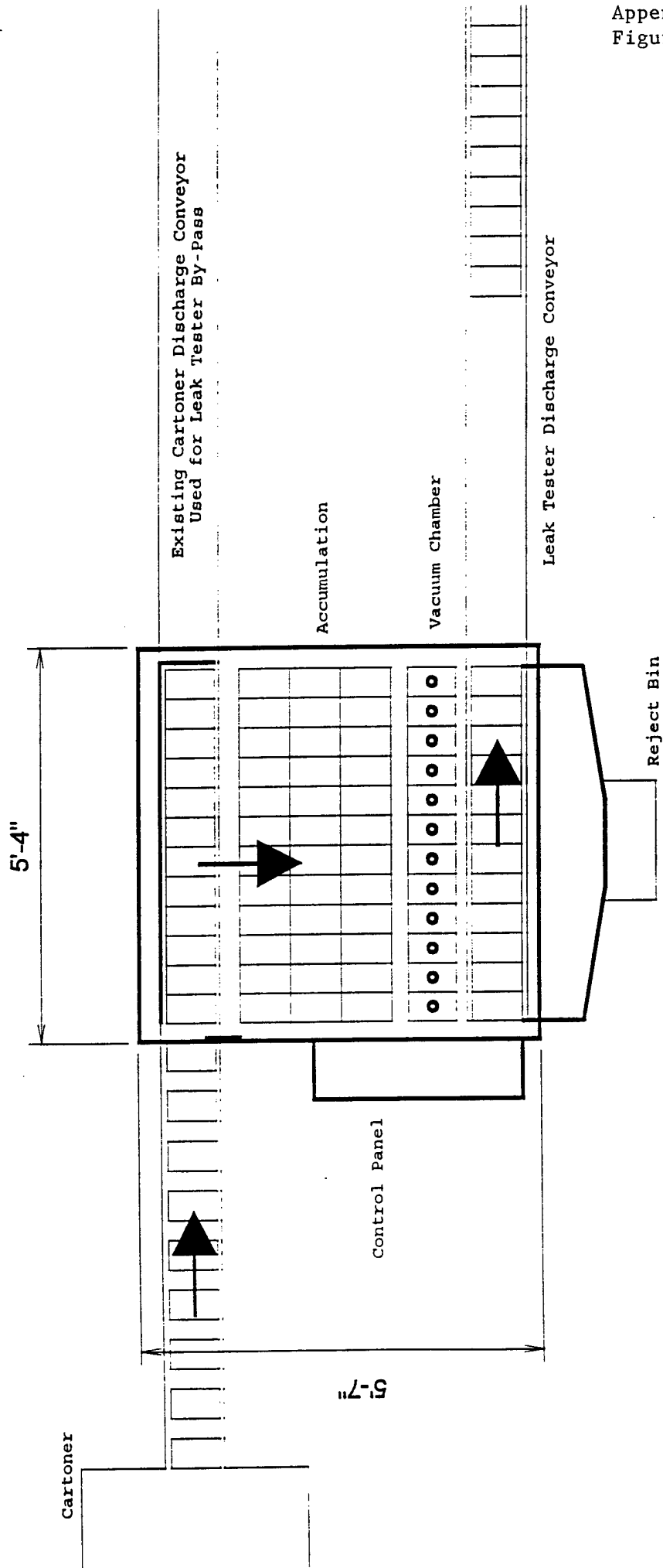


Chart3

### Leak Testing In-Carton





# MRE On-Line Leak Test Machine

## STP # 75, "Leak Detection Implementation"

### Literature Review

Package integrity is a critical step in any quality assurance program. Pouch defect is one of the major problems in MRE (Meal, Ready-to-Eat) production. It is the cause for the high and frequent rate of rejection in produced lots. The high rate of rejection is attributed to the leaks, holes, and microholes detected on the pouches during inspection. The major direct physical causes of leaks in MRE pouches are pouch-to-pouch contact, poor pouch handling, improper design of equipment and retort racks, and poor operating practices.

Leaks have been identified as the major reason for post-process contamination of packaged food, pharmaceutical, and medical products (Anema and Schram, 1980; Put et al., 1980). Detection of leaks in flexible containers is important to package safety and integrity. The types of leaks observed in the MRE pouches are seal defects, puncture (more than 100 microns), abrasion (more than 24 microns), and flexing (more than 11 microns). Based on results of several published studies, it is unlikely that microorganisms will penetrate pinholes less than 20 microns, therefore, test or system capable of detecting leak size of 20 microns will be adequate.

The type of product in MRE pouches may complicate detection of leaks and defects. In retorted pouches, Lampi (1977) stated that fluid can effectively plug small holes and severely reduce the sensitivity of common techniques for detecting gas-flow leaks. In the common Mead test, which involves pulling a vacuum on a submerged pouch and inspecting for escaping bubbles, Lampi (1977) reported that in dry 4.75 X 7.5-inch retort pouches sealed with air only, a 5-micron-diameter hole was easily detected in the pouch body, whereas a 68-micron hole was not detectable in the body of the same pouches filled with distilled water. In biotesting pouches of semisolid agar containing dextrose, Lampi (1977) reported that there is little likelihood of penetration through a defect smaller than 11 microns.

The MRE pouches are subjected to 100% inspection after sealing and retorting. This inspection is conducted by inspectors who check every pouch for defects. The human (visual)

inspection of pouches might be inadequate due to an improper handling of pouches, e.g., pouches are too hot to handle, unclean pouches, untrained employees, and/or fatigue of employees after few hours of work. The integrity of MRE pouches is currently tested by off-line destructive methods such as the burst and dye penetrate (Zyglo) tests. Such methods are labor intensive, slow, costly, and not capable of rapidly detecting pouch defects that occur during processing. A report by Meal Ready-to-Eat Task Force, (1986) showed that leak detected by the Zyglo lab test, (a test used for detection leaks and holes in pouches and pouch materials), are in the visual size range, and are not microscopic in nature. According to this report, the average size hole audited was 2.3 mm (2,300 microns), with a range of 0.2 to 17 mm (200 to 17,000 microns).

It was reported that a non-destructive on-line rotary high speed leak test method using a special vacuum approach was equal or better than the dye test in detecting leaks and invisible cracks in ampules and vials (PTI News, vol 5). Therefore, an effective, non-destructive on-line inspection technique is a good alternative for package inspection. The advantages of such non-destructive technique is quite clear; it is rapid, on-line, and cost effective. It is crucial, in such method, to create real conditions for certain packages, and to pre-set simulated physical stress conditions based on established criteria of a good package (Stauffer, 1990). Therefore, to determine the leak size which is feasible to be detected on a specific package, empirical tests have to be conducted. Calibrated leak sizes made in the package can be correlated, so as to give an accurate idea of how sensitive the tester can be adjusted.

In a technique to test pouches containing fluid food, Lampi (1977) measured the changes in conductivity of deionized water caused by product pushed through the leaks by external pressure applied on the pouches. In this regard, he reported that in laser-drilled defect holes in pouches containing fluid food (chicken a la king, beef slices in barbecue sauce, and pickle-flavored sauce with ground beef), this technique could not be depended upon to detect holes of 100 microns or smaller.

In a simulated handling abuse test, where each package was put through a vibration and drop test sequence, Burke and Schulz (1972) reported that a total of 41 retort pouch failures out of a total of 3600 pouches tested were observed. The smallest defects were found in the body areas of two beefsteak packages. These defects, caused by abrasion and flexing, were small in size (20 - 40 microns) and could not be detected visually.

Critical issues must be addressed when selecting a method for testing, such as the integrity of a package, sensitivity, reliability, repeatability, minimum leak size, type of product in the tested package, and cost (Gnanasekharana and Floros, 1994). Yam (1994) suggested different units or concepts for leak detection. A light sensor unit capable of detecting 10 microns pinholes within a second in lid stock and empty formed pouches. The second suggested unit is a pressure unit capable of detecting channel leaks and seal strength. The principle of this unit is applying a compressed gas through a channel surrounding the seal of the pouch. If the pouch has a weak seal or a leak, the gas will go into and cause a slight movement of the pouch which can be detected by a proximity sensor. Testing conditions in this method is manipulated by the gas pressure and the distance between the two constraining plates holding the pouch in the test chamber. The third suggested unit is a vacuum unit capable of detecting gross leaks and testing seal strength of MRE pouches. In this method, a package or a pouch is placed between two parallel plates in a closed chamber, and air is withdrawn from the chamber to create a vacuum. In this case, the pouch will expand and exert force on the plates. The exerted force as a function of time is monitored with a sensitive load cell connected to a data acquisition system. The behavior of load versus time are indicated by a curve. The slope of the curve for a leaky pouch is significantly different from that of a non-leaky one. The response in this method is influenced by the plate separation, the speed of vacuum applied, the amount of residual gas in the pouch, and the size of the leak.

The vacuum method works well for packages containing dry product or packages having well-defined residual gas. It can detect seal strength and gross leak of 100 microns or more. This method is not appropriate for detecting smaller leaks, particularly in packages containing wet products, since the liquid in such products might plug the leak and make detection

impossible or give false results. Meanwhile, and since this technique relies on gas expansion, a certain amount of residual gas must be present in the tested packages. Yam (1994) stated that a minimum of 2 to 3 cc residual gas is required to satisfy the test.

A single sample vacuum unit (ATC-3 Electronic Package Tester, Applied Technology Concepts, Inc. Towaco, New Jersey) will be used as a model to test the adequacy of vacuum technique in detecting leaks in pouches. This tester can recognize leaks of 5 microns or less, automatically records physical data throughout the test cycle, signals a clear pass/fail and stores complete results. In their final technical report of STP # 21, Litman and Yam reported that the ATC tester can detect for pinholes in MRE pouches consistently with the exception of pinholes at the bottom-center or contaminated seal. They also reported that the ATC tester has a significant higher accuracy for leaks in MRE pouches with 5 cc headspace than that of the Wilco tester.

