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THEIR TESTING AND A PROPOSED SPECIFICATION

By

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JAR RINGS FOR USE IN HOME CANNING: THEIR TESTING AND A PROPOSED SPECIFICATION

By Rolla H. Taylor, Helen G. Wheeler,[1] and Frances Benedict[1]

ABSTRACT

Canning tests were made on 20 rings from each of 50 different samples. The rings were analyzed for rubber content, and measurements were made of their tensile strength, ultimate elongation, stress at 100-percent elongation, swelling on processing, indentation by a ring simulating a jar cap, and hardness. The canning failures in tests by the pressure-cooker method bore no relation to rubber content or tensile properties, of the rings but were related to swelling, indentation, and hardness, and to the change of these properties with processing. The relation was not exact because some failures probably resulted from excessive variations in jars and tops. Apparatus was developed for accurately measuring profiles of sealing surfaces. The results of the investigation are expressed in terms of a proposed specification for jar rings.

CONTENTS

I. INTRODUCTION

An investigation of jar rings was undertaken in the spring of 1941 by the Bureau of Human Nutrition and Home Economics, United States Department of Agriculture, in collaboration with manufacturers and the National Bureau of Standards. The original purpose of the investigation was to determine whether satisfactory jar rings could be made from reclaimed rubber without the admixture of new

[1] Detailed by the Bureau of Human Nutrition and Home Economics, United States Department of Agriculture, to the National Bureau of Standards for work on this project.

natural rubber, which at that time was becoming increasingly scarce. The results indicated that, for the experimental rings studied, there was no evident correlation between the performance of the rings and the relative percentages of new and reclaimed rubber entering into their composition.

In the course of the work, a study was made of the relation between the properties of the rings as measured in the laboratory and their performance in canning experiments. A brief study was also made of the irregularities of the sealing surfaces of jars and tops in order to ascertain the amount that a jar ring might have to be compressed in order to insure a satisfactory seal.

As a result of these studies, a proposed performance specification for jar rings was formulated, which is thought to be applicable to all jar rings regardless of whether they are made from mixtures of new and reclaimed rubber, reclaimed rubber alone, or from synthetic rubber.

II. VARIATIONS IN JARS AND TOPS

The function of a jar ring is to form a seal between a jar and the cap, or top. As the surfaces to be sealed do not fit perfectly, it is necessary to determine the approximate magnitude and distribution of the irregularities to know how much capacity for indentation a jar ring must have to insure a satisfactory seal. The occurrence of a failure in canning does not necessarily mean that the jar ring was unsatisfactory or defective. It may be that the irregularities in the sealing surfaces exceeded those that the ring was designed to overcome.

The profiles of the sealing surfaces of jars and tops were accurately measured by means of a Last Word dial gage graduated to 0.0001 inch and accurate to about plus or minus 0.0001 inch. The apparatus is

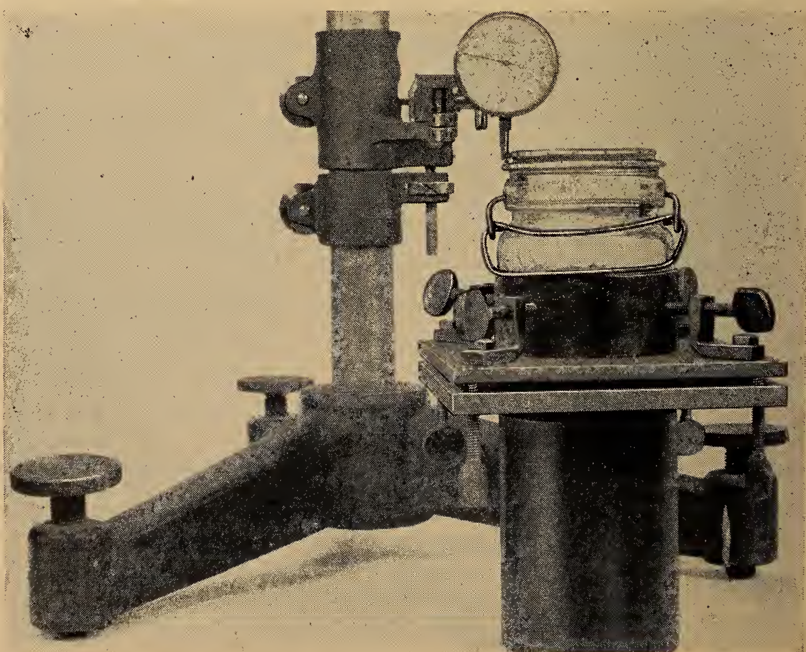

FIGURE 1.—*Apparatus for measuring irregularities of sealing surfaces.*

shown in figure 1. The procedure employed was as follows: The jar or top was placed on the turn table and was carefully centered and leveled with reference to the axis of the table. The foot of the gage was then so set that readings could be taken at any point around a circle in the sealing surface by rotating the table. The surface to be measured was arbitrarily divided into 16 equal radial sectors, starting with a molding seam or some other mark that could be subsequently identified.

The table was then rotated and readings of the gage were taken at each of the 16 points. Any irregular variations between the points were also noted. The readings thus obtained showed the departure of the surface from a true surface. As a matter of convenience, the lowest point of the contour was taken as the reference point.

Figure 2 shows typical profiles that were found for two jars and two tops of the bail type. The 16 sectors are plotted as abscissas and the gage readings as ordinates. In this figure the maximum departure of the sealing surface of jar 14 from a true surface is 0.0086 inch and that of top 14 is 0.0073 inch. The maximum irregularity, then, which a ring would have to overcome would be the sum of these, or 0.0159 inch. Obviously, if the relative positions of the jar and the top are changed, the irregularity to be overcome may be somewhat less than this amount, but in practical canning it would not be possible to pick the best position of the top relative to the jar. The worst condition that might occur must, therefore, be considered. Furthermore, for bail-type jars the relative position of the top to the jar is determined by the design, within narrow limits. The profiles of the sealing surfaces are therefore shown approximately as they would come together.

