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# THE RELIABILITY OF FLEXIBLE PACKAGES **

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The development of flexible packaging for items needing a high level of package integrity, such as freeze-dried or thermoprocessed ration items, has brought into sharper focus two distinct yet interrelated facets of packaging reliability. These are the performance of the package itself capability of the packaging system to perform properly.

Concurrent to the development of optimum packaging, "reliability" and "reliability engineering" concepts as applied to products and manufacturing processes have become formalized.[1,2] Programs to apply "reliability" reasoning to existing situations are well underway. Reliability by a prevalent definition[1,2] is the mathematical probability that a product will function for a stipulated period of time. Other definitions, perhaps more apropos to packaging, include average numbers of failures per part per number of hours of use or average time between failures.[1] Translation and adaptation to our packaging efforts, on recognition of the types of failures encountered, becomes useful and valid only when the two distinct reliability facets of the package and the packaging or manufacturing system are recognized.

Before any valid quantitative reliability "number" can be applied to either facet, appropriate test methods must be developed.

This report will present some efforts to assess the level of reliability attainable with flexible packages for thermoprocessed foods. Initially, the results have been in abstract and relative terms. As progress is made and data becomes available, the qualitative assessment will become quantitative.

The Military has been investigating the use of flexible materials for thermoprocessed foods to replace the rigid metal containers for approximately a decade.[3,4,5] Initial effort was limited to a search for suitable materials but over the past four to five years significant overall progress has been made. Effort to date has indicated that it is technically feasible to use flexible, laminated packaging materials to hermetically contain thermoprocessed foods. Films are available which are capable of withstanding 250° F processes and which comply with FDA regulations. Various heating media have been evaluated and either steam, steam-air mixtures or water can be used.[6,7] Storage stability can be equivalent to or greater than that attained with rigid cans.[4] Most significantly, field tests have shown that

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the anticipated advantages—portability and lighter weight—can be achieved.[8]

## Reliability

There are three modes available through which information pertinent to reliability assessment can become available:

1. Experience with actual use.
2. Stress-strain testing (Abuse or accelerated).
3. Nondestructive testing procedures.

## Experience with Actual Use

Experience through actual use is the most direct method of gathering information on and assessing the reliability of the end item. Experience forms the basis against which all other methods can be compared and evaluated.

Although the application of flexible packaging to thermoprocessed foods is still in the developmental stage, some data of this type are available.

Engineering/service tests incorporating the thermoprocessed flexible packages have been carried out. These tests consist of shipping the test rations to the point of issue; in this case, to advanced troops on field training maneuvers. The rations, following preliminary inspection, are issued prior to the exercises, carried by the troops until consumed in the field, and evaluated by filling out enclosed cards. Preliminary familiarization briefings are given for the totally new ration. Records are kept of defective packages.

A recent test report [8] indicated, in addition to gross defects eliminated at the point of manufacture, the presence of defects at a rate of 0.30% based on over 50,000 individual meal items inspected. Approximately two-thirds of the defects were related to sealing and one-third to mishandling. The nature of the defects indicated that further effort is required to improve the reliability of the manufacturing operations. Furthermore, the results indicated that if the packages were sound at the point of manufacture, they held up excellently during shipment and field use.

## Stress Strain Tests

Stress-strain tests have involved the entire package and consist of simulated or accelerated use or abuse tests. Two approaches have been attempted with thermoprocessed foods in flexible packages. The results of both indicated that in comparison with packages of similar laminated materials and design the packages performed well. But, little confidence or sense of reliability of an *absolute* nature would be gained. Use had apparently been made of the best materials available, but no assessment could be made as to whether these were good enough. The intent had been to establish stress-strain procedures that would simulate actual use; however, the results indicated that the abuse given the packages was not ordinary.

One stress-strain evaluation procedure was established by the Continental Can Company.[9,10] This consisted of subjecting the packages, in the listed sequence, to the following:

1. Vibration of cartons at 1G for 1 hour (jacketed pouches in corrugated cartons)
2. Carton drop test, 10 random drops from 30 inches (ASTM D1776-61, Objective B)
3. Jacketed pouch drop test, 10 random drops from 3 feet.
4. Static load of 200 pounds on

jacketed pouches for 3 minutes.

