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SEALING THROUGH CONTAMINATED POUCH SURFACES

by

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FOREWORD

The work covered by this report was performed under Project 1J662708D552, Packaging Exploratory Development, Task 02 - Design of Flexible Packaging Systems.

Flexible packaging offers numerous logistic advantages, making it highly desirable for military applications. Experience with thermoprocessed foods in flexible packages has revealed that defective closure seals, resulting from contamination of the seal surfaces during filling, accounts for a large percentage of the failures in this type of package. The curved-bar sealing technique described offers an effective means of sealing flexible packages where the seal interface surfaces are contaminated with grease or water.

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ABSTRACT

Examination of a large number of thermally processed flexible packages has shown that the primary cause of package failure can be attributed to occluded matter in the closure seal.

This study indicated that by using a curved-bar sealing system, reliable closure seals are attainable even when the sealing surfaces are heavily contaminated with grease or covered with water. Even without precise control of all sealing conditions, a significant improvement in seal reliability was obtained by use of curved sealing bars.

Steam-flushing of the closure area was effective in reducing headspace gas volume and removing particulate contaminants from the sealing surfaces of flexible packages. Curved-bar closure seals applied after steam-flushing produced highly efficient seals.

SEALING THROUGH CONTAMINATED POUCH SURFACES

1. Introduction.

Since the introduction of flexible packages, assurance of reliable, hermetic closure seals has been a major concern. The use of flexible packaging for thermoprocessed foods, where microbial recontamination could result in a health hazard, has given increased impetus to efforts in improving closure seal reliability. Examination of a large number of test packages of thermoprocessed foods showed that only 0.3% of the packages contained defects; however, 57% of the failures were classified as "seal defects"(1). The primary cause of defective seals has been attributed to occluded matter in the closure seal.

Efforts to prevent contamination of the seal interface surfaces to the extent now felt necessary have been relatively unsuccessful. Present methods require the filling of the package at relatively high speeds through a comparatively small opening. Positive prevention of contamination resulting from splashing of product or grease transfer from a filling horn to the package surfaces has not been attainable, even with the most sophisticated filling equipment available.

Contamination of the sealing surfaces by particles and fibers, as well as aqueous and fatty contaminants can result in a defective closure seal. Detection of particulate contamination, although difficult and unreliable, is possible by visual inspection of the seal surfaces prior to sealing. Visual detection of small amounts of liquids or fats, however, is virtually impossible. The first efforts were, therefore, concentrated on the development of a technique which would provide positive heat seals in the presence of liquids (water), greases, or both, on the seal interface surfaces.

Several approaches were considered during preliminary studies. These included ultrasonic and mechanical cleaning to remove contamination from the seal area prior to sealing, multiple closure seals, redesigned packages, and new sealing bar configurations. Encouraging results from previous work on sealing techniques using transversely radiused sealing bars* prompted further investigation of this technique(2). These studies showed that high pressures, combined with opposing radiused or curved metal sealing bars produced "flowing" of the thermoplastic inner lamina, resulting in a fillet at the inner face of the seal junction. Based on this data, it was felt that with proper design of the sealing bars, the same flowing action could be utilized to force liquid contaminants out

*Hereafter referred to as curved bars.

of the seal area without damaging the packaging material. Therefore, studies were initiated to evaluate the effect of curved sealing bars for removal of contamination and package sealing. The objective of the studies was to establish the feasibility of curved-bar sealing for contaminated packages and to establish the critical design parameters applicable to a curved-bar sealer for packaging materials currently used for thermoprocessed food applications.

Following studies on curved-bar sealing of package surfaces contaminated with liquids, a limited study was conducted to determine the feasibility of using a steam flush, followed by curved-bar sealing to remove solid or particulate contamination and effect a positive seal. In addition to cleaning the seal surface, reduction of head-space gas volume to an acceptable level was accomplished as a result of the steam flushing.

2. Materials and Equipment.

a. Materials.

Two commercially available heat processable packaging materials were used for this study. They are as follows:

(1) 0.003-inch modified polyolefin-0.00035-inch 1145-0 aluminum alloy foil-0.0005-inch polyester.

(2) 0.003-inch high density polyethylene-0.00035-inch 1145-0 aluminum alloy foil-0.0005-inch polyester.

b. Control (Flat-Bar) Sealer.

A Sentinel, Model 12-12 AS laboratory heat sealer was the "control" sealer, representing the normal sealing system used on most packaging equipment (Figure 1). The sealing bar is a Teflon-coated 1-inch by 12-inch aluminum flat bar. Heating is accomplished by a constant resistance cartridge type heating element extending the entire length of the bar. Temperature and pressure are accurately controllable within the limits of the sealing range of the packaging materials in use. Temperature variation from one location to another along the length of the bar is shown in Figure 2a.

c. Prototype Curved-Bar Sealer.