The sealing surface of jar 2 departs much less from a true surface than does that of jar 14. As may be seen from the figure, however, the surface of jar 2 has sharp, narrow depressions at the molding seams. These depressions might lead to failures in canning on account of the difficulty in forcing rubber into such narrow spaces. Thus, both the shape and the magnitude of the irregularities are important from the standpoint of potential failures.

Measurements made on several different types of jars and tops showed variations in the departures of the sealing surfaces from true surfaces ranging from approximately 0.002 inch to 0.015 inch. These measurements are given primarily for purposes of illustration and are not to be regarded as fully or adequately representing the jars in common use throughout the country. The collection and measurement of a sufficient number of jars and tops to give a generally valid figure for the magnitude of the irregularities and the frequency of their occurrence would be a major investigation in itself.

It was decided from the foregoing measurements and information furnished by manufacturers of jars, that rings should be designed to take care of irregularities of the order of 0.020 inch. On this basis, rings cut 12 to the inch would have to be capable of being indented nearly one-fourth of their thickness under the stresses usually applied in canning, and rings cut 16 to the inch would have to compress about one-third of their thickness.

In the factory, jars and tops are usually inspected with a metal ring having an accurately finished surface. This ring is placed against the sealing surface, and if any rocking can be detected by a skilled operator, the jar or top under test is rejected. It is possible, however, for the profile to be such that significant irregularities cannot be detected by this means.

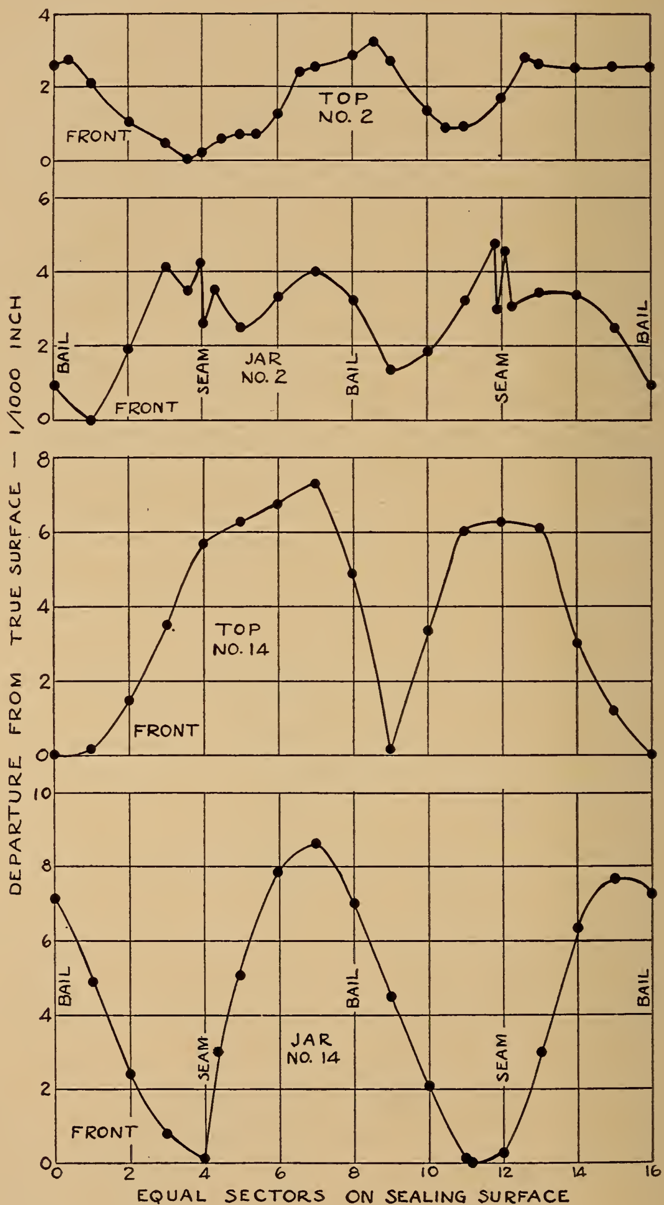

FIGURE 2.—*Representative profiles of sealing surfaces on jars and tops*

III. LABORATORY PROCESSING OF JAR RINGS

The properties of jar rings may be affected considerably by the temperature and the action of the steam encountered in canning. It is important, therefore, that laboratory tests of the rings be designed to show the effect on the rings of a standard canning procedure. Inasmuch as the pressure-cooker method seemed likely to have the greatest effect on the rings of any of the common methods, a uniform procedure was developed for processing the rings so as to simulate the effect of canning in the pressure cooker.

In this procedure the jar rings to be processed were placed on clean absorbent paper on horizontal grids in a pressure cooker of the type used for home canning. The number of rings processed at one time was no more than could be tested for swelling and indentation within 1 hour. The rings were placed well above the level of the water and were distributed so that steam had access to all surfaces.

The water in the pressure cooker was brought to boiling in approximately 15 minutes, and steam was allowed to escape from the vent for 7 minutes to displace all air from the cooker. The vent was then closed, and the temperature was brought to $121° \pm 1°$ C in approximately 15 minutes and held for 120 minutes at that temperature. The cooker was then cooled to 100° C in approximately 15 minutes. The rings were then removed from the cooker.

The rings for the measurement of swelling were placed in water at room temperature, care being taken that their surfaces did not become dry, even momentarily. The rings for the indentation measurements likewise were placed at once in water that was kept boiling. The measurements described below were made as quickly as possible, and in no case more than 1 hour after the removal of the rings from the pressure cooker. No significant difference was found between measurements of swelling immediately on removal from the pressure cooker and after the lapse of 1 hour, during which the rings were kept in water at room temperature. The measurements of indentation were found to change considerably if the rings were kept for any length of time in water at room temperature between removal from the pressure cooker and testing. It was found, however, that they could be kept in boiling water for an hour without significant change.