5. Biotesting of unjacketed pouches for 30 cycles in inoculated water.

The results, based on exposure of 418 packages to the above cycle, indicated a failure rate of 5%. A direct comparison with actual use is not possible since the objective of the stress-strain cycle was measurement of pouch and material performance. No notation was therefore made of non-leak seal defects,—a type related to the manufacturing operation. The actual disparity between the results of the two approaches, therefore, is much greater than tenfold.

A second approach to stress-strain evaluations of the flexible packages was the use of an obstacle course at the General Equipment Test Activity, Fort Lee, Virginia.[11] Tests consisted of personnel carrying a package in each of four field jacket pockets and traversing a course of 16 rather rugged obstacles such as crawling under wire, climbing over wooden barriers, and using cobblestone slides. Each package was subjected to 10 traversals. Results showed the same magnitude of failures as the Continental Can Company procedure. Chicken a la king failed at a 5.5% rate and green beans at 7.4%; again significantly above rates evidenced in actual use.

Both stress-strain procedures gave quantitative data. The significance of the numbers, both as to magnitude and assignment to causes, is a matter of judgment and the validity of this judgment will be strengthened by experience and comparison with actual use. One summation of the stress-strain tests has been that any package that passes is a good one; but conversely, nothing derogatory can be said about the failures. Modifications of the procedures and courses are underway.

## Nondestructive Testing

The third mode for gathering information relative to reliability is nondestructive testing. Effort in this area related to the flexible package for thermoprocessed foods has been aimed at detecting two types of defects, pinholes and seal defects. In addition, some work has gone into establishing definable "synthetic" defects in the specified packaging material. These "synthetic" defects are to be used for establishing the basic sensitivity of candidate test techniques and for calibrating the developed systems.

Pinholes are perforations through the body area of the pouch or seal channels that leak and could permit bacterial recontamination of the pouch contents. Foil breaks are excluded. Present knowledge concerning bacterial penetration, critical defect size, and ease of detection is limited and empirical.

It is known that:

1. Microscopic examination, because of the irregularity of shape and tortuosity of path, is inadequate for detailed definition or size estimation of pinholes.

2. Holes approximately 100 microns in diameter can be detected with the naked eye and product will exude through such holes on application of pressure.

3. Pouches punctured with 500 micron diameter needles did not totally indicate penetration following submersion in an inoculated media.[5] Only 50% of pouches tested indicated contamination. Surface

tension and wettability are suspected factors affecting bacterial penetration.

4. A Biotester, whereby individual pouches are subjected to kneading action while submerged in an inoculated bath, has improved the detection of purposely punctured pinholes. Table 1, although based on a limited number of replicates, shows recovery rates obtained with purposely punctured packages using two sizes of puncturing probes. These improved recovery rates were mostly in the 80 to 100% range. In addition to the known punctures, the Biotester has detected holes not visible to the naked eye, resulting from extreme abuse of packages.[9, 10, 12] The size range of these latter pinholes was 33-160 microns.

**Table 1. Summary of Laboratory Biotest Runs Recovery Rates with Various Products**

| *Product* | *Number of Replicates* | *Diameter of Puncturing Probe* | *Per Cent Positive* |
|---|---|---|---|
| Chicken a la King | 30 | 100 | 60 |
| | 85 | 300 | 78 |
| Chicken Loaf | 10 | 100 | 90 |
| | 10 | 300 | 100 |
| Beef Loaf | 10 | 100 | 70 |
| | 10 | 300 | 90 |
| Beef Steak | 10 | 100 | 80 |
| | 10 | 300 | 80 |
| Pork Sausage | 10 | 100 | 100 |
| | 10 | 300 | 80 |
| Beef Stew | 10 | 100 | 50 |
| | 10 | 300 | 100 |
| Ham and Chicken Loaf | 10 | 100 | 90 |
| | 10 | 100 | 90 |

Organism; Aerobacter aerogenes at concentration of $6 \times 10^6$ viable cells/mil.

Biotest conditions; Line pressure: 5 psig; Seconds/cycle: 30; Number of cycles: 30.

5. Methods commonly used for performance tests in the laboratory, such as drum tumbling, vibration, and twisting (Gelbo), have caused pinholes larger than 95 x 140 microns (microscopic estimation). Likewise, the finest probe found strong enough to puncture the packaging material of interest causes holes estimated at 60 microns in diameter.