A prototype sealer fabricated by Midwest Research Institute was modified to provide the features required for our studies[2]. Modification consisted of redesign of the sealing bars and replacement of the lower curved bar with a silicone rubber anvil (Figure 3).

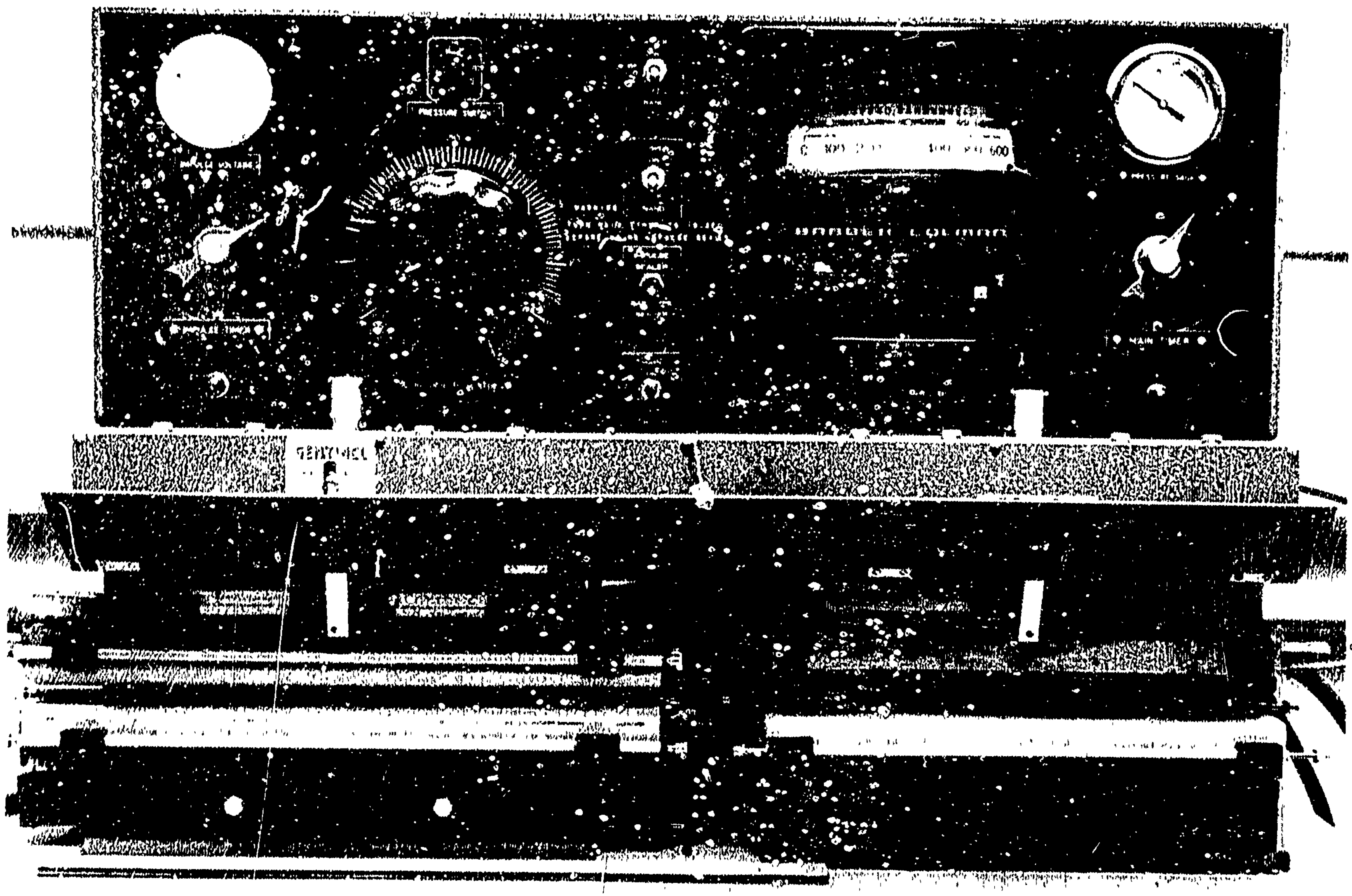

Figure 1. Sentinel Model 12-12 AS Sealer.

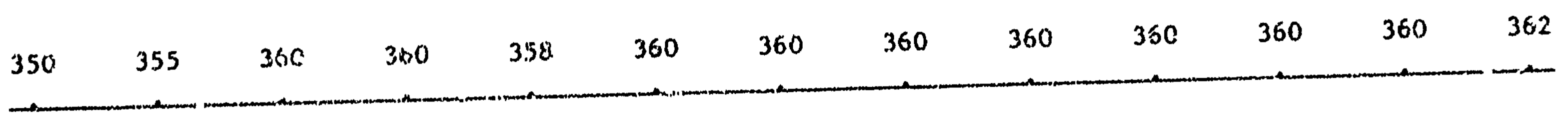

Figure 2a. Temperature Variation, Sentinel, Model 12-12 AS Sealer (Temperatures at one-inch intervals, temperature setting - 360°F.).