IV. METHODS OF MEASURING PHYSICAL PROPERTIES OF JAR RINGS

Several different types of measurements were made on jar rings for the purpose of finding characteristics that might be correlated with the behavior of the rings in canning experiments. Tensile strength and ultimate elongation were measured because they were used as criteria of quality in Federal Specification ZZ–R–351 for Jar Rings, which was in effect at the time this investigation was initiated. Measurements of load at an elongation of 100 percent were made at the suggestion of a manufacturer who had found them useful as an index of quality. The swelling that took place during processing was measured because it had been observed that some rings took up moisture to such an extent that they changed significantly both in dimensions and in properties. Inasmuch as sealing by the rings depends directly upon their behavior in compression, measurements of indentation were made both before and after the rings were processed. At the suggestion of one of the jar-ring manufacturer's, measurements of hardness by means of the Shore Durometer were also made. The hardness and indentation measurements are related, as they both measure the same property. The measurements of indentation, however, were much more sensitive and simulate service conditions much more closely than the measurements of hardness.

1. TENSILE STRENGTH AND ULTIMATE ELONGATION

Measurements of tensile strength and ultimate elongation were made on the rings as a whole by the method described in Federal Specification ZZ–R–351 for Jar Rings. This method involved the stretching of the rings by the procedure commonly employed for ring specimens.

2. TENSILE STRESS AT AN ELONGATION OF 100 PERCENT

The force measured was that required to stretch a jar ring until the mean circumference had doubled. In making this measurement the ring was placed over two ⅜-inch mandrels and stretched within a few seconds to the required elongation by means of a hand-operated device. The force was registered by an accurate spring scale. As the force decreased considerably with time, readings were made at regular intervals over a period of several minutes. When these readings were plotted as a function of the logarithm of the time they gave a linear relation, which was extrapolated to give the value of the load at approximately 1 second after stretching.

Measurements were made at room temperature, about 25° or 30° C, and at 100° C. The latter temperature was obtained by stretching the rings in a bath of boiling water.

Measurements were also made on some rings that had been processed for 2 hours at 121° C, but the number of observations was not sufficient to warrant their inclusion in the present report.

3. SWELLING

In the study of the swelling, the weight and volume of a ring were found before and after processing, and from these the percentages of water absorbed by weight and by volume were calculated. In making the determinations the rings were cleaned, dried, and weighed to the nearest milligram, first in air and then in water. They were then processed as described above and kept under water until they could be reweighed but not longer than 1 hour. Each ring was then reweighed in water and in air. It was found that rings could be weighed in air with sufficient accuracy if they were blotted and allowed to dry superficially and were weighed within 1 minute after their removal from the water. The use of a weighing bottle was not found necessary.

From the four weights of each ring the percentage increase in weight and in volume were calculated as follows: Let

w_1=weight of ring in air before processing
w_2=weight of ring in water before processing
w_3=weight of ring in water after processing
w_4=weight of ring in air after processing

$$\frac{w_4-w_1}{w_1}100=\text{increase in weight, percent}$$

$$\frac{(w_4-w_3)-(w_1-w_2)}{(w_1-w_2)}100=\text{increase in volume, percent.}$$

A correction for the temperature of the water used for weighing the rings before and after processing is necessary if the temperatures differ by more than 5° C. In the present work, however, the difference was never more than 2° C.

At the beginning of the investigation the swelling was measured only in percentage increase in weight. The percentage increase in volume, however, was found from the increase in weight and the specific gravity of the rings which had been measured on different specimens from the same lots. In this case,

$$100d\left(\frac{w_4}{w_1}-1\right)=\text{percentage increase in volume,}$$

where d is the specific gravity. This relation is based on the assumption that the volume of a swollen ring is the sum of the volume of the ring and the volume of the water separately.

The increases in thickness and diameter of rings that resulted from processing were found from direct measurements on the rings made by the methods described in Federal Specification ZZ–R–601a. The precision, however, was considerably less than that of the swelling measurements, and although there were indications of pronounced grain effects with certain rings, little information was secured that was not obtainable from the swelling measurements.

4. INDENTATION

The apparatus shown in figure 3 was designed to give a test simulating the conditions of pressure and loading to which jar rings are subjected in canning. It consisted essentially of two parts—a plane metal bearing plate to represent the jar and a Duralumin indentor plate with a flange to represent the top. The indentor used for shoulder rings had a flange 0.2 inch high, 2.70 inches in mean diameter, and 0.050 inch wide, with a flat bearing surface. A vacuum pump was connected to a hole in the bearing plate, and a dial gage graduated to read 0.0001 inch was so mounted as to indicate the changes in the height of the cover plate above the bearing plate.

In making a test the jar ring was placed over the guide on the bearing plate, and the indentor was lightly placed concentrically on the ring. The dial gage, which was supported rigidly with reference to the bear-

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ing plate, was mounted in such a position that its stem rested on the center of the indentor plate and was adjusted to read zero. The small chamber formed by the bearing plate, the ring, and the indentor was then evacuated through the hole in the bearing plate. This procedure caused the indentor flange to press against the jar ring with a force approximately equal to that resulting from a pressure of 1 atmosphere acting over the area inside the indentor flange. This condition gave a pressure of 190 ± 4 lb/in.^{2} on the indentor flange.