Pending clarification of the smallest defect through which bacteria will pass under simulated distribution or field conditions and/or the smallest defect likely to be encountered, the Biotester developed by the Continental Can Company is considered the primary pinhole detection device. Its measurement is direct and its effect on packages is essentially nondestructive.[10]

For on-line usage, a significantly more rapid method is necessary. To this end, studies have been initiated to establish the applicability of gas leak detection methods. Appropriate methodology for many applications is well documented; however, specific to the package for thermoprocessed foods, at least three factors must be resolved; namely, moisture can effectively block gas flow through small pores, the total residual and tracer gas in the package should be no greater than 10 cubic centimeters, and the gas used must be legally and organoleptically compatible with the food.

For use as sensitivity criteria for candidate gas leak methods and for calibration, methods have been established for drilling small, definable holes in pouches of the suitable materials by a laser beam. Holes with diameters as small as 3 microns are feasible. Similar defects will be used to further define the capabilities of the Biotester.

The second type of defect pertains to seals. Seal defects include wrinkles, voids and occluded matter. Occluded matter is usually the result of the filling operation and can consist of food fibers or particles, grease or moisture. The defective seal with the defect may or may not be leaking at the time of inspection.

No sources of quantitative or reproducible data on flexible package seal defects were found. Therefore, to simulate such defects, single food fibers (celery, pineapple), freeze-dried pork, food particles (weighed amounts of dehydrated potato powder, single sugar crystals), grease (oleo) streaks, and moisture were occluded separately in the seal area. For "fabricated" voids, 3.5, 5.5, and 8 mil diameter threads were sealed in and then withdrawn. To obtain defects of a quantitative nature, the various sized threads were left imbedded in the seals. It is difficult to visualize the frequent occurrence of smaller defects.

Various nondestructive testing and scanning techniques were considered and several were evaluated by cursory trials with representative seal defects. Three methods showed promise:

1. Ultrasonics
2. X-Rays (30–50 Kilovolts; 5–9 Milliamperes; Vidicon pick-up transmitted to a 17" TV screen)
3. Infrared measurement of thermal impedance.

The first two methods detected a majority of the defects. Ultrasonics missed voids and wrinkles whereas X-Rays missed grease and fine powder. The infrared scanning system did respond to some degree to all the defects and therefore greater emphasis was put on establishing the feasibility of the infrared approach.

The infrared detection procedures measure the impedance to heat flow through the seal thickness caused by defects. Figure *1* illustrates the test

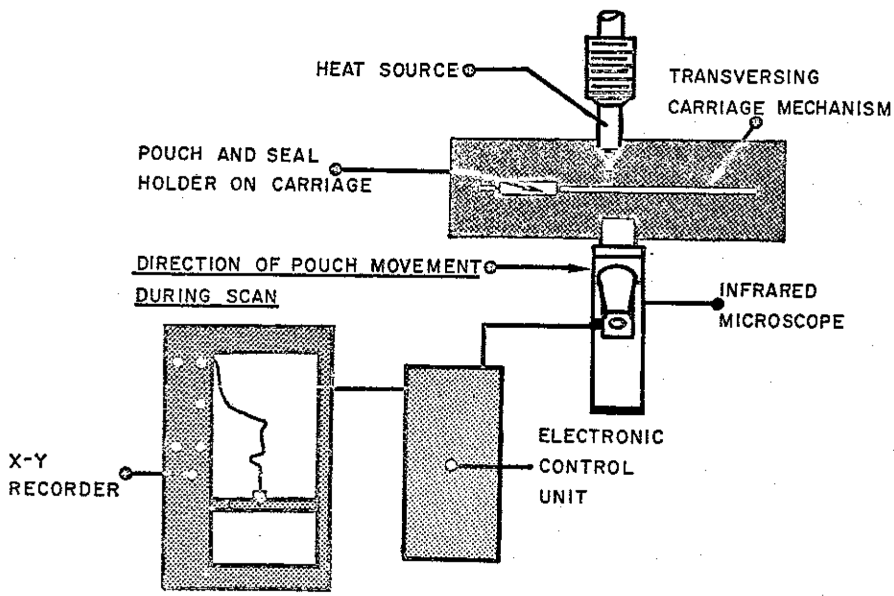


Figure 1. (Top view) Schematic of infrared seal scanning apparatus.