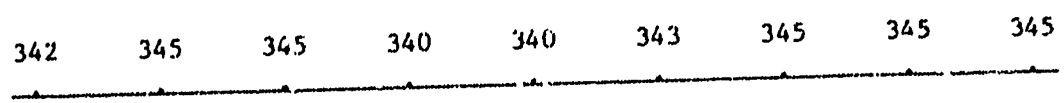

Figure 2b. Temperature Variation, Prototype Curved-Bar Sealer (Temperatures at one-inch intervals, temperature setting - 345°F.).

Figure 3. Sealing Bar and Anvil System - Prototype Sealer.

Temperature and pressure controls are comparable to those of the standard commercial sealer and the bar temperature variation is shown in Figure 2b.

d. Sealing Bar Configuration and Anvil System.

The precise alignment and extremely accurate pressure control essential to assure production of uniform seals, especially over a lengthy production period when using opposing metal sealing bars, were considered impractical[2]. In addition, the high pressures required to cause the thermoplastic sealing media to flow were unnecessary to produce sufficient expulsion of liquid contaminants to adequately clean the seal area. Therefore, efforts were concentrated on a sealing system composed of a heated, curved upper sealing bar, opposed by a resilient silicone rubber anvil. The principle of the curved sealing bar-silicone rubber anvil system is essentially a squeegee action, which physically removes contaminants during sealing, as illustrated in Figure 4.

Sealing bars of 1/8-, 1/4-, and 3/8-inch width, with 1/8- and 1/4-inch transverse radii, were evaluated on the basis of cleaning action and the strength of seals produced on each. Excessive deformation of the material was caused by the 1/8-inch-wide bar resulting in damage to the packaging material immediately adjacent to the seal. Reduction in jaw pressure to a level which eliminated this condition resulted in a partial loss of cleaning action and a significant decrease in seal strength. Although there were no appreciable differences in the strengths of seals made with the 1/4- and 3/8-inch-wide bars, the best overall performance for the materials used in this study was obtained with a 3/8-inch-wide bar having radius of 1/4-inch on the sealing surface.

Viton and silicone rubber anvil materials were evaluated for use with the sealing bars discussed above. A silicone rubber material, having a durometer (Shore A) of 72, was found to possess the desired physical characteristics and durability for this application. A harder material, Viton, having a durometer of 80 became permanently deformed after 100 seals. A softer silicone rubber, having a durometer of 56, developed hairline breaks after approximately 24,000 seals (10 hours at 40 seals per minute). No changes were evident in the 72-durometer silicone rubber anvil after more than 150,000 seals (more than 62 hours at 40 seals per minute).