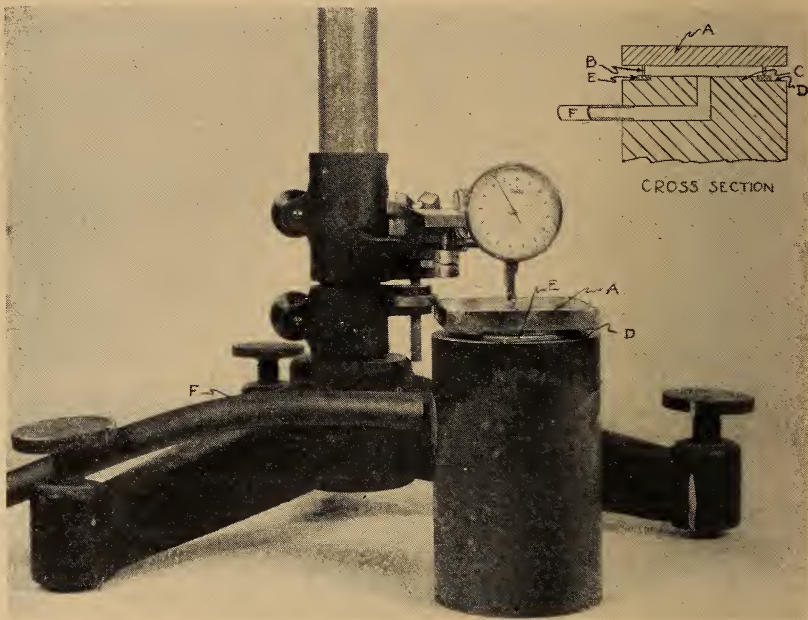

FIGURE 3—*Indentation apparatus.*

A, Indentor plate; B, indentor flange; C, center guide; D, bearing plate; E, jar ring; F, vacuum line.

The pressure on the ring was equivalent to that sustained in canning. This pressure was maintained for 1 minute, at the end of which the indentation was read from the dial gage. Measurements were made on the original rings and on rings that had been processed as described above. The latter were kept in boiling water up to the time of measurement. They were then cooled quickly, blotted dry, lubricated with castor oil, and tested.

5. HARDNESS

Measurements of hardness were made by means of the Shore Durometer according to the procedure outlined in ASTM Specification D–676–42T. As the jar rings were not as thick as the specimens called for by this procedure, the rings were mounted for measurement on a rubber pad having a Shore hardness number of 60.

V. CHEMICAL ANALYSIS OF JAR RINGS

One of the objects of the initial investigation was to determine how much new rubber, if any, it was necessary to add to reclaimed rubber in order to produce satisfactory jar rings. To this end each manufacturer collaborating in the work furnished a series of jar rings made from compounds containing different percentages of new rubber, usually 0, 2.5, 5, and 10 percent. The kinds and amounts of ingredients other than new rubber were left to the discretion of the manufacturers.

It was soon found that there was no correlation between the percentage of new rubber used and the properties or performance of the rings. As a matter of fact, no correlation should be expected because the larger part of the rubber in the rings was derived from reclaimed rubber, and hence variations in the kinds and amounts of reclaim would overshadow the relatively small differences in the percentage of new rubber. The principal reason for using new rubber was not to improve the properties of the finished rings so much as to facilitate the processing and manufacturing operations.

Some of the manufacturers stated the percentage of reclaimed rubber used, but as they did not give its hydrocarbon content, it was necessary to analyze the rings to reduce them to a common denominator.[2]

About 40 different rings were analyzed by the method described in Federal Specification ZZ–R–601a. This method gave the total rubber content but did not differentiate between rubber that had been derived from new crude and that which had been derived from reclaim. The total rubber content thus found was expressed in percent by volume because it is the proportion of rubber by volume not by weight that determines the physical properties of a compound.

The results are summarized in table 1 and are discussed in a subsequent section in relation to the performance of the rings.

VI. TASTE IMPARTED TO CANNED FOOD BY JAR RINGS

Oral reports have indicated that taste imparted to the canned food by jar rings has been a prolific source of complaints regarding wartime jar rings. Unfortunately, taste cannot be dealt with by direct, objective measurements, such as are employed for evaluating other characteristics and properties of the jar rings. The present investigation did not include an evaluation of taste.

Taste imparted by jar rings does not come from the rubber itself but from minor constituents that are present in such small amounts that they cannot be readily detected by the usual chemical tests. As mentioned in a preceding section, most jar rings are made from reclaimed rubber produced from discarded tires, inner tubes, and various other scrap-rubber articles. These articles, of course, are made for mechanical purposes without regard to taste or odor, and are likely to contain tars, asphaltic substances, organic accelerators and antioxidants, and various other materials unpleasant to the taste. These offending materials can be avoided to a considerable extent in normal times by a careful selection of the scrap, which is not possible under present conditions. The reclaiming processes remove the offending constituents to a greater or lesser extent, but at the present stage of the art do not produce a tasteless and odorless product.

The synthetic rubber GR–S is being used to some extent in the production of jar rings. As ordinarily produced, GR–S has an appreciable taste and odor due to the residual styrene. The styrene can be

[2] Reclaim, or reclaimed rubber, contains most of the fillers and other compounding ingredients that were in the original scrap and, in addition, softeners and other materials added during reclaiming. The constituent of principal value is the rubber hydrocarbon, and this is commonly used as an index for comparing different reclaims.