## References

- [1] Anema, P. J. and Schram, B. L. 1980. Prevention of post-process contamination of semi-rigid and flexible containers. *J. Food Protec.* 43 (6): 460-464.
- [2] Burke, P. T. And Schulz, G. L. 1972. "The Comparative Performance of Flexible Packages and Metal Cans," Tech Rep. 73-62-GP. US. Army Natick Laboratories, Natick, Massachusetts.
- [3] Gnanasekharan, V. and Floros, J. D. 1994. Package integrity evaluation: Criteria for selecting a method. *Packaging Tech. Engin.* August/September.
- [4] Lampi, R. A. 1977. Flexible Packaging for Thermoprocessed Foods. p. 305. In "Advances in Food Research", C. O. Chichester (ed), Volume 23, Academic Press, New York
- [5] Litman, N. and Yam, K. "Non-Destructive Prototype to Inspect MRE Pouch Seal Integrity". Final Technical Report, STP#21. Rutgers, The State University of New Jersey, The Center for Advanced Food Technology, Cook College. December, 1996.
- [6] Meal, Ready-to-Eat (MRE) Task Force Report. July, 1986. Sponsored by Office of the Deputy Chief of Staff for Logistics Headquarters Department of the Army, The Pentagon, Washington, DC. 20310-0500
- [7] PTI News. Vol 5. Published by Packaging Technology and Inspection, 145 Main Street Tuckahoe, New York, 10707. USA
- [8] Put, H. M. C., Witvoet, H. J. and Warner, W. R. 1980. Mechanism of microbiological leaker spoilage of canned foods, Biophysical aspects. *J. Food Protec.* 43 (6): 488-497.
- [9] Stauffer, T. 1990. Non-destructive testing on flexible packaging. *J. Pack. Technol.* July/August.
- [10] Yam, K. L. 1994. On-line inspection system and testing method for pouch integrity. Final technical report, STP#7. The Center for Advanced Food Technology, Rutgers University, Cook college, New Brunswick, New Jersey.

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**COMBAT RATION  
ADVANCED MANUFACTURING  
TECHNOLOGY DEMONSTRATION  
(CRAMTD)**

**Leak Detection Benchmark Testing:  
Modified ATC-3**

**Technical Working Paper (TWP) 115**

**M. Gultekin, I.M. Laham, E.A. Elsayed and H.B. Bruins**

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## LEAK DETECTION BENCHMARK TESTING: MODIFIED ATC-3

### Introduction and Background

The leak detection technique analyzed in this project is a nondestructive one which tests the pouches in a vacuumed environment (Leak Detection Tester, model ATC-3, No. 920616, Applied Technology Concept, Inc. Towaco, New Jersey).

The ATC-3 leak tester used in this study intend to test flexible foil-laminate pouches. A pouch is placed into the test chamber or drawer, and the drawer is then closed, where the tested pouch will be placed below a sensor (the distance between the pouch and the bottom of the sensor is an important factor that should be adjusted before the experiments). When the test starts, a vacuum is drawn inside the drawer and the pouch expands. The expansion of the pouch is monitored with the sensor. The vacuum and expansion data collected during the test is used to determine if the pouch is leaking. A non-defective pouch is expected to expand as the vacuum increases, while a defective pouch is expected either not to expand or to deflate after a certain level. Examples of curves of a non-defective and a defective pouch are given in Figures 1 and 2.

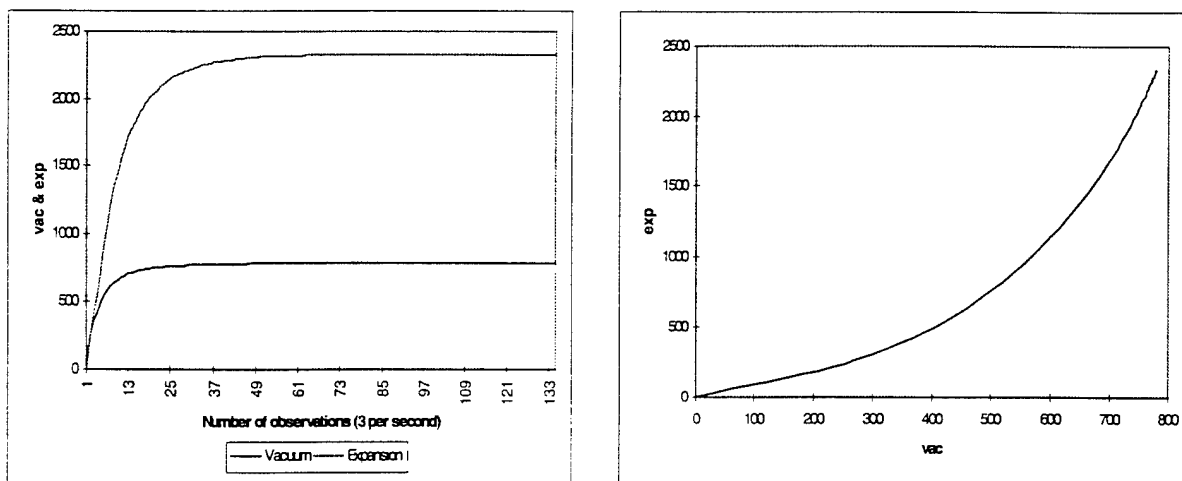
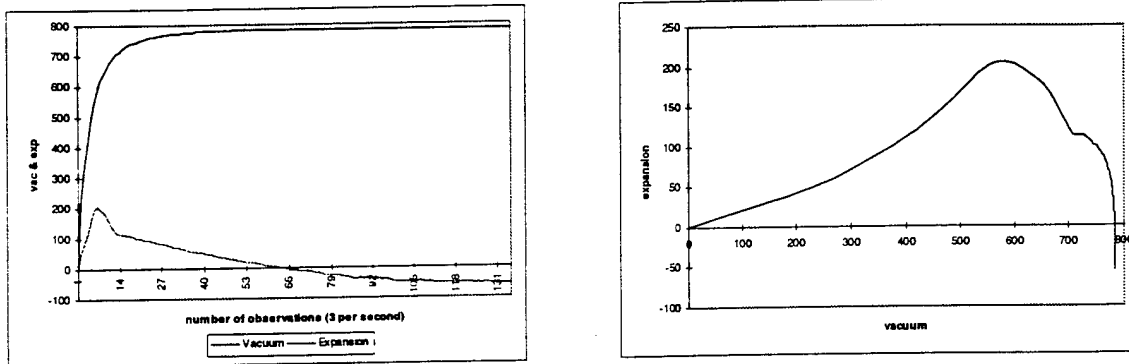


Figure 1. Vacuum and Expansion vs. Number of Observations and Expansion vs. Vacuum curves of a nondefective pouch.



**Figure 2. Vacuum and Expansion vs. Number of Observations and Expansion vs. Vacuum curves of a defective pouch.**

The ATC-3 leak tester was originally designed to test small size packages. This can be easily seen when the foot print of the sensor area is compared to the small area of a pouch. A pouch is placed in the drawer in such a way that the sensor touches the middle of the pouch. However, it is not always the case that the pouch expands uniformly over the whole area. Modifications were made to the ATC-3 tester to ensure that it measures an average expansion of the pouch rather than the expansion of a small area.

Expansion of the pouch is due to the expansion of gases inside the pouch. The material inside the pouch is a factor which should be considered. In some cases, the residual gas inside the pouch may be entrapped in the food materials and resist escaping. This might cause the food to expand due to the residual gas in it.

To make the leak tester more suitable for testing the pouches, some modifications were made prior to testing. These modifications are explained below:

1. In order for the vacuum to reach the steady state level quicker, the drawer was filled with glass beads to reduce the head space.
2. Since the area of a pouch was much larger than the area of the sensor, it was not possible to get repeatable measurements of expansion of the pouch (in areas other than the middle). Therefore, aluminum plates were placed on top of the pouch during the experiment and the sensor measured the movement of the plate. The area of a plate

was large enough to cover the whole pouch. This set up, in combination with item # 4, ensured us that we were measuring an average expansion of the pouch.

3. The plates at the bottom and on the top of the pouch were covered with polyethylene type mesh to allow the pouch to leak and prevent the plates from sealing the defect.
4. To cause pressure difference and to help the pouches expand uniformly, a spring was used to exert a force on the plate, which lays on the top of the pouch (see item # 2). The effect of this spring load was that a force ranging from 0.5 lbf to 2.5 lbf was created as the pouch expanded. This force was converted with the aid of the plate into a pressure differential ranging from approximately 0.02 psi to 0.1 psi over a potential hole in the pouch, causing flow of liquid or gas through the hole. Due to design limitation of the instrument, we were not able to test stronger springs, however it is expected that a stronger spring will make the tester more sensitive to smaller holes but less sensitive to lower residual gas levels. The spring in combination with the plates also improved the test repeatability.

## **Experiments**

### **Objective of the Experiments:**

The main objective of this study was to characterize the performance of the ATC tester as a function of various product and process parameters such as the type of leak, residual gas, pouch temperature, location of defect, etc.

### **Factors:**

An important step in designing an experiment is determining the variables (or factors). Generally, there are four classes of variables that should be considered:

1. Response variables: These are the dependent variables that capture, as much as possible, a quantity or quality of interest for the experimental unit.
2. Control variables: These are the variables that are measurable, controllable and thought to be influential.
3. Held-constant factors: Held-constant factors are controllable and their effects are not of interest in the experiment.
4. Uncontrollable (nuisance) factors: These factors either cannot be controlled or they are difficult to control.

The factors chosen for our experiments are explained in the tables given below. While determining the factors, both the experience of the CRAMTD people and the previous studies made on leak detection were utilized.

### Response Variables

Response variable (units)	Normal operating level or range	How is it known?	Relationship of response variable to objective
maximum expansion	no information	Given as a result of the test.	For a good pouch, the expansion curve increases continuously.
correlation	no information	Given as a result of the test.	For a good pouch, the correlation between the expansion and vacuum curves is high.
drop off	no information	Given as a result of the test.	For a good pouch, no or very small drop off is expected.
area	no information	Given as a result of the test.	For a good pouch, the area is negative.

### Control Variables

Control variable (units)	Normal level or range	How is it known?	Proposed settings, based on predicted effects	Predicted effects (for various responses)
residual gas	0 - 10	During the production, sample pouches were taken and the amount of residual gas was measured in these samples. Precision of these measurements is unknown.	005-15-25 cc.	When the amount of residual gas inside the pouch increases, the pouch is expected to expand more.
temperat-ure	70°F- ambient temp. 100°F-post-retort temp.		70-85-100 °F	The temperature is expected to have a slight effect on the residual gas.
defect type a. hole size  b. slit		Holes will be formed by using needles of the appropriate size.	300-600 μm	The shape of the expansion curve may change according to the defect type.
location of defect	top film bottom film		1/16-1/8" top film bottom film	If the defect is at the bottom center, the food inside the pouch may clog the defect.