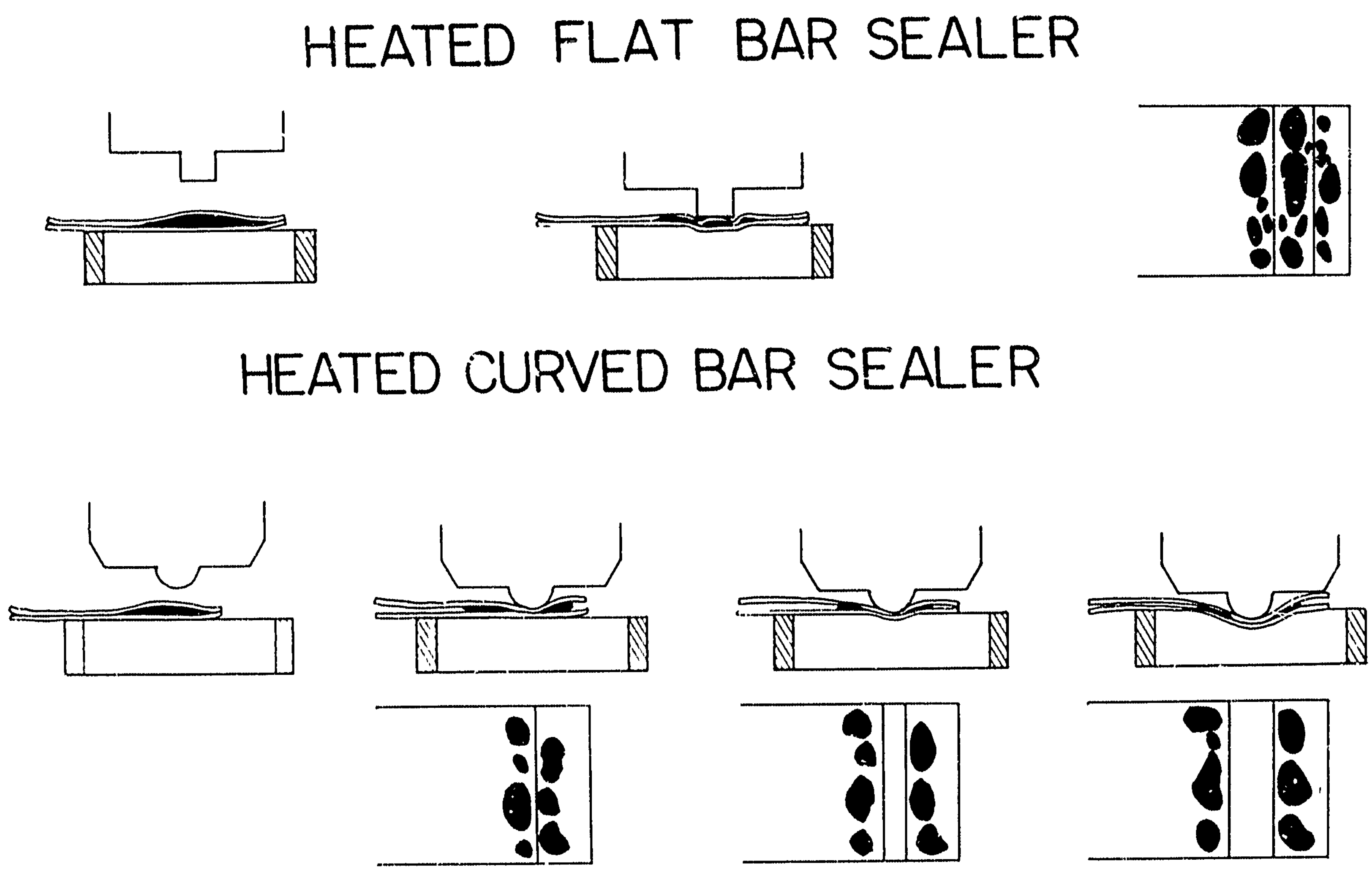

Figure 4. Removal of Contamination by Curved Sealing Bar.

3. Experimental.

a. Precision Laboratory Equipment.

(1) Sealing Conditions.

Comparative seal strength tests, conducted as described below, were performed to establish optimum* sealing conditions for the two test materials on the curved-bar and flat-bar sealers. The sealing conditions shown in Table I were followed in the preparation of all subsequent test samples in this study.

(2) Seal Strength Tests.

To determine the effect of water and grease contamination on seals produced on the curved-bar sealer, the seal interface surfaces of pouches were coated with each of the contaminants and sealed at the "optimum" conditions established for each of the materials. A second set of samples, prepared in the same manner, were sealed on the flat-bar sealer. In both cases margarine was used as the grease contaminant. Seal strength values were measured on an Instron tensile tester, using 1/2-inch-wide specimens cut from the closure seal of the test packages. The loading rate (crosshead speed) used was ten inches per minute. Seal strength values are reported in pounds-per-inch of seal width.

(3) Effects of Heat Processing.

Commercially fabricated pouches, 4-1/2-inch x 7-inch, made from the two test materials, were filled with beans and tomato sauce and sealed on the flat- and curved-bar sealers at the previously established optimum sealing conditions. Prior to sealing, a coating of sauce from the product was spread evenly over the entire seal interface surfaces of each pouch. Manual manipulation of the filled pouches was used to expel excess air prior to sealing. A nondestructive test was conducted to assure that redisual gas volumes in the test packages were below the 6-cc limit established for heat-processed foods in flexible packages of this size[3].

Pouches, prepared as described above, were screened. and defective packages were removed. The acceptable packages were

*Optimum refers to the pressure-temperature-dwell time combinations, within the ranges included in the studies, which resulted in the highest seal strength values. Other combinations would produce comparable strength values. Ranges used were those within the limits of most commercial packaging equipment.

TABLE I

SEALING CONDITIONS

FLAT-BAR SEALER:

Material	Seal Surfaces: Clean		Seal Surfaces: Contaminated*	
High density polyethylene-aluminum foil-polyester	Temperature:	410°F.	Temperature:	420°F.
	Pressure:	40 psig.	Pressure:	40 psig.
	Dwell Time:	1 Sec.	Dwell Time:	1 Sec.
Modified polyolefin-aluminum foil-polyester	Temperature:	410°F.	Temperature:	430°F.
	Pressure:	40 psig.	Pressure:	40 psig.
	Dwell Time:	1 Sec.	Dwell Time:	1 Sec.

CURVED-BAR SEALER:

Material	Seal Surfaces: Clean		Seal Surfaces: Contaminated*	
High density polyethylene-aluminum foil-polyester	Temperature:	420°F.	Temperature:	420°F.
	Pressure:	30 psig.	Pressure:	30 psig.
	Dwell Time:	1 Sec.	Dwell Time:	1 Sec.
Modified polyolefin-aluminum foil-polyester	Temperature:	380°F.	Temperature:	390°F.
	Pressure:	30 psig.	Pressure:	30 psig.
	Dwell Time:	1 Sec.	Dwell Time:	1 Sec.