TABLE 1.—*Comparison of physical properties of jar rings with canning failures*

NBS No.	Company	Type and color	Composition		Canning method				Unprocessed		Unprocessed (load at 100-percent elongation)		Rubber by volume	Specific gravity	Swelling on processing		Indentations			Shore hardness	
					Hot fill		Pressure cooker														
			Crude	Reclaim[b]	Number canned	Number of failures	Number canned	Number of failures	Tensile strength	Ultimate elongation	Room temperature	100° C.			Increase in weight	Increase in volume	Unprocessed	Processed	Increase	Unprocessed	Processed
									Lb/in.²	*Percent*	*Pounds*	*Pounds*	*Percent*		*Percent*	*Percent*	*Inch*	*Inch*	*Percent*		
1	A	"Mechanical blend" black	0	56	10	0	10	0	1,060	260	14.85	6.60	--------	1.514	10.4	15.7	0.0110	0.0271	146	67	48
2	A	do	2	52.14	10	0	10	4	1,060	210	17.15	7.60	--------	1.535	11.8	18.0	.0120	.0221	84	73	50
3	A	do	5	49	10	0	8	0	1,250	260	17.05	8.60	--------	1.560	9.2	14.3	.0131	.0194	48	71	55
4	A	do	10	38	10	0	10	0	1,460	310	19.90	11.10	--------	1.534	8.6	13.1	.0109	.0170	56	72	56
5	B	Tube red	0	50	10	0	10	2	1,060	340	15.90	7.65	56.6	1.550	6.8	10.5	.0162	.0191	18	64	49
6	B	do	2½	50	10	1	10	1	950	350	14.10	7.20	57.4	1.524	8.4	12.7	.0170	.0210	24	64	48
6A	B	do	2½	------	------	------	------	------	1,130	370	13.10	7.50	56.4	1.512	7.8	11.7	.0178	.0289	62	64	48
7	B	do	5	50	10	0	10	0	1,150	370	13.70	7.60	55.6	1.495	7.2	10.7	.0143	.0234	64	63	48
8	B	do	10	40	10	0	8	3	1,290	390	14.38	8.20	55.8	1.501	6.4	9.6	.0160	.0207	29	62	47
9	B	Tire black	0	------	10	0	10	4	1,030	290	12.70	5.30	58.9	1.380	27.6	38.0	.0192	.0400	109	58	40
10	B	do	2½	------	10	0	9	6	1,220	310	13.55	6.55	56.3	1.363	22.4	30.4	.0180	.0325	81	62	44
11	C	do	0	68	10	0	10	0	1,050	180	18.70	9.30	48.3	1.365	15.2	20.6	.0168	.0218	30	66	55
12	C	do	2½	62	10	1	9	0	1,250	170	19.00	10.05	49.6	1.369	15.3	20.8	.0126	.0144	14	73	58
13	C	do	5	56	10	0	9	1	1,165	240	17.00	9.80	49.6	1.358	13.1	17.6	.0079	.0111	41	73	66
14	C	do	10	43	10	1	9	0	1,280	190	19.65	11.35	47.3	1.370	10.4	14.2	.0113	.0122	8	73	68
15	D	Ruby red inner-tube	0	64.5	10	0	10	3	1,220	380	10.45	6.70	54.7	1.502	9.1	13.6	.0166	.0250	51	58	46
16	D	do	2½	60	10	0	10	2	1,310	370	10.85	7.70	54.6	1.523	10.8	16.4	.0145	.0250	72	63	52
17	D	do	5	55	10	0	10	1	1,060	330	11.60	8.10	55.6	1.540	9.3	14.3	.0124	.0202	63	64	52
18	D	do	10	45	10	0	9	2	1,270	340	14.00	9.75	56.4	1.556	6.3	9.7	.0115	.0170	48	64	58
19	D	Black tire and a small amount of inner tube	0	70	9	0	10	7	760	230	10.12	5.55	47.3	1.421	45.8	65.0	.0168	.0417	148	59	44
20	D	do	2½	65	10	0	10	5	921	210	15.90	7.70	49.8	1.467	36.4	53.1	.0146	.0435	198	65	40
21	D	do	5	60	10	0	10	5	1,110	260	15.00	7.70	49.8	1.467	30.4	44.3	.0134	.0430	221	66	40
22	D	do	10	55	10	2	10	2	1,210	300	13.22	7.20	52.4	1.443	26.1	37.5	.0135	.0408	202	65	42
23	E	Tube red	0	54	10	0	9	1	760	160	14.00	8.95	48.1	1.615	3.5	5.6	.0105	.0141	34	68	58
24	E	do	2½	49	10	0	10	1	860	200	15.20	9.30	47.2	1.611	6.0	9.6	.0114	.0160	40	69	57
25	E	do	5	44.8	10	0	9	1	1.070	250	15.80	10.60	48.3	1.604	4.5	7.2	.0117	.0136	16	68	59
26	E	do	8.8	37.4	10	0	10	0	1,070	250	14.50	9.90	48.7	1.600	4.6	7.3	.0116	.0139	20	67	61
27	E	do	10	35	10	0	10	3	1,060	250	15.50	10.35	48.2	1.607	4.7	7.5	.0122	.0145	19	66	61