**Note 1.** Top film is the non-formed film in a pouch manufactured on a horizontal form fill seal line.

**Note 2.** Bottom film is the formed film in a pouch manufactured on a horizontal form fill seal line.

### Held-constant Factors

Factor (units)	Desired experimental level and allowable range	How to control (in experiment)	Anticipated effects
product type	ham slice	-	May show a behavior different than that of a product with liquid component.
vacuum level of ATC	20 inches Hg	check at the beginning of each set of experiment. Also see Note 1.	-
test duration	45 sec.	set at the beginning of the experiment as a threshold.	-
A/D conversions	20	set at the beginning of the experiment as a threshold.	-
range	10 volt	set at the beginning of the experiment as a threshold.	-
carton	in carton (See Note 2)	-	The pouches are expected to expand more regularly.
drawer volume	small	fill the drawer	If the volume is small, the curve comes up quicker.
film	Reynolds	-	-
ham slice size	5/8"	Sliced on mechanical slicer	-

**Note 1:** A table mount manometer was set up and used to calibrate the vacuum gauge on the leak tester.

**Note 2:** As a result of the preliminary tests, it has been decided to test the pouches out of the carton. During these preliminary tests, it was found that the edges of the carton prevent the plates placed on top from touching the pouch. These prevented the measurement of the real expansion of the pouch.

### Interactions

Control variable	residual gas	temperature	hole	slit	location of defect
residual gas	-	weak	none	none	none
temperature	-	-	none	none	none
hole	-	-	-	none	none
slit	-	-	-	-	none
defect location	-	-	-	-	-

The interactions given in the above table are based on discussions with CRAMTD personnel.

## **Experimental Design.**

### **Phase I:**

The experiments were run after defining the factors. The ham slices were packed into the pouches and retorted. During packaging, three different packing conditions were used to yield lots with different residual gas levels (5 cc, 15 cc and 25 cc). After retorting, each lot was divided into three groups and each group was kept under different temperature (70°F, 85°F and 100°F). During the experiments, each level combination was tested in a randomized order.

Three sets of experiments were run; pouches with no defects, pouches with holes, and pouches with slits. The design selected for the experiments was a full factorial design with the factors and levels given below. Three replications were made for each combination.

<u>Factors</u>	<u>Levels</u>
Temperature	70 , 85 , 100°F
Residual Gas	5 , 15 , 25 cc.
Defect Size:	
Hole Size	300 , 600 µm.
Slit Size	1/16" , 1/8"
Location of Defect	Top film , Bottom film

The thresholds of the ATC-3 tester were set as follows:

Minimum expansion	0.5%
Drop off	2
Regression	0

Threshold values means that a pouch will fail the test if it does not expand as much as 0.5% or its drop off value is greater than "2", or if its regression value is less than "0". Otherwise, the pouch passes the test.

**Phase II:**

To improve the efficiency of the leak tester, a second set of experiments was performed, in which the pouch was tested twice, once straight up and once upside down. It was concluded after the first experiment, that the efficiency of the tester is significantly affected by the location of the defect, leading to the hypothesis that the ham slice was sealing the defect from the inside, and that a performance increase could be achieved if the pouch was tested in two positions. The accept/reject criteria would then be based on the combined result of both tests. Each experiment was repeated twice. The parameter values were as follows:

Temperature	70 , 85 , 100°F
Residual Gas	5 , 15 , 25 cc.
Hole Size	300 $\mu$ m.
Location of Defect	Top film , Bottom film
Test Position	Straight-up and Up-side-down

## Results

### Phase I.

#### A. Non-Defective Pouches:

First, the experiments with non-defective pouches were made. The pouches were first tested straight up (on top), where, pouches were laying on their bottom film, and then tested up-side-down (on bottom) where pouches were laying on their top film. A total of 54 experiments were made (three replicates per tests). The number of pouches that were signaled as defective pouches are shown in Table 1 below.

	5 cc		15 cc		25 cc		
	OT	OB	OT	OB	OT	OB	
70°F							
85°F							
100°F	2		1		2	1	6
	2		1		2		6

**Table 1. Experiments with nondefective pouches. The number of pouches that failed in the test are shown in each cell (OT: Tested on top, OB: Tested on bottom).**

Using Table 1, Type I error ( $\alpha$  error) can be obtained. This is defined as the probability of rejecting a pouch given that it is a nondefective one ( $= P(\text{rejecting a pouch} / \text{a nondefective pouch})$ ). Since the same pouches were used when testing on top and on bottom, each testing position was considered separately.

$$\text{Type I error (OT)} = 5/27 = 18.5\%$$

$$\text{Type I error (OB)} = 1/27 = 3.7\%$$

Type I error can be obtained under different groups as given below:

$$\text{Type I error (5 cc - OT)} = 2/9 = 22.2\%$$

$$\text{Type I error (15 cc - OT)} = 1/9 = 11.1\%$$

$$\text{Type I error (25 cc - OT)} = 2/9 = 22.2\%$$

$$\text{Type I error (5 cc - OB)} = 0.0\%$$

$$\text{Type I error (15 cc - OB)} = 0.0\%$$

$$\text{Type I error (25 cc - OB)} = 1/9 = 11.1\%$$

$$\text{Type I error (70°F - OT)} = 0.0\%$$

$$\text{Type I error (85°F - OT)} = 0.0\%$$

$$\text{Type I error (100°F - OT)} = 5/9 = 55.5\%$$

$$\text{Type I error (70°F - OB)} = 0.0\%$$

$$\text{Type I error (85°F - OB)} = 0.0\%$$

$$\text{Type I error (100°F - OB)} = 1/9 = 11.1\%$$

The large Type I error at 100°F was noticed immediately. The reason for the rejection was the negative regression number, calculated by the ATC software. This negative regression number might be related to the cooling effect of the pouches at 100°F. Cooling might cause the residual gas inside the pouch to shrink. This would affect the inflation curve of the pouch when the vacuum is applied in the tester chamber and causes higher Type I error.

#### B. Pouches with Holes and Slits:

The second and third set of experiments were made on the pouches with holes and slits, respectively. In each set, a total of 108 experiments were made. Based on the results, Type II error ( $\beta$  error) can be calculated. Type II error is defined as the probability of accepting a pouch given that it is a defective pouch (=  $P(\text{accepting a pouch} / \text{a defective pouch})$ ). The number of pouches that were signaled as nondefective are given in Tables 2 and 3. The Type II error, in general and according to different groups, can be found under the tables. All the pouches were placed up-side-down in the test chamber.

		5 cc		15 cc		25 cc		
		300 $\mu\text{m}$	600 $\mu\text{m}$	300 $\mu\text{m}$	600 $\mu\text{m}$	300 $\mu\text{m}$	600 $\mu\text{m}$	
70°F	T	3	1	2	1	1	1	9
	B							
85°F	T	2	1	3		1		7
	B							
100°F	T	1	2	1	2	2		8
	B							
		6	4	6	3	4	1	24

**Table 2. Pouches with holes. The number of pouches that passed the test are shown in each cell. T: Defect is located on top film. B: Defect is located on bottom film (formed film).**

**Note:** Pouches were tested up-side-down

	<u>Efficiency</u>
Type II error = $24/108 = 22.2\%$	77.8%
Type II error (5 cc) = $10/36 = 27.8\%$	72.2%
Type II error (15 cc) = $9/36 = 25.0\%$	75%
Type II error (25 cc) = $5/36 = 13.8\%$	86.2%
Type II error (70°F) = $9/36 = 25.0\%$	75%
Type II error (85°F) = $7/36 = 19.4\%$	80.6%
Type II error (100°F) = $8/36 = 22.2\%$	77.8%
Type II error (300 $\mu\text{m}$ ) = $16/54 = 29.6\%$	70.4%
Type II error (600 $\mu\text{m}$ ) = $8/54 = 14.8\%$	85.2%
Type II error (defect in top film) = $24/54 = 44.4\%$	55.6%
Type II error (defect in bottom film) = $0.0\%$	100%

		5 cc		15 cc		25 cc		
		1/8"	1/16"	1/8"	1/16"	1/8"	1/16"	
70°F	T		3		2		1	6
	B							
85°F	T			1	3		3	7
	B			1				
100°F	T				1	1	2	4
	B							
			3		2		6	1
							6	18

**Table 3. Pouches with slits. The number of pouches that passed the test are shown in each cell. T: Defect is located on top film. B: Defect is located on bottom film (formed film).**

	<u>Efficiency</u>
Type II error = 18/108 = 16.7%	83.3%
Type II error (5 cc) = 3/36 = 8.33%	91.7%
Type II error (15 cc) = 8/36 = 22.2%	77.8%
Type II error (25 cc) = 7/36 = 19.4%	80.6%
Type II error (70°F) = 6/36 = 16.7%	83.3%
Type II error (85°F) = 8/36 = 22.2%	77.8%
Type II error (100°F) = 4/36 = 11.1%	88.9%
Type II error (1/8") = 3/54 = 5.6%	94.4%
Type II error (1/16") = 15/54 = 27.8%	72.2%
Type II error (defect on top film) = 17/54 = 31.5%	68.5%
Type II error (defect on bottom film) = 1/54 = 1.9%	98.1%

Considering the last two sets of experiments together, an average Type II error of 19.4% was obtained with the range of variables. The efficiency of a test is defined as

$$\text{Efficiency} = 1 - (\beta \text{ error})$$

It can be concluded that the efficiency of the leak tester increases as the defect size increases, and it can also be concluded that the efficiency of the leak tester is significantly effected by the location of the defect. This last observation leads to the hypothesis that a significant performance increase is expected if the pouch is tested in both positions (straight up and up-side-down).

### C. Failure Types

The pouches fail the tests according to following three criteria.