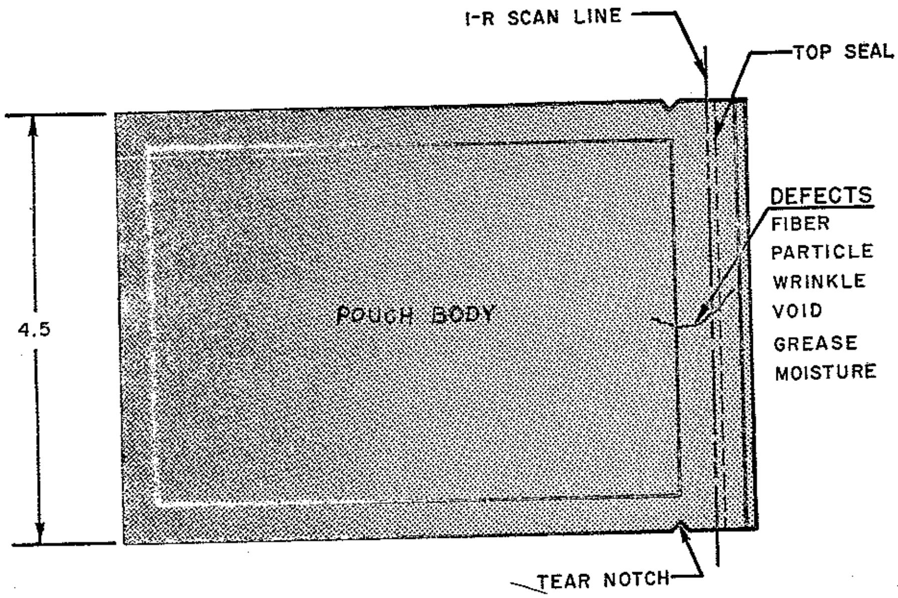


Figure 2. Schematic of seal defects.

procedures. A stream of hot air is directed at one side of the seal area and the infrared microscope at the other to detect the resultant variations in surface temperatures. In practice the heat source and the infrared microscope are stationary while the package seal area is moved between the two components at a constant speed. The output can be in degrees of temperature or in millivolts.

Figure *2* shows the scan line and the location of the simulated defects relative to the package. Thus far, the final seal only has been scanned since it is the one most likely to contain contamination. This figure also lists generically the defects sought. Table *2* lists the specific defects and corresponding infrared responses in terms of millivolts above the maximum background noise level.[13] Figure *3* shows a response curve from a scan of a void left by the withdrawal of a

**Table 2. Response of Infrared Microscope to Thermal Impedance Caused by Simulated Seal Defects**

| | | *Response—Mv Replicate—Samples* | |
|---|---|---|---|
| *Description* | *Size/Quantity* | *I* | *II* |
| Pork Fibers | 0.5 mg; 1.0 mg | 16 | 18 |
| | 1.0 mg | 40 | |
| Celery Fiber | Single | 26 | |
| Pineapple Fiber | Single | 17 | 30 |
| Sugar Crystals | Single | 14 | |
| | 3 each | 18 | |
| Potato Powder | 0.5 mg | 7 | 14 |
| | 1.0 mg | 14 | |
| Grease | Streaks | 20 | 16 |
| Moisture | Droplets | 11 | Off Scale |
| Wrinkle | 1/16" Fold* | 10 | |
| Void | 3.5 Mil** | 9 | 8 |
| | 26 Mil | Off Scale | |
| Thread | 3.5 Mil** | 17 | 10 |
| | 5.5 Mil | 13 | |
| | 8.0 Mil | 11 | |

* 1/8" difference in length of seal surfaces.
** Nominal diameter of thread or wire prior to sealing.