*Contamination was accomplished by spreading a heavy layer of margarine over the entire seal surface.

heat-processed at 250°F. for 30 minutes, in accordance with flexible material screening procedures for thermoprocessing applications(4). A water cook, with fluctuating overriding air pressure during the cook and cooling cycles, was used to simulate conditions which may occur in a commercial processing system.

(4) Internal Pressure Burst Tests.

Internal pressure burst tests were conducted on retorted and unretorted packages containing beans and tomato sauce, prepared as described above. Pressurization was accomplished with a hypodermic needle through a sealant patch on the center of each pouch. During pressure testing, the pouches were restrained between two rigid plates to limit expansion to one inch. A pressure increase rate of 1 psig. per minute was used.

b. Application to Commercial Equipment.

The tests discussed above were conducted on seals produced by laboratory sealers with accurate, sensitive controls. To determine if improved performance would be obtained from minimum modification of a commercial production-type sealing machine, a comparison of seals from the standard sealing bar and a modified bar was made. The sealing bar was modified to approach as closely as possible the configuration which yielded the best results with the prototype curved-bar sealer discussed above. Because of the size and location of the cartridge heater in this bar, it could only be milled to 1/2-inch width, with a 1/4-inch radius instead of the desired 3/8-inch width. Jaw pressure and dwell time were constant for all seals, with temperature varied at 25° intervals from 350°F. to 500°F.

c. Steam-Flush Curved-Bar Seal.

Encouraging results from studies on sealing through areas contaminated with grease and water prompted consideration of steam-flushing followed by curved-bar sealing as a possible method of removing fibrous material from the seal area and reducing headspace gas volume to an acceptable level, following steam condensation within the package. This eliminated a separate mechanical vacuumizing operation.

Pouches, 4-1/2-inch x 7-inch, made from the two test materials, were filled with 4-1/2 ounces of ground beef in barbecue sauce. The seal surfaces of each pouch were heavily contaminated with product prior to sealing. After steam-flushing for 2-1/2 seconds, the steam nozzle was withdrawn and the pouch sealed with the curved-bar sealer. The steam nozzle was designed to provide distribution of steam over the entire seal surface, with the steam directed downward and into the pouch surface at an angle of approximately 45 degrees. Residual gas measurements and burst tests were conducted on the packages after retorting for 30 minutes, as described above.

4. Results.

a. Seal Strength Tests.

Table II shows the average seal strength values obtained with flat- and curved-bar sealers. Under ideal conditions, i.e., clean seal surfaces sealed at optimum conditions, the flat-bar seals were slightly stronger than those made on the curved-bar sealer. When seal surfaces were contaminated with water or grease, the strength of flat-bar seals dropped to less than the minimum acceptable strength of 10 pounds per inch, while those made on the curved-bar sealer showed considerably less strength loss and were all above the 10-pound minimum. It was also noted that water had a slightly greater effect on sealability than did grease. Analysis of variance shows a significant difference at the 1% level between clean and contaminated packages and between curved- and flat-bar seals (see Table III).

b. Effects of Heat-Processing.

Immediately after sealing, visual examination revealed leakage of product through the closure seal of 20% of the contaminated packages, which had been sealed on the flat-bar sealer. No leakage was found in the packages sealed on the curved-bar sealer. After retorting, nearly 90% of the flat-bar sealed packages showed leakage at the closure seal. All packages sealed on the curved-bar sealer remained intact. Figure 5 shows the comparative failure (leakage at the closure seal) rates of the curved- vs. flat-bar seals for the two materials tested, both before and after retorting.

c. Internal Pressure Burst Tests.

Table IV shows the average burst strength values of pouches with clean and contaminated curved-bar closure seals and clean flat-bar closure seals. Because of the high failure rate of contaminated seals made with the flat sealing bar, no pressure tests were conducted on these packages.

d. Application to Commercial Equipment.

Figures 6 and 7 show the strength values obtained from flat- and curved-bar seals made on standard and modified commercial equipment.

TABLE II

Effect of water and grease contamination on strength of seals produced on curved- and flat-bar sealers.

Seal Condition	Seal strength pounds per inch of seal width	
	Flat-Bar	Curved-Bar
High-density polyethylene-aluminum foil-Mylar		
Clean	13.1	12.6
Water	5.4	11.3
Grease	8.7	12.4
Modified polyolefin-aluminum foil-Mylar		
Clean	16.5	15.9
Water	8.0	10.8
Grease	6.7	14.3

TABLE III

Analysis of Variance

	Degrees of Freedom	Sum of Squares	Mean Square	Test Statistic F, Variance Ratio
Clean vs. Water vs. Grease	2	471.85	235.92	51.7 **
Material a vs. Material b	1	22.72	22.72	4.98*
Curved-Bar vs. Flat-Bar	1	185.23	185.23	40.7 **
Error (Individuals)	66	300.99	4.56	
TOTAL	70	980.79		

*Significant difference at 5%.
**Significant difference at 1%.