1. Regression analysis failure: The regression threshold limit is defined while setting up the leak tester. If the regression figure calculated by the leak tester is below this limit, then the pouch fails the test.
2. Pouch does not expand: A threshold limit for minimum expansion is defined while setting up the leak tester. If the pouch does not expand as much as the threshold value, the pouch fails the test.
3. Pouch expands and then deflates: A threshold limit for the drop off is defined while setting up the leak tester. If the calculated drop off figure is greater than the threshold value, the pouch fails the test.

The failure pattern of the pouches can be analyzed by grouping the failure criteria for different testing conditions. This grouping has been done for nondefective pouches (Figure 3), pouches with holes (Figure 4) and pouches with slits (Figure 5).

When Figure 3 is analysed, it will be seen that whenever a nondefective pouch failed, it was more likely that the reason was Criteria #1 (regression analysis failure) or Criteria #1 accompanied by Criteria #3 (pouch expands and then deflates). It should be noted that all of the failures occurred at 100°F.

The failure pattern of the pouches with holes is illustrated in Figure 4. It is seen that none of the pouches failed due to Criteria #2. The pouches always expanded more than the minimum threshold limit defined. The difference in the patterns when the hole is located on the top or on the bottom is quite noticeable. Although there is not much difference between the number of failures due to Criteria #1 or Criteria #3 when the hole is located on the top, the number of failures due to Criteria #3 only or due to Criteria #1 and #3 increases when the hole is located on the bottom. The same comparison can be made for the pouches with 300  $\mu\text{m}$ . and 600  $\mu\text{m}$  holes. As the hole size increases, Criteria #3 alone or together with the Criteria #1 becomes more dominant.

This analysis can be made for pouches with slits, too (Figure 5). Even though the number of failures due to Criteria #2 is not significant, these kind of failures are observed in some cases. The observations related to the location and size of the defect made for pouches with holes are also valid in the case of pouches with slits.

With the exception of a few cases, it can be seen from these figures that the number of failures due to Criteria #3 is greater than the number of failures due to Criteria #1, and most of the time they occur together. This can be explained in the following way: The regression figure (the slope of the line fitted by least squares method) is calculated using the last one third of the data points, whereas the drop off is calculated using all the data points. It is possible for a defective pouch to expand again slightly even after a significant drop off.

It is also possible to calculate the probability that the pouch with a hole (or a slit) at a given condition failed because of a certain criteria.

$P_x^d(ABC)$  = The probability that a pouch failed due to Criteria ABC, given that it has a defect type d (hole or slit) and failed at the testing condition x.

For example, if a pouch with a hole at 70°F failed, the probability that it was due to only Criteria #3 is 0.17 and the probability that it was due to only Criteria #1 is 0.72.

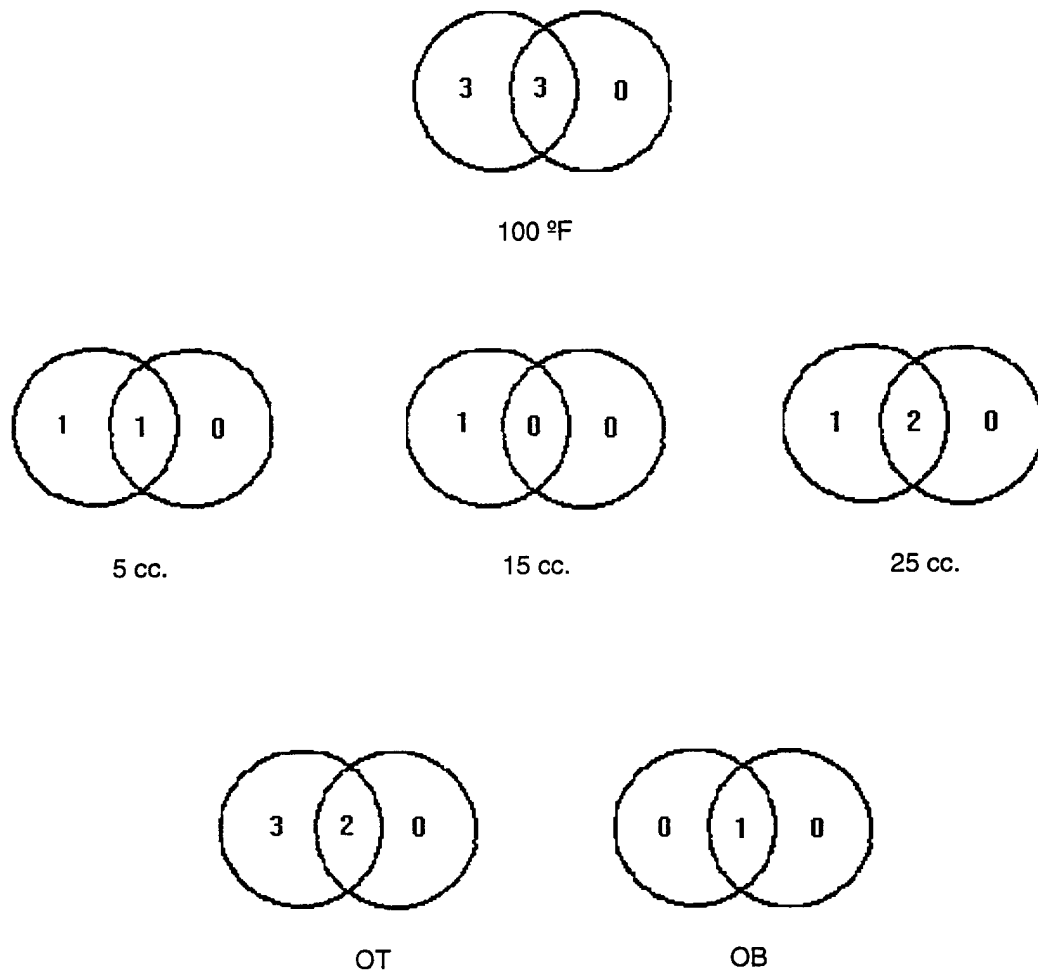


Figure 3:  $\overset{A}{\circ} \overset{B}{\circ}$  Failure types A and B grouped under different conditions for nondefective pouches. A (Criteria #1): Pouch failed due to regression analysis failure, B (Criteria #3): Pouch expanded and then deflated.

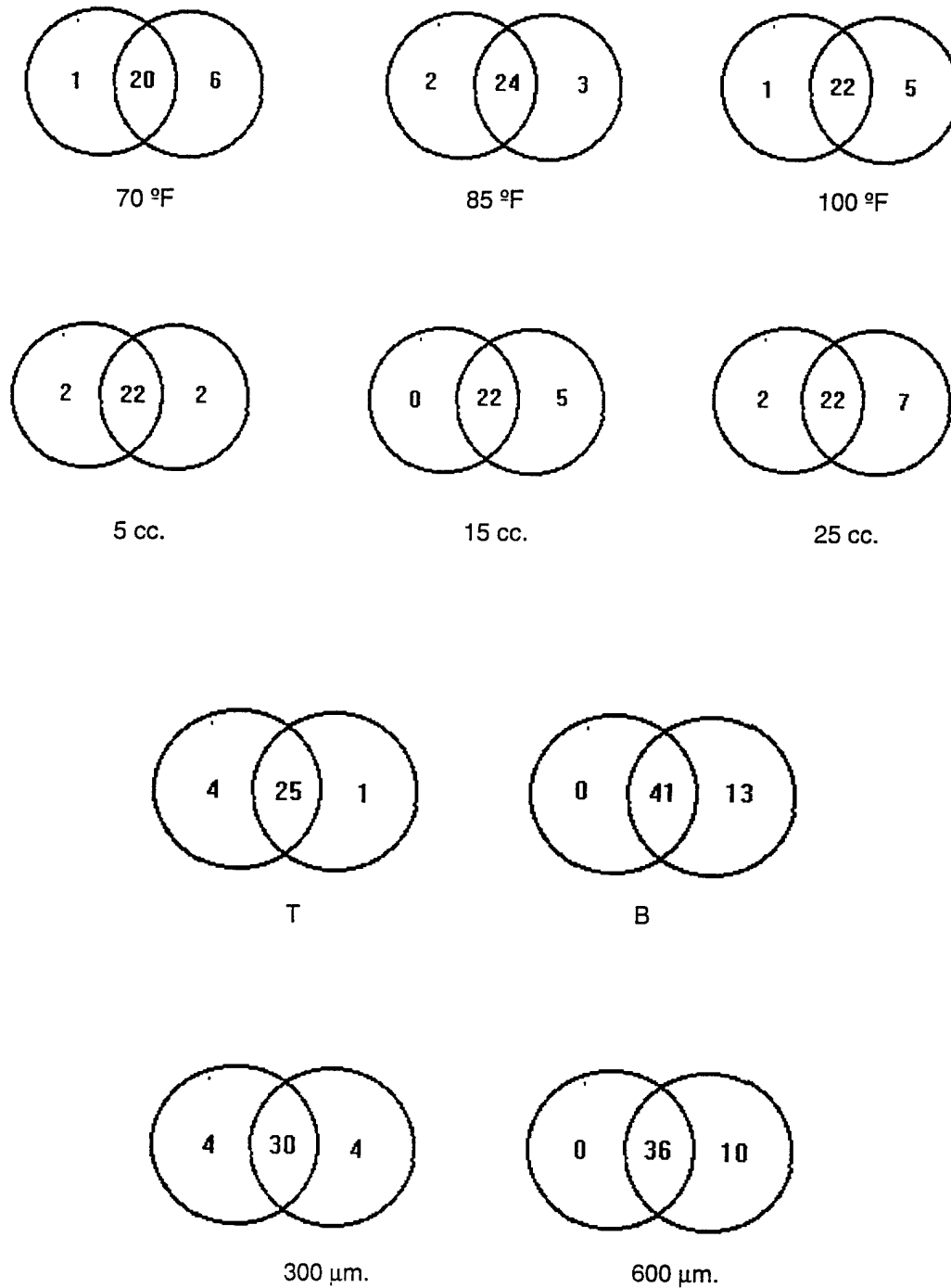



Figure 4:  Failure types A and B grouped under different conditions for pouches with holes. A (Criteria #1): Pouch failed due to regression analysis failure, B (Criteria #3): Pouch expanded and then deflated.