28	F	Tube red	0	49.63 6.20	10	0	10	0	920	300	12.20	6.90	47.2	1.555	8.2	12.7	.0147	.0208	42	62	52
29	F	do	2.45	46.19 6.77	9	0	10	3	990	310	13.10	7.80	46.6	1.570	8.4	13.1	.0146	.0206	41	60	53
30	F	do	4.89	42.74 7.33	10	2	10	0	1,080	340	13.10	8.80	47.8	1.570	9.5	14.9	.0143	.0192	34	65	55
31	G	Tube black	0	52	9	0	10	2	1,310	370	13.70	8.45		1.541	2.4	3.6	.0112	.0155	38	67	64
32	G	do	2½	47	10	0	10	0	1,370	370	13.70	8.75		1.544	4.7	7.7	.0109	.0149	37	66	62
33	G	do	5	43	10	0	9	0	1,360	270	16.70	10.55		1.460	3.7	5.4	.0102	.0130	27	68	59
34	H	Tube red	0		10	0	10	2	1,410	320	20.80	9.70	60.9	1.524	11.1	16.8	.0154	.0299	94	64	48
35	H	do	2½	0	10	0	10	2	1,160	350	15.40	10.20	55.0	1.645	8.4	13.7	.0163	.0200	23	64	52
36	H	do	5		10	0	8	0	1,140	440	11.55	8.10	54.0	1.640	7.8	12.7	.0164	.0209	27	62	54
37	H	do	10		10	0	9	2	1,340	360	12.10	9.30			6.7		.0170	.0240	41	63	52
38	H	Tire black (12 cut)	0		10	0	10	1	1,550	230	22.00	11.70	64.8	1.370	4.6	6.3	.0134	.0150	12	73	62
39	H	do	2½		10	2	10	0	1,260	240	16.70	10.30	55.6	1.410	3.4	4.7	.0111	.156	41	71	62
40	H	do	5		10	0	10	0	1,320	220	16.10	10.10	55.0	1.454	3.5	5.1	.0097	.0139	43	74	64
41	H	do	10		10	0	10	2	1,220	250	14.50	9.80	54.4	1.465	3.1	4.5	.0102	.0144	41	74	64
42	I	Tire black	0	61.2	10	1	10	4	1,250	90	(a)	(a)		1.339	3.8	5.0	.0099	.0107	8	81	76
43	I	do	2½	59.7	10	0	9	0	1,330	160	20.65	12.70		1.331	4.1	5.4	.0101	.0130	29	75	69
44	I	do	5	58.2	10	0	9	2	1,300	120	(a)	(a)		1.348	3.8	5.0	.0089	.0108	21	79	72
45	I	Red inner tube	8.6	30	10	0	10	1	1,033	280	16.10	10.50			8.3		.0092	.0160	74	70	58
46	J	Red (tube?)	0	45	10	0	10	3	820	180	15.25	7.30	46.8	1.702	11.2	19.0	.0099	.0321	224	67	45
47	J	do	3	42	10	0	10	3	990	270	13.10	8.40	48.7	1.707	5.9	10.0	.0088	.0200	127	69	53
48	J	do	5	39	10	2	10	1	950	240	16.75	9.75	50.9	1.672	5.1	8.5	.0082	.0187	128	70	56
49	J	Tube black	0	42.7	10	0	9	1	800	140	(a)	7.90	40.9	1.665	4.3	7.1	.0066	.0163	147	76	56
50	J	do	2½	40.8	10	1	10	2	840	170	15.15	8.80	42.5	1.653	4.3	7.0	.0067	.0131	96	74	57
51	J	do	5	39.0	10	0	10	0	930	110	17.70	9.80	43.7	1.674	5.1	8.5	.0069	.0121	75	72	63
52	J	do	10	35.3	10	0	9	0	930	160	13.95	8.40	46.1	1.657	6.3	10.3	.0092	.0152	65	69	58
53	K	Red			10	0	9	0	720	300	8.70	5.55			2.5		.0146	.0211	45	64	57

[a] Broke.
[b] The first values for samples 28, 29, and 30 are for red-tube reclaim; the second values are for red custom reclaim.

removed in large part at some added cost of manufacture, and the production of a special grade of GR–S latex for use by the food processing industries has been authorized by the Rubber Reserve Co.

VII. AGING OF JAR RINGS

At the outset of the investigation representative rings were subjected to the accelerated aging tests that are commonly applied to rubber goods. Some of the ring were aged in air at 70° C for 7 days, and others were subjected to oxygen at 300-lb/in.^{2} pressure at 70° C for periods of 2 days and 4 days. Measurements of tensile strength and ultimate elongation were made before and after accelerated aging. The results obtained indicate that the rubber probably would last for several years without becoming soft and sticky or hard and brittle.

Measurements of indentation and hardness, however, as given in table 2, showed that the rings might undergo appreciable changes in these characteristics as a result of natural aging within a relatively few months. In general, tests on aged rings made before processing showed a decreased indentation and an increased hardness; tests made after processing showed an increased indentation and a decreased hardness. This effect is not necessarily associated with the failure of rubber. It rather represents a change that is of little consequence for many types of rubber articles, but which may be of importance in connection with jar rings, especially if they are near the limits of acceptable performance. A comparison of the changes in indentation shown in table 2 with the number of canning failures shown for the same rings in table 1 indicates that the greater the change in indentation with aging the greater the number of canning failures.

Table 2.—*Effect of aging on swelling, indentation and hardness of jar rings*

Ring number	Date tested	Swelling, %		Indentation			Shore hardness	
		Increase in volume	Increase in weight	Unprocessed	Processed	Percentage increase	Unprocessed	Processed
				Inch	*Inch*			
2	June	18.0	11.8	0.0120	0.0221	84	-----	-----
	Sept	-----	-----	-----	-----	-----	73	50
	Nov	19.0	12.2	.0088	.0314	257	74	40
9	June	38.0	27.6	.0192	.0400	109	58	40
	Sept	-----	-----	-----	-----	-----	-----	-----
	Nov	33.4	24.1	.0143	.0482	236	61	35
23	June	5.6	3.8	.0105	.0141	35	68	58
	Sept	-----	-----	-----	-----	-----	-----	-----
	Nov	5.8	3.3	.0097	.0141	44	68	56
28	June	12.7	7.5	.0147	.0208	42	-----	-----
	Sept	-----	-----	-----	-----	-----	62	52
	Nov	12.6	8.0	.0120	.0235	95	69	44
40	June	5.1	3.5	.0097	.0139	44	-----	-----
	Sept	-----	-----	-----	-----	-----	74	64
	Nov	5.2	3.5	.0083	.0140	68	75	55
42	June	5.0	3.8	.0099	.0107	8	-----	-----
	Sept	-----	-----	-----	-----	-----	81	76
	Nov	4.6	3.4	.0101	.0128	26	83	66

VIII. CANNING TESTS AS A BASIS FOR DEVELOPMENT OF A JAR-RING SPECIFICATION

Approximately 50 different lots of shoulder rings obtained from 10 different manufacturers were used for canning tests by the Bureau of Human Nutrition and Home Economics. These lots of rings were duplicates of those tested by the National Bureau of Standards. Canning tests were made on 20 rings from each lot. Ten were tested by the hot-fill method and 10 by the pressure-cooker method. In the hot-fill method, preheated jars of the bail type were filled with hot water, sealed immediately, and placed in a gentian violet dye bath to cool. Leakage was determined by the presence of dye inside the jars. In the pressure-cooker method, the jars were filled with a mixture of ground meat, corn, cottonseed oil, and water, partially sealed, and processed at 121° C in a pressure cooker for 2 hours. Immediately upon removal of the jars from the pressure cooker, the seal was completed and the jars were immersed in a cooling bath that was heavily contaminated with the spores of an especially heat-resistant strain of *Clostridium sporogenes*. Leakage was determined from spoilage that occurred during an incubation period or the subsequent subculturing of the contents of the jars.