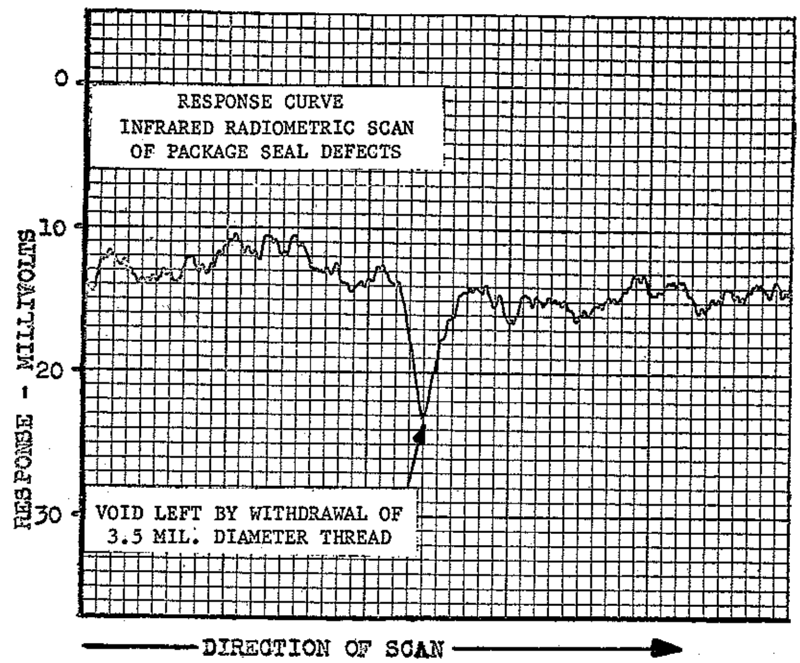


Figure 3.

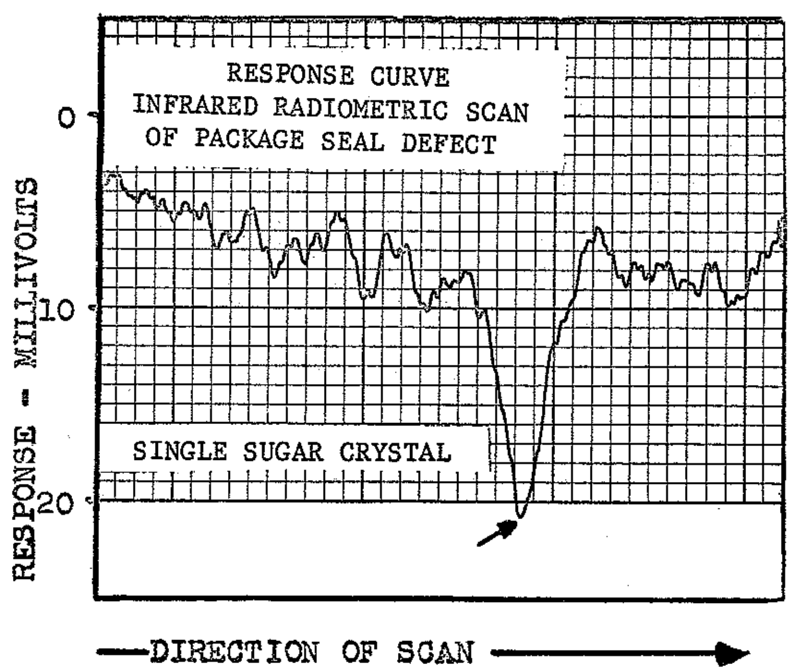


Figure 4.

3.5 mil diameter thread from the seal. Figure *4* shows the results of scanning a seal containing a single granulated sugar crystal. Based on these preliminary tests, the infrared scanning method is considered a very promising nondestructive seal defect detection method.

## Summary

Without delving extensively into the philosophies of prediction, probability, or reliability, this report has attempted to present the approaches to and status of the NLABS testing efforts to establish confidence in, and therefore, establish the reliability of, the flexible package for thermoprocessed foods.

Experience using the package in the field during training maneuvers followed by an assessment of the types and causes of the defects encountered revealed that the package *per se,* properly prepared, performs well. This actual usage experience, therefore, brought into focus the need to consider two distinct aspects of reliability—the package and its preparation operations. Stress-strain (accelerated use) experience confirmed that the package is strong.

The basic causes of the defects encountered at the present stage of development are attributed to the preparation (form, fill, seal operation; package handling) operations. In addition to elimination of these causes, test methodology, preferably nondestructive, must be developed as a prerequisite to full assessment of the degree of reliability that can be attained. Progress on testing for pinhole type defects is presently limited to cursory definition of the sizes likely to be encountered. For the second major category of defects, contaminated or badly wrinkled seals, an infrared scanning procedure shows promise.

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