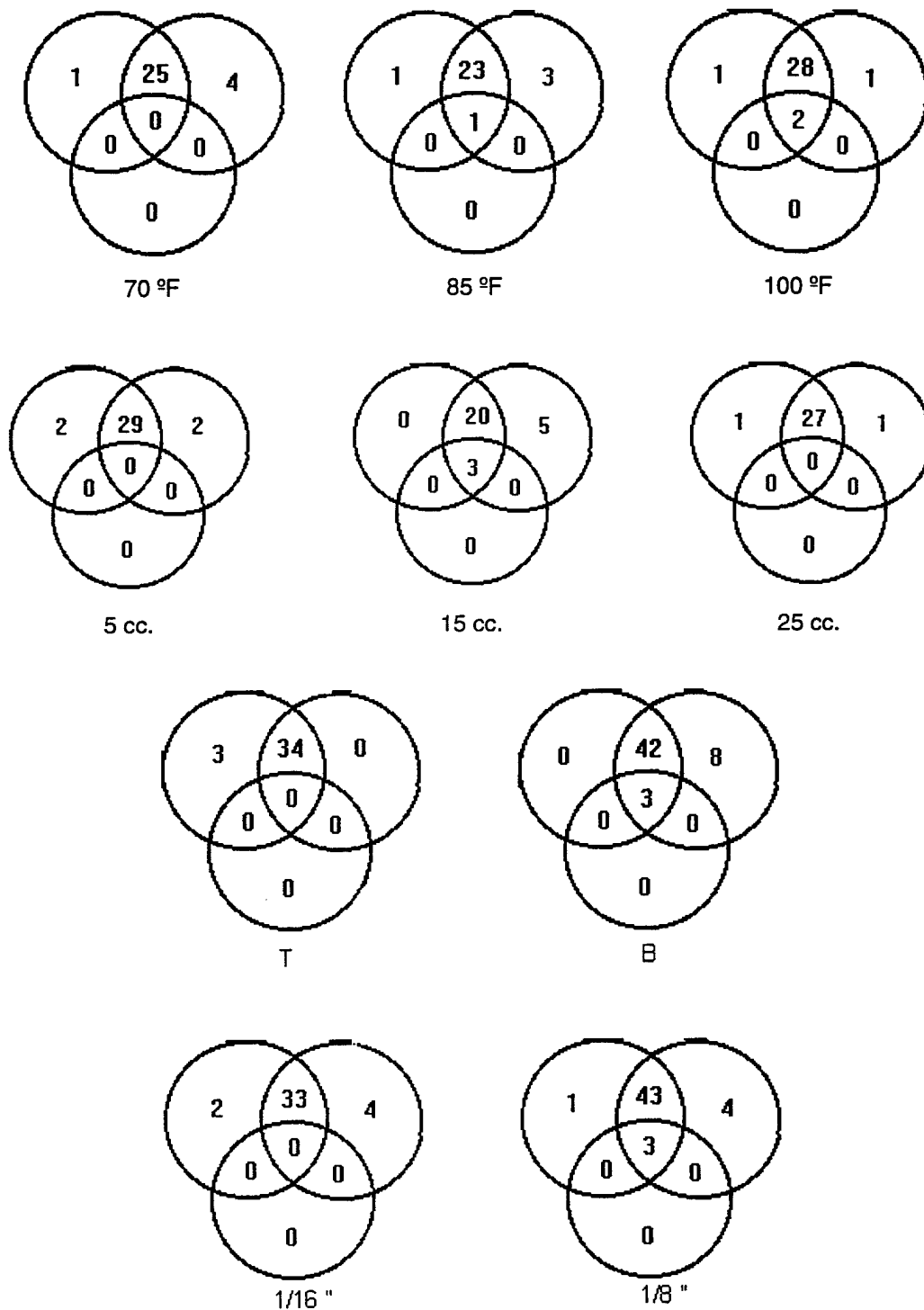


Figure 5: Failure types A, B and C grouped under different conditions for pouches with slits. A (Criteria #1): Pouch failed due to regression analysis failure, B (Criteria #3): Pouch expanded and then deflated, C (Criteria #2): Pouch failed to expand.

#### D. Further Analysis on the Curves and Threshold Values:

1. If an abnormality is observed in the expansion vs. time or expansion vs. vacuum curves, the first thing to do must be to check whether there was a decrease in the vacuum level during the experiment. If there is no decrease, then these curves can be analyzed further.
2. Even though some of the defective pouches were signaled as nondefective by the tester, considering of the curve pattern could increase accuracy. Two figures showing the expansion vs. vacuum curves are presented below. Figure 6 shows the curve of a pouch with a 300  $\mu\text{m}$  hole, while figure 7 shows the curve of a pouch with a 1/8'' slit. These pouches were signaled as nondefective pouches by the tester. These curves would allow us to reject these two pouches (Also see Table 4).

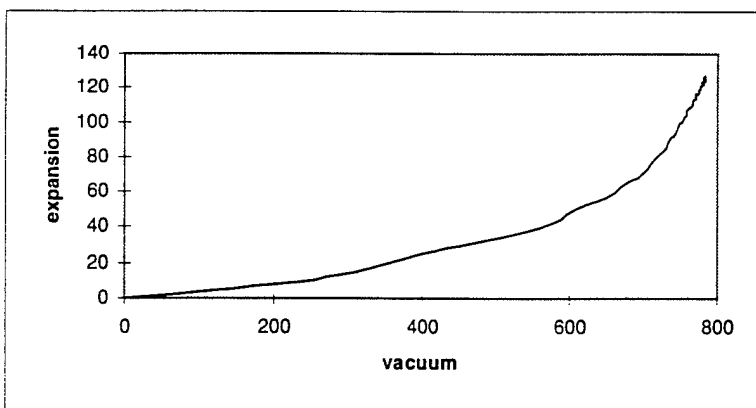


Figure 6. Expansion vs. vacuum curve of a pouch with a 300  $\mu\text{m}$  hole.

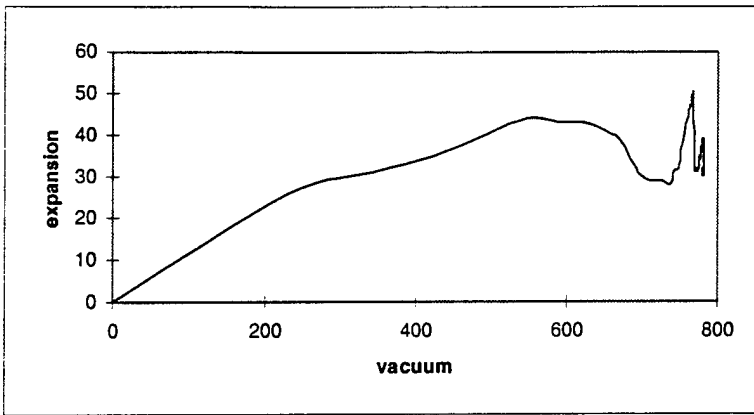


Figure 7. Expansion vs. vacuum curve of a pouch with a 1/8" slit.

3. Results with different ATC set ups:

If changes are made to the threshold values and set as follows:

Minimum expansion 0.5%

Drop off 0

Regression 0

then an increase in the Type I error and a decrease in the Type II error can result (Table 4).

	5 cc		15 cc		25 cc			
	OT	OB	OT	OB	OT	OB		
70°F								
85°F					1*		1	
100°F	2		2*		2	1	7	
	2		2		3		1	8

Table 4a. Number of nondefective pouches rejected as defective.

\*1 pouch is accepted because of the change in threshold values.

		5 cc		15 cc		25 cc		
		300 $\mu\text{m}$	600 $\mu\text{m}$	300 $\mu\text{m}$	600 $\mu\text{m}$	300 $\mu\text{m}$	600 $\mu\text{m}$	
70°F	T	1*	1	1**	1	1	1	6
	B							
85°F	T	2	1	3		1		7
	B							
100°F	T	1	1**	1	2	2		7
	B							
		4	3	5	3	4	1	20

**Table 4b. Number of pouches with holes that are accepted as nondefective.**

\*1 pouch is rejected because of the irregular pattern of its expansion vs. vacuum curve and another pouch is rejected because of the change in threshold values.

\*\*1 pouch is rejected because of the change in threshold values.

		5 cc		15 cc		25 cc		
		1/8"	1/16"	1/8"	1/16"	1/8"	1/16"	
70°F	T		3		2		1	6
	B							
85°F	T			1	2**		2**	5
	B			0*				
100°F	T				0**	1	2	3
	B							
			3	1	4	1	5	14

**Table 4c. Number of pouches with slits that are accepted as nondefective.**

\*1 pouch is rejected because of the irregular pattern of its expansion vs. vacuum curve.

\*\*1 pouch is rejected because of the change in threshold values.

Type II error decreased from 19.4% to 15.7%, so the efficiency of the tester increased to 84.3%. But Type I error (OT & OB) increased from 11.1% to 14.8%. If we exclude the experimental data at 100 F, type I error would increase from 0% to 1.9%

4. During the analysis of the expansion vs. vacuum curves, the slope between the initial point and other points on the curve was calculated. It was found that the slope between the first two points may be an indication of a defective pouch that behaves like a nondefective one. This point should be analyzed further.