The failures resulting from tests made by the hot-fill method could not be correlated with the failures resulting from the tests made by the pressure-cooker method. In fact, the few random failures that did occur in the hot-fill tests were probably attributable to variables other than the jar rings, such as warped sealing surfaces. Unfortunately, the study of variations in jars and tops described in a previous section of this paper had not been made when these canning tests were conducted.

It seemed desirable therefore to use only the tests made by the pressure-cooker method as a basis for the development of a specification. The results of these canning tests are summarized in table 1, along with the measurements of physical properties and chemical composition on the same rings. The data given in this table were used as described in a later section for establishing the limits to be employed in a specification.

After a tentative specification had been developed a number of additional samples of rings produced in connection with experimental and development work were also tested.

IX. CORRELATION OF PROPERTIES AND COMPOSITION OF JAR RINGS WITH RESULTS OF CANNING TESTS

The results summarized in table 1 were examined to determine which of the laboratory measurements could be correlated with the failures in canning and what limits should be imposed on each of the significant properties in order to differentiate between satisfactory and unsatisfactory rings.

1. METHOD OF CORRELATING RESULTS

Table 3 gives the limits used in the two methods that were employed in correlating the results of the physical measurements with the canning tests. The first method consisted in noting the limits, designated as *A* limits, of the various physical measurements that were made on the lots of rings showing no canning failures, and in applying these limits to those rings with which canning failures were observed. In the ideal case this method would suffice for the development of limits for the purposes of a specification. The variations in the canning tests, however, are such that reliable conclusions must be based on averages rather than individual observations. Hence in the second method of treating the data, narrower sets of limits, designated as *B* limits, were established by trial and error methods. In arriving at the *B* limits consideration was given both to the significance of the individual properties and to the effectiveness of a combination of properties in defining rings that would show the desired performance.

TABLE 3.—*Limits of physical requirements*

Property	Limits required to pass all rings having no canning failures (*A*)	Suggested limits (*B*)
Tensile strength, lb/in.[2]	720 min	----------
Elongation, percent	112 min	----------
Tensile strength [1] at 100-percent elongation, lb/in [2]:		
At room temperature	198 min	----------
At 100° C	126 min	----------
Swelling on processing:		
Weight, percent	15.3 max	12 max
Volume, percent	20.8 max	16 max
Indentation (unit 0.0001 inch):		
Unprocessed	168 max	165 max
	69 min	100 min
Processed	271 max	250 max
	121 min	120 min
Increase, percent	145 max	110 max
Shore hardness:		
Unprocessed	62 min	60 min
	75 max	75 max
Processed	48 min	50 min
	69 max	65 max
Decrease	19 max	15 max
Rubber by volume, percent	43.7 min	----------

[1] These values of tensile stress were derived from the values of load at 100-percent elongation given in table 1. The actual values of load given in table 1 were used to show the effectiveness of tensile stress in eliminating poor jar rings. This procedure is justified by the fact that the cross-sectional area of all rings tested was approximately the same.

The *B* limits were set relatively narrower than the *A* limits. They would eliminate 58 percent of the lots of rings with which no failure occurred, 50 percent of those with one failure, 64 percent with two failures, 66 percent with three failures, and 100 percent of all lots showing more than three failures. It was not possible to devise limits which would pass all the rings showing no failures and at the same time bar a high percentage of those with which failures occurred. It was felt that it would be better to set a specification so as to reject some rings which might give satisfactory results than to pass many rings with which failures are likely to occur.

2. EFFECTIVENESS OF LIMITS IN EXCLUDING RINGS SHOWING CANNING FAILURES

The effectiveness of the two sets of limits in excluding rings with which canning failures were found is shown in summary form in table 4. The results of canning tests are given at the top of the table in terms of the number of failures per lot of rings. The table also shows the percentage of rings that would be barred by the *A* and the *B* limits for each property.

The *A* limits, which were arrived at by a purely mechanical process, would pass all rings with which there were no canning failures, and would bar 30 percent of the lots in which there was one canning failure, 45 percent of the lots with two failures, 66 percent of the lots with three failures, and all lots showing more than three failures.

The application of the *A* limits shows clearly that certain properties which are commonly used in specifications for rubber goods are not effective in affording a basis for separating rings that are shown to be unsatisfactory from the standpoint of performance. This is particularly true of tensile strength and ultimate elongation, and to a lesser extent of load at 100 percent elongation, or tensile stress which may be calculated from the load.