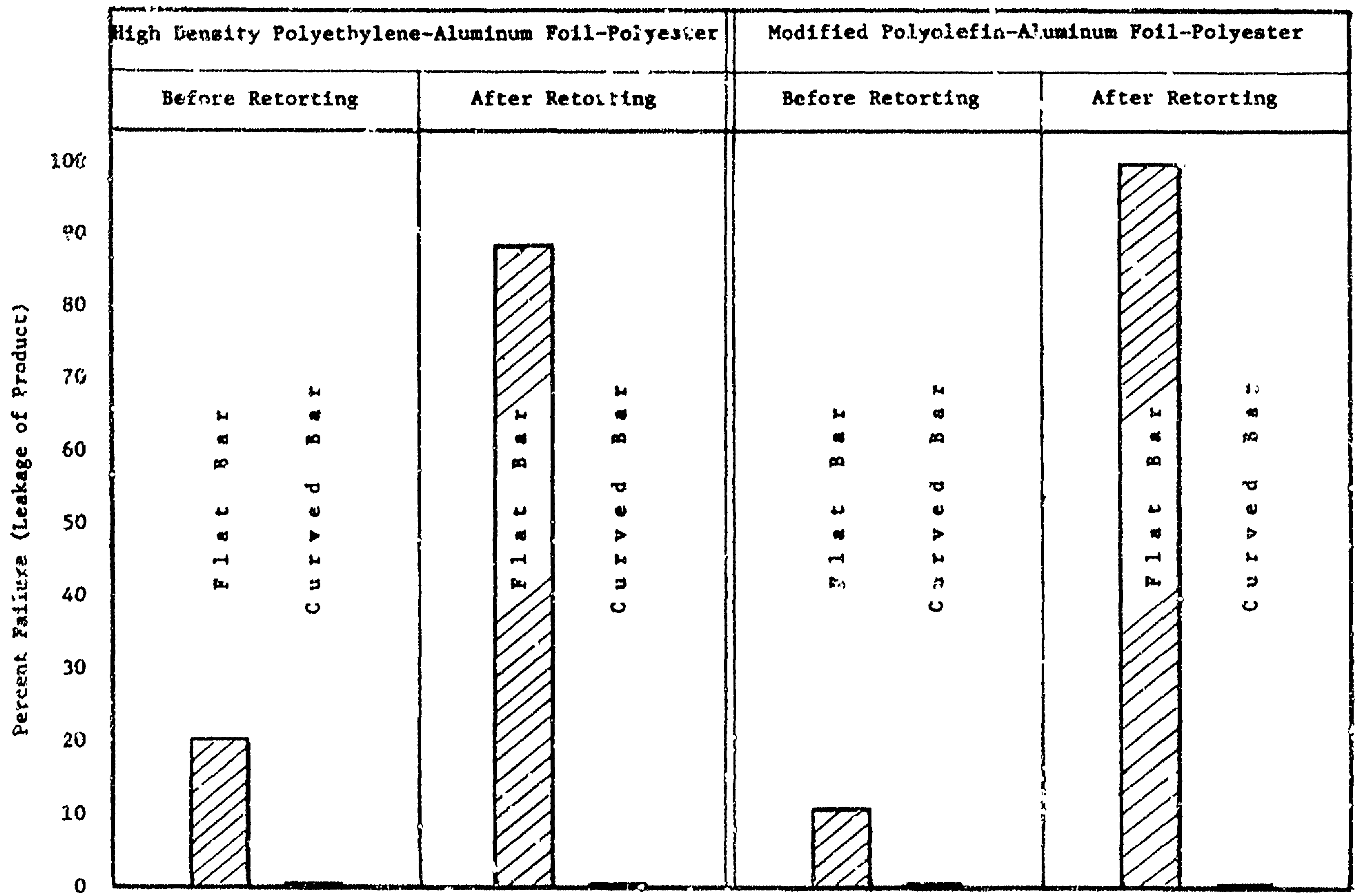

Figure 5. Failure rates of curved- vs. flat-bar seals — seal surfaces contaminated with tomato sauce.

TABLE IV

Internal Pressure Burst Tests

High Density Polyethylene-Aluminum Foil-Polyester

Sealer	Seal Surface	Burst Strength, Psig. Unretorted	Retorted
Flat Bar	Clean	12.8	10.5
Flat Bar	Contaminated	0	0
Curved Bar	Clean	12.3	10.0
Curved Bar	Contaminated	13.0	10.8

Modified Polyolefin-Aluminum Foil-Polyester

Sealer	Seal Surface	Burst Strength, Psig. Unretorted	Retorted
Flat Bar	Clean	11.0	10.8
Flat Bar	Contaminated	0	0
Curved Bar	Clean	11.3	11.3
Curved Bar	Contaminated	11.5	11.2