**Phase II.**

Based on the results of the previously described experiments, it was concluded that the type II errors could significant be reduced if the pouch would be tested on both sides rather than on only one side. To test this hypothesis, a defective pouch was tested by the ATC first in the up-side-down position and then in the straight-up position. The same criteria were used as initially used in the first experiments. To limit the scope of these experiments, only 300 micron holes were created, and each condition has only two repeats. Table 5 contains the results of this test, a "P" stands for Pass and a "F" stands for Fail. The assumption is that if a pouch fails either tests then the pouch is defective. Table 6 summarizes the data and displays the number of false predictions (defective pouch passed both tests)

		5 cc		15 cc		25 cc	
		OB	OT	OB	OT	OB	OT
70°F	T	F/F	P/P	F/F	P/P	F/F	P/P
	B	P/F	P/P	F/F	F/P	F/F	F/F
85°F	T	P/P	P/P	F/F	P/P	F/F	P/F
	B	P/P	F/P	P/F	F/F	F/F	F/F
100°F	T	F/F	F/F	F/F	P/P	F/F	P/P
	B	F/P	F/F	F/F	F/F	F/P	F/F

**Table 5. Results of the experiments made by testing pouches both on their top and bottom. OB: tested on bottom (straight up). OT: tested on top (up-side-down). T: defect is located on top web of the pouch. B: defect is located on bottom web of the pouch)**

Product Temp.	Defect Location	5 cc	15 cc	25 cc
70 F	Top Film	0	0	0
	Bottom Film	1	0	0
85 F	Top Film	2	0	0
	Bottom Film	1	0	0
100 F	Top Film	0	0	0
	Bottom Film	0	0	0

**Table 6. Type II errors of double sided test protocol**

The results of these experiments can be summarized as follows:

1. The total number of defective pouches that failed either straight up or up-side down was 32 out of 36, hence the type II error would be reduced from 29.6% to 11.1%.
2. In order to calculate the type I error, we have to go back to Phase I where nondefective pouches were tested on both sides. The total number of good pouches that failed either the straight-up or the up-side-down test was 6 pouches out of 27 pouches, increasing the type I error from 11.1% to 22.2%. If we exclude the experimental results with 100 F product temperature, then the type I error would remain at 0%
3. Adjusting the threshold values, as we did previously, does not improve the type II error results.
4. Even though the double testing decreases the type II error, a major drawback of this procedure is that it consumes more time and requires more capital to automate.

## Recommendations

The intent of these tests was to establish a base line performance against which other leak testing equipment should be compared. The performance of a tester needs to be expressed in type I and type II errors. Even though the performance of the ATC, both in type I and type II errors was not spectacular, it performed better than the human inspectors. The methodology followed to quantify the performance of the ATC should be used to quantify the performance of other leak detection systems as well. Systematic evaluation of a tester can supply valuable information regarding the tester and its performance as function of various process and product factors. The following recommendations can be made to potentially improve the performance of the ATC tester:

1. It was demonstrated that testing a pouch on both sides, reduces the type II error. However it also double the time requirements for the test. The limiting factor for the test is the evacuation system. It is recommended to equip the ATC with a vacuum pump and vacuum reservoir in order to reduce the evacuation time to less than 2 seconds.
2. Type I error seems to increase as the product temperature increases. It might be necessary to control the temperature of the test chamber in order to avoid the cooling of the pouch. This problem might, however, not be as severe as indicate in these experiments if the test cycle time is significantly reduced.
3. The use of the spring in the system increased the repeatability of the system as it created a pressure differential on the defect. It is recommended to change the design of the ATC to either allow the use of stronger springs or the use of hydraulic pressure to increase the pressure differential.
4. Frictional forces are still causing some variations in repeatability experiments. It is recommended to review the design of the ATC to reduce/eliminate any frictional forces.

5. It was concluded during the preliminary trials that a plate should be used to enforce uniform expansion of the pouch, and that the plates needed to be covered with a mesh material to allow gas or fluid to flow out of the pouch.
  
6. Some advanced algorithms and tests methods were evaluated within the limited time of this project. However, we recommend that this effort continue.

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**COMBAT RATION  
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**Human Inspection of Retort Pouches:  
Experimental Method and Example**

**Technical Working Paper (TWP) 116**

**M. Gultekin, I.M. Laham and H.B. Bruins**

**February 1997**

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## **Human Inspection of Retort Pouches: Experimental Method and Example**

### **Introduction:**

It is a requirement, in any retorted MRE producing plant, to employ two 100% inspection pre- and post-retorting. The MRE producing plants are currently rely on human inspection to fulfill this requirement. The human inspection of pouches might be inadequate due to an improper handling of pouches, e.g., pouches are too hot to handle, unclean pouches, untrained employees, and/or fatigue of employees after few hours of work. This allows an excessive number of defects in the finished product lots, and lowers the probability of lot acceptance to an undesirable level. Increasing the efficiency of inspection would decrease the defect ratio in the finished product lot, and hence, increase the probability of lot acceptance.

One of the technical activities of short term project (STP# 75) is to characterize the human inspection and to determine the efficiency of human inspection system. An experiment was initiated to inspect retorted ham slice pouches at different speeds, under two source of lights; Table light, and Light with magnifying glass.

### **Experiment Outlines:**

A quantity of 100 pouches of retorted ham slice were used in this experiment. Defects were made on 6 pouches (6% of the pouches), and defected pouches were cleaned (wiped) and placed among the good ones. The defects were a **600 microns hole** (one hole per pouch) . Locations of defect were varied from one pouch to another. The pouch inspection station in the plant was used for inspection.

The variables for this study were as follows:

1. Inspection time:

3 seconds

5 seconds

7 seconds

2. Inspection environment (Lighting):

Table light (Light above the table)

Magnifying lens & light.

Three employees at the facility, with no hours of inspection experience, were asked to be the pouch inspectors. Those employees were given a brief (10 - 15 minutes) training by showing them the type of defects they are expected to find on the pouches. Each inspector had the chance to inspect the pouches at the three stated time rates under both sources of light. The inspectors were asked to isolate and set aside the defective pouches. At the end of each inspection, the isolated pouches were divided into two parts:

1. Defective Pouches (Pouches contains holes).
2. Non-Defective Pouches (Non-defective pouches picked up as defective).

To ensure accuracy of the study, each pouch was uniquely identified by a barcode. At the end of the study, the tested pouches were read by the barcode reader, the real defective pouches were separated the non-defective ones, and the fraction of False Positive (FP) and False Negative (FN) pouches were calculated and plotted against the inspection time.

The False Positive (FP) and False Negatives (FN) are identified as follows:

**False Positive (FP): Non-Leakers identified by the inspectors as leakers.**

**False Negative (FN): Leakers identified by the inspectors as non-leakers.**

The efficiency of human inspection was then calculated from the number of False Negative pouches using the following formula:

$$\text{Efficiency of Inspection} = 1.00 - \text{FN}$$

The fractions of False Positives (FP) and False Negatives (FN) were calculated using the formulas stated in the attached Inspection Statistic Sheet.

### **Results:**

The results in Table 1 show the number of good and defective pouches selected by the inspectors at three different speeds using two sources of lights. The fractions of false positives (FP) and false negatives (FN) were calculated for each run, and the average of the fractions were computed (Table 2). The efficiency of human inspection was calculated from the average false negative fractions and plotted against the inspection time (Figure 1). Under the table light experiment, the efficiency of human inspection increased from 33.3 to 44.4% when time of inspection increased from 3 to 7 seconds per pouch, whereas under the light with magnifying glass experiment, the efficiency increased from 11.1 to 38.9% at the stated inspection times respectively (Figure 1). This indicates that the table light is more efficient in finding the defective pouches in this experiment. The total inspection time for the tested 100 pouches was about 12.5 minutes when 7 second, (the longest inspection time, or in other words, longest experimental shift), was given for each pouch. At this inspection time, the efficiency of human inspection was 44.4%. It should be noted that the efficiency of human inspection might be

affected negatively by the fatigue and the status of inspectors when they work a whole 8 hour shift, which results in more rejected lots and more loss of product. The efficiency might be positively affected if the inspectors training was improved and if on job (experienced) inspectors were used in this study. The 44.4% efficiency obtained in this study is considered low and has a negative effect on the number of accepted lots as can be displayed in the following example: Assume a 50,000 pouch lot with a defect ratio of 0.04% ( $p = 4 / 10,000$  pouches), an inspection efficiency of 50%, and a false positive of 0.03. Hence, the lot has 20 pouches with holes, of which 10 pouches are sorted out together with  $(50,000 \times 0.03) = 1500$  good pouches. Based on a 200 pouch sample size, the chance for accepting the lot would increase from 92% before inspection to 96% after inspection.

**Table 1. Number of Good and Defective Pouches Selected by the Inspectors\***

		TIME					
		3 Seconds		5 Seconds		7 Seconds	
		Defective	Good	Defective	Good	Defective	Good
LIGHT	1	2	0	2	0	3	2
		1	3	2	5	2	10
		3	4	2	21	3	5
	2	0	1	0	0	2	0
		2	2	2	4	3	8
		0	5	2	5	2	4

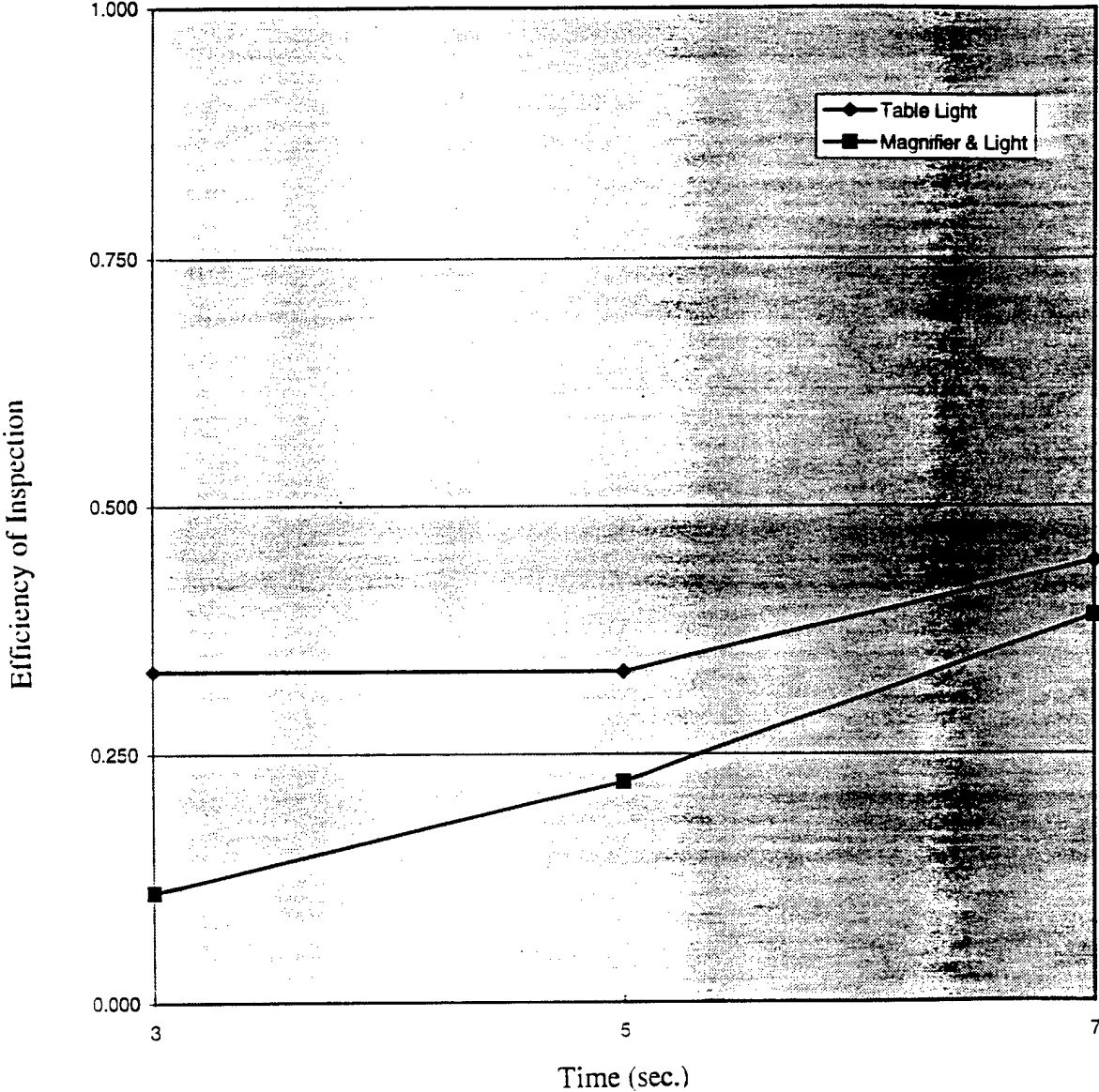
\* Defective Pouches are the real defective pouches selected by the inspectors, whereas Good Pouches are non-defective (good) pouches selected by the inspector as defective.