3. RELATION OF COMPOSITION TO PROPERTIES

Likewise, the composition, within the range covered by the present investigation, bore no definite relation to the results of canning tests. It had been expected that the number of canning failures would be less the higher the percentage of rubber in the rings, but such was not found to be the case. The rings may be divided, for example,

TABLE 4.—*Correlation between canning tests and physical properties of jar rings*

	Number of failures per lot							
	0	1	2	3	4	5	6	7
Results of canning tests:								
Number of lots	19	10	11	6	3	2	1	1
Number of jars canned	180	96	107	58	30	20	10	10
Total number of failures (jars)	0	10	22	18	12	10	6	7
Rings eliminated under (A) maximum limits assigned to physical properties by:	%	%	%	%	%	%	%	%
Tensile strength	0	0	0	0	0	0	0	0
Elongation	0	0	0	0	33	0	0	0
Load—100-percent elongation—								
Room temperature	0	9	8	0	33	0	0	0
100° C	0	0	8	0	67	0	0	0
Swelling, percent—								
Weight	0	0	9	0	33	100	100	100
Volume	0	0	9	0	33	100	100	100
Indentation—								
Unprocessed	0	20	18	14	33	0	100	0
Processed	0	9	27	17	67	100	100	100
Increase, percent	0	9	9	17	0	100	0	100
Rubber by volume	0	9	9	0	0	0	0	0
Shore hardness—								
Unprocessed	0	9	8	34	67	0	0	100
Processed	0	0	18	48	67	100	100	100
Decrease	0	9	9	34	33	100	0	0
Total eliminated [1]	0	29	45	66	100	100	100	100
Rings eliminated under (B) suggested limits assigned to physical properties by:								
Swelling, percent—								
Weight	11	9	9	0	33	100	100	100
Volume	11	9	28	17	67	100	100	100
Indentation—								
Unprocessed	22	40	26	66	67	0	100	100
Processed	6	9	27	17	67	100	100	100
Increase, percent	6	20	9	34	0	100	0	100
Shore hardness—								
Unprocessed	0	9	8	17	67	0	0	100
Processed	21	20	36	48	67	100	100	100
Decrease	16	20	28	50	33	100	100	0
Total eliminated [1]	58	50	64	66	100	100	100	100

[1] The total percentage of rings eliminated is the total number of rings eliminated by 1 or more tests multiplied by 100 and divided by the number used in canning. Sometimes different tests eliminate the same rings, sometimes different rings.

into two groups, 1 group of 19 lots containing more than 50 percent of rubber by volume, and the other group of 22 lots containing less than 50 percent. The first group shows a total of 41 canning failures and the second, likewise, 41 canning failures. It should not be concluded from this that the rubber content is immaterial, but rather that within the range of compositions here dealt with there were no differences that could be attributed to the rubber content. The lack of correlation between the number of failures per lot and the percentage of rubber by volume is clearly shown by figure 4.

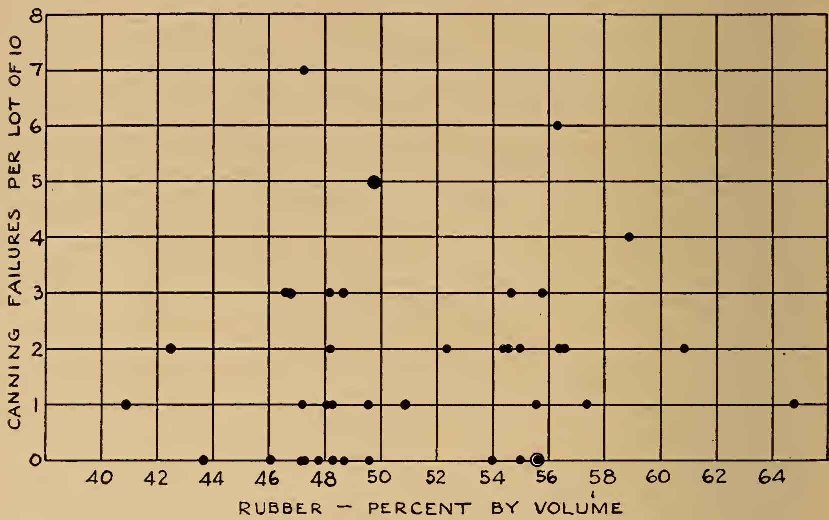

FIGURE 4.—*Relation of canning failures to percentage of rubber by volume.*

X. PROPOSED SPECIFICATION FOR JAR RINGS

The results presented in the foregoing sections of this paper were used as the basis for drawing up a proposed specification for jar rings. This specification deals only with the performance of the rings and hence should be applicable to any rings irrespective of the composition.

PROPOSED SPECIFICATION

FOR

RUBBER RINGS: JAR (FOR HOME CANNING)

A. APPLICABLE FEDERAL SPECIFICATIONS

A-1. The following Federal specification of the issue in effect on date of invitation for bids shall form a part of this specification.

ZZ-R-601. Rubber Goods: General Specifications (Methods of physical tests and chemical analysis).

B. TYPES AND GRADES

B-1. Rings shall be of a single grade in each of the two types described below.

Type I. Top seal.
Type II. Shoulder seal.

C. MATERIAL AND WORKMANSHIP

C-1. Jar rings shall be free from defects in material and workmanship. (See paragraph I-1.)

D. GENERAL REQUIREMENTS

D–1. Jar rings shall be suitable for use in the canning of vegetables, fruits, meats, and other food products by the hot-fill, the water-bath, the oven, and the pressure-cooker methods. Jar rings shall not impart off flavors to the canned food.

E. DETAIL REQUIREMENTS

E–1. *Dimensions.*—Jar rings shall have dimensions within the following limits.

	TYPE I		TYPE II	
	Max.	Min.	Max.	Min.
Thickness, inch	0.086	0.080	0.086	0.080
Width of flange, inch	.28	.25	.28	.25
Internal diameter, inches	-----	2.00	-----	2.20

E–2. *Application.*—Jar rings shall have sufficient strength and elasticity to permit application to jars without tearing or other damage to the ring. When applied the rings shall fit snugly without buckling.

E–3. *Mechanical properties.*—Jar rings shall meet the following requirements when tested in accordance with the methods described in section F:

Property	Max.	Min.
INDENTATION:*		
Indentation of original rings, inch	0.0165	0.010
Indentation of rings after processing, inch	.0250	.012
Increase of indentation on processing, percent	110	-----
SWELLING:		
Increase of volume on processing, percent	16	-----
Increase of weight on processing, percent	12	-----
HARDNESS:*		
Hardness of original rings, Shore scale	75	60
Hardness after processing, Shore scale	65	50
Decrease of hardness on processing	15