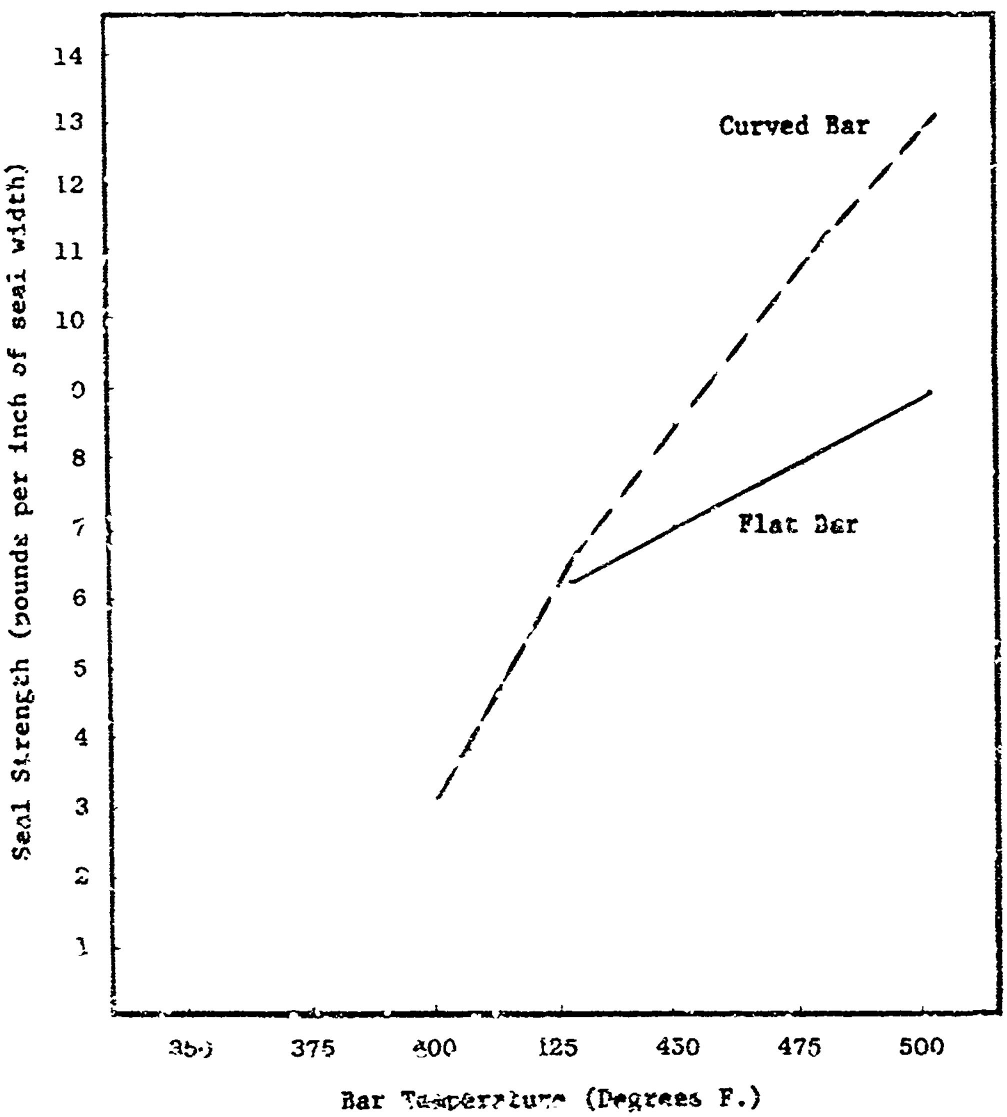

Figure 6. Seal strength, high density polyethylene-aluminum foil-polyester, sealed on a commercial sealer with standard and experimental sealing bars. Seal surfaces were contaminated with margarine.