Light: 1. Table light;      2. Magnifying glass & light

**Table 2. Fractions of False Positives (FP) and False Negatives (FN)**

		TIME					
		3 Seconds		5 Seconds		7 Seconds	
		FP	FN	FP	FN	FP	FN
LIGHT	1	0.000	0.667	0.000	0.667	0.021	0.500
		0.032	0.833	0.053	0.667	0.106	0.667
		0.043	0.500	0.223	0.667	0.053	0.500
	Ave	<b>0.025</b>	<b>0.667</b>	<b>0.092</b>	<b>0.667</b>	<b>0.060</b>	<b>0.556</b>
	2	0.011	1.000	0.000	1.000	0.000	0.667
		0.021	0.667	0.043	0.667	0.085	0.500
		0.053	1.000	0.053	0.667	0.043	0.667
	Ave	<b>0.028</b>	<b>0.889</b>	<b>0.032</b>	<b>0.778</b>	<b>0.043</b>	<b>0.611</b>

Figure 1. Efficiency of Human Inspection of Pouches at Different Inspection Times



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**COMBAT RATION  
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**Non-Destructive Residual Gas Testing:  
ATC-3 Preliminary Results**

**Technical Working Paper (TWP) 117**

**M. Gultekin, I.M. Laham E.A. Elsayed and H.B. Bruins**

**February 1997**

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# Non-Destructive Residual Gas Testing: ATC-3 Preliminary Results

## Objective

The objectives of this project was to analyze whether the ATC-3 leak tester can be used in measuring the amount of residual gas inside the MRE pouches.

## Background

While the ATC tester was originally developed for detecting a leaking pouch, the measuring principle that the tester uses, might enable it to predict the residual gas level in a pouch. The ATC uses a vacuum to expand gasses inside the pouch. Sensors measure both the vacuum level as well as the expansion of the pouch. Under the ideal gas law, the volume of the gas inside the pouch is a function of the temperature of the gas and the pressure of the gas.

$$P * V = n * R * T$$

where: P = absolute pressure [atm]

V= Gas Volume [cm<sup>3</sup>]

n = mole's of gas [gram]

R= Gas Constant = 82.05 [atm.cm<sup>3</sup>/g.°K ]

T=Temperature [°K]

Therefore, under constant temperature conditions, a change in absolute pressure is inversely related to a change in gas volume.

$$V_1/V_2 = P_2/P_1$$

Under vacuum conditions, the pouch expands predominantly in one direction, therefore the measurement of this expansion should be an indication of the volume of gas inside the pouch.

The use of the ideal gas law to determine the residual gas level in MRE pouches is not unprecedented. MIL-P-44073B, section 4.3.3.2 describes a non destructive method that uses this law. That method is however rather complicated and labor intensive and not commonly used in the industry.

## **Potential Cost Benefit**

The cost benefit of using the ATC-3 type tester in measuring the amount of residual gas can be substantial. The following benefits have been identified:

1. Measuring residual gas would be non-destructive.
2. The algorithm for determining residual gas level could compensate for product temperature variations.
3. The test cycle for measuring the residual gas is less than one minute. Current procedures take significantly longer as the pouch temperature has to be equilibrated at 75 F before the volume can be measured.
3. More pouches can be tested during production, yielding valuable data regarding Statistical Process Control.
4. The measurement of residual gas algorithm can be combined with an SPC algorithm. This SPC algorithm could automatically warn the operator when the residual gas level of the pouch is out of statistical control.

## **Preliminary Test Results**

Preliminary studies were made in the Food Manufacturing Technology Facility to quantify feasibility of the ATC-3 as a residual gas tester. As product, ham slice in MRE pouches was used and tested under various residual gas levels (5, 15, and 25 cc) and product temperatures (70, 85, and 100 F). Three groups of pouches, A, B, and C (150 pouches per group) were prepared on the Tiromat at estimated residual gas of 5, 15, and 25 cc respectively. The pouches were then labeled and uniquely identified with barcodes.

1. A preliminary model, the “Proportional Hazards Model”, described in “*Reliability Engineering*, pp 371-378, by Elsayed A. E., Addison Wesley, 1996” was selected to estimate and calculate the amount of residual gas in a pouch

$$RG = K \exp -(b_1(1/T) + b_2E)$$

where

RG: Residual gas [cc.]

T: Temperature [°K]

E: Maximum expansion of the pouch [ATC units]

K,  $b_1$ , and  $b_2$  are constants (The values of these constants for this particular experiment are 0.46, -909.906, and -0.00085, respectively.)

2. The model was calibrated against the destructive manual measurements method as described in MIL-P-44073B, section 4.3.3.1. The predicted vs. measured values of residual gas used to fit the model are displayed in Figure 1. Twenty seven samples were used to establish the correlation coefficient between the predicted and the measured values. This correlation coefficient was found to be 0.952.
3. After fitting the model, trial runs were made to verify the model. Twenty seven samples were used in this verification. The predicted vs. measured values of residual gas used to verify the model are displayed in Figure 2. The predicted results from the model are close to the trial run results with a mean absolute error of 1.75 cc. and a mean squared error of 11.26 cc. The correlation coefficient between the trial run results and the predicted value is 0.967. The mean squared error for 70, 85, and 100 F are 7.32, 6.75, and 5.26 cc respectively

## Next Steps

The ATC tester was not originally designed for the purposes of measuring residual gas level inside pouches. This type of measurement requires precise and repeatable measurements of pressure, expansion and temperature. Therefore, to improve on the

functionality of the ATC as a residual gas tester, upgrades of the hardware and software should be considered. Following are four examples that could improve the system:

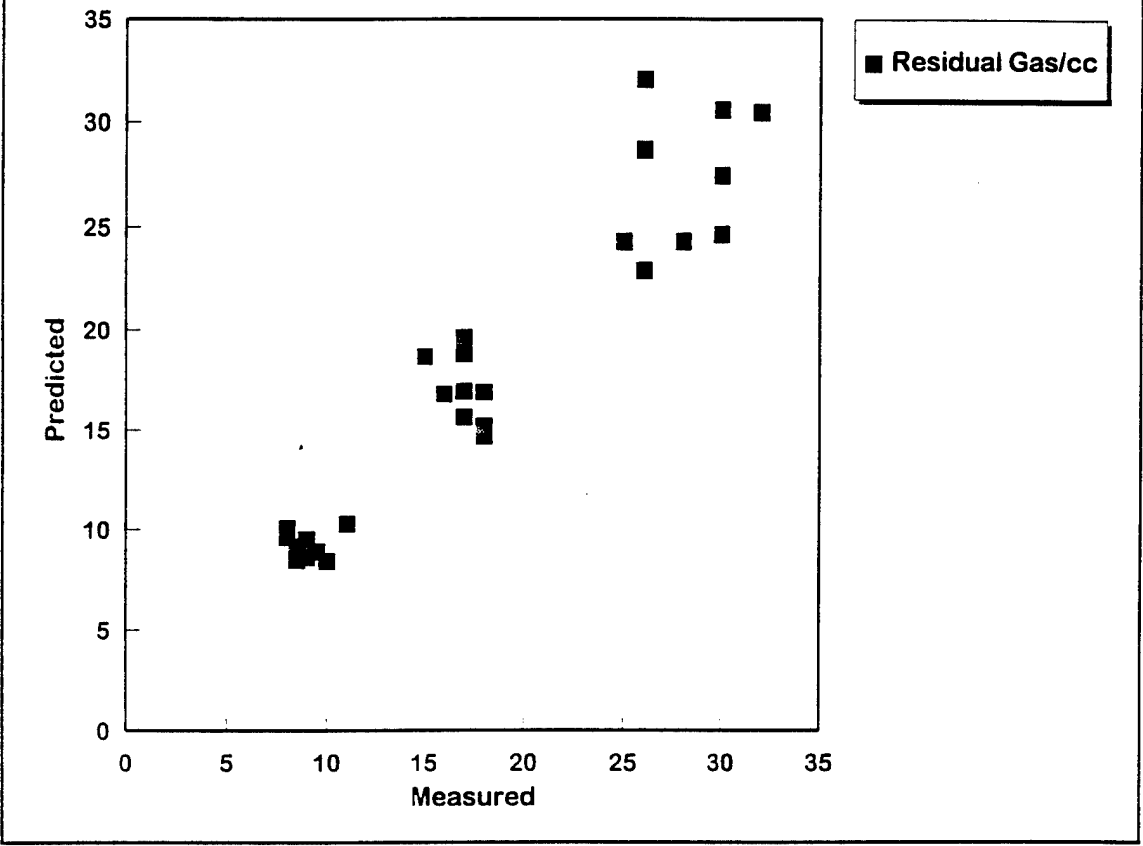
- 1) The effect of frictional forces during the pouch expansion can be reduced by redesign of various component, resulting in improvements of the repeatability of the expansion signal.
- 2) The signal from the vacuum sensor can be improved by use of a higher quality sensor and A/D converter.
- 3) Pouch temperature is an important factor in measuring the residual gas level and should be measured during the test.
- 4) The software that measures the vacuum, expansion and product temperature and controls the instrument needs to be custom tailored for this type measurement. With additional hardware the measurement could be automated.

Besides instrument changes, additional research needs to be conducted to establish the best possible model to predict the residual gas level as function of various product and process variables. The research done for the purpose of this report was limited as it fell beyond the scope of the original project.

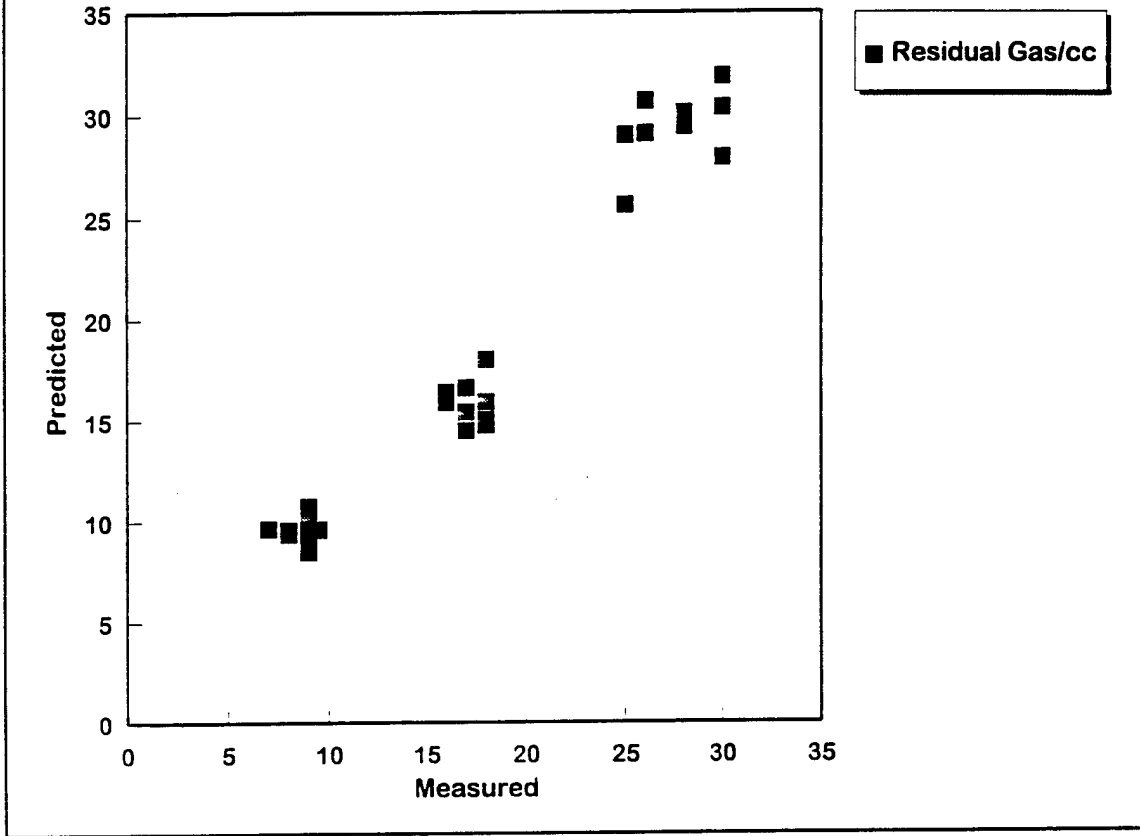
## **Conclusions**

Based on the fitted model, the ATC-3 leak testing equipment was found to be a potential instrument to measure, non-destructively, the residual gas level inside pouches. Further research in this area is proposed to identify the best possible model that will improve the precision of the measuring instrument. Also, upgrades of the ATC hardware are proposed to increase the repeatability of the instrument.

**Figure 1. Predicted vs Measured Residual Gas Values  
Used to Fit the Model**



**Figure 2. Predicted vs Measured Values of Residual Gas Used to Verify the Model**



**PACK CHECK  
LEAK DETECTION**

Appendix 4.10

# CHECKING YOUR WEAKEST POINT

any vehicle is able to  
perform a high quality  
leak detection in  
seconds.



**PEI Dansensor**

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# A Unique New Path i

New state of the art in Leak and Seal Integrity Detection -  
Based upon a newly Developed Revolutionary CO<sub>2</sub> Sensor  
which Changes the Concept of Packaging Quality Control.

## Pack Check

Leak detection has become one of the most important issues in the food and drink industry, - a weak point in high quality packaging, as the existing equipment and methods do not meet the demand for a userfriendly and reliable precision detector at an affordable price.

With Pack Check PBI Dansensor has developed an important new method in leak detection and is therefore able to meet these demands.

Pack Check is based upon a unique new concept which removes existing problems in leak detection. The most important key entries are:

- Easy to operate and set up
- Extremely high testing accuracy
- Non destructive testing
- Detects nearly all sizes of flexible and non flexible packages
- CO<sub>2</sub> gas trace gas. This means that in most cases, you can use the CO<sub>2</sub> from the packaging process itself.

Only PBI Dansensor's Pack Check offers you this - and at a reasonable price.

The heart of Pack Check is a unique new ceramic CO<sub>2</sub> sensor, developed by PBI Dansensor. This sen-

sor is very fast and sensitive and needs only a small amount of sample gas. Applying this sensor in leak detection gives many significant advantages and makes Pack Check bypass all existing methods, both in leak - and seal/film integrity testing.

Pack Check is controlled by a sophisticated software. This means that performing a leak detection is extremely easy. It all runs fully automatically and mistakes are not possible. This userfriendly concept is carried through all the way e.g. menu operated software with an easy symbol based touch screen.

Pack Check also offers you an advanced statistic function, easy calibration methods and of course full self diagnostics, so you can always rely upon your Pack Check.

With Pack Check a new generation of userfriendly high precision leak detectors is born. If package tightness is a weak point, Pack Check will surely be your best friend.



Pack Check which is the new easy to use, high precision leak detector from PBI-Dansensor is as well designed for seal integrity test and is available both with castor and as table top model. Leak detection Pack Check is non destructive for the packing - and demands no add on trace gas, when using Modified Atmosphere Packaging with CO<sub>2</sub>.

## Advantages

- Detection of extremely small leaks
- Very easy to use
- Fast response time
- Trace gas: CO<sub>2</sub>
- Individual programmes for many various package types and sizes
- Easy set up - programming by learn mode
- COMBINED leak and seal/film integrity test
- Complete diagnostic
- Statistic - and batch sorting
- RS 232
- A very reasonable price level

# h in Leak Detection

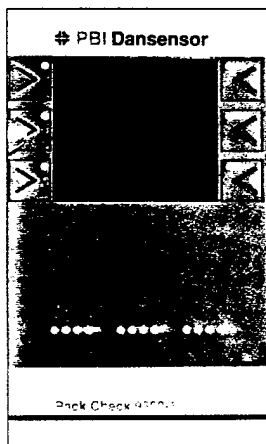
## Easy to use

With Pack Check anyone can perform a high quality test with a minimum of instruction. Pack Check is recommended for laboratories and production, where the test can be performed in conjunction with the standard gas analysis. This improves quality control in general.

The procedure is as follows:

- 1 Choose programme number for the particular type of package (touch "Program" and point).
- 2 Place the package to be tested in the chamber and close the lid.
- 3 Touch symbol for "Detect" - Pack Check now performs the whole test fully automatically.
- 4 The lid opens automatically.

The test results are clearly indicated on the display. It indicates whether a leak is present or not and the data is stored.



The large Pack Check display is a graphic screen with easy identifiable symbols. In detection mode results are clearly displayed for "GOOD" or "NOT GOOD" packing.

## Set up - 2 ways

Set up of alarm level for leak rates is very easy and can be performed in 2 ways:

- 1 A specially designed calibration cartridge device. Each cartridge refers to a certain leak rate, depending upon packing and pressure. The entire calibration process runs automatically.
- 2 An alarm level can also be inserted directly onto the display, if the user knows the depending parameters.

## Documentation

Pack Check offers an advanced statistic function. Each test batch can refer to a greater production batch which might be to a specific customer, if documentation is needed for internal or external purposes. Test results can be displayed on the Pack Check screen or printed.

## Diagnostic

Pack Check features a complete self test of all sensor parameters and electronics. This also applies to certain possible fault in user's operation of the device. Consequently you will have maximum safety for fault - and you can always rely upon your Pack Check.

## Seal Integrity Testing

Pack Check is not only for leak detection, but is also ideal for testing seal integrity.

In seal - or film - integrity mode Pack Check tests whether the sealing, performed by the packaging machine, is of the appropriate quality, and whether damage, if any, has occurred to the film.

In this testing mode, Pack Check stresses the sealing and film by establishing a vacuum, which is higher than the leak test mode. If the sealing breaks the alarm is activated.

In the same mode, Pack Check also proves to be extremely sensitive in detecting CO<sub>2</sub> leaks from the packaging. This means that Pack Check can detect a.o. increased permeability, caused by damaged film, which could be critical to products with a long shelf life.

Parameters in stress mode is user specified, and can be activated by the user directly, alternatively test intervals can easily be defined in programme set up.

## Applications

Pack Check is suitable for the laboratory, the production and most flexible packages and cans, containing meat, powder, liquid etc.

The only condition for applying Pack Check is that the package/container contains some CO<sub>2</sub>, either as a standard part of the packaging process, or added before taking out test samples from the line.

Pack Check can be applied in:

- Meat industries
- Industrial bakeries
- Pharmaceutical industries
- Breweries and soft drink industries
- Coffee Packaging industries
- Powder Milk industries