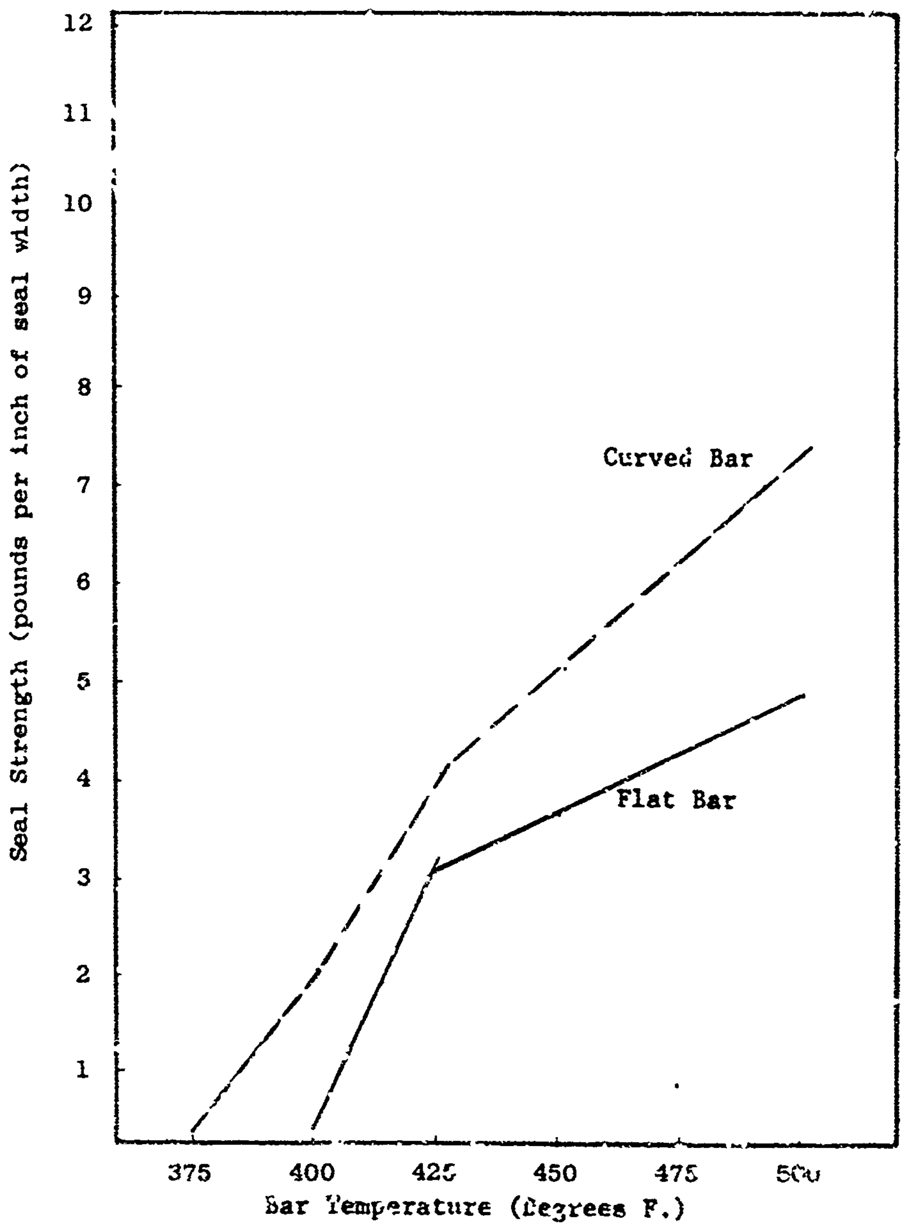

Figure 7. Seal strength, modified polyolefin-aluminum foil-polyester, sealed on a commercial sealer with standard and experimental sealing bars. Seal surfaces were contaminated with margarine.

With seal surfaces heavily contaminated with margarine, a significant improvement in strength (28.6% and 31.8%) resulted from the use of a curved sealing bar.

c. Steam-Flush Curved-Bar Seal.

Residual gas volumes, determined by water displacement, are shown in Table V. The wide difference (0.4 cc to 3.6 cc) in total residual gas volume has been attributed to variations in total flush time. Packages were hand held for flushing, and manually transferred to the sealer. The steam cycle was also manually controlled through hand valves. Despite these conditions, all test packages were below the maximum allowable headspace gas volume of 6 cc[4].

Visual examination of pouches prior to retorting showed no defective seals, and all test packages survived retorting with no visible evidence of closure seal degradation. Pressure tests of retorted pouches showed an average value of 21.5* psig before failure.

5. Conclusions.

The purpose of this study was to evaluate a curved-bar sealing system as a means of obtaining reliable closure seals of flexible packages when the sealing surfaces are contaminated. The data shows that highly efficient seals can be obtained with this system, even when seal interface surfaces have been heavily contaminated with grease or covered with water. It has also shown that precise control of all sealing conditions is not necessary to realize a significant improvement in seal reliability by use of curved sealing bars. Steam-flushing is effective in reducing headspace gas volume and removing particulate contaminants from the seal surfaces.

*These burst pressure values are not directly comparable to other burst values reported because a 1/2-inch restraining device was used instead of 1-inch, as used in previous tests.

TABLE V

Residual Gas Volume -
Pouches steam-flushed approximately 2-1/2 seconds

Group 1 High Density Polyethylene-Aluminum Foil-Polyester	Group 2 Modified Polyolefin-Aluminum Foil-Polyester
3.6 cc	3.1 cc
0.9 cc	1.4 cc
0.4 cc	4.8 cc
0.9 cc	4.0 cc
3.4 cc	1.0 cc
2.8 cc	0.7 cc
2.7 cc	1.0 cc
2.0 cc	0.9 cc
0.5 cc	2.7 cc
Average 1.90 cc	Average 2.17 cc

6. Literature Cited.

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13. ABSTRACT

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Heat Sealing	8		4			
Pouches (Food)	9		9,4			
Curved Sealing Bars	10					
Cleaning			8			
Surfaces			9			
Closures			9			
Steam			10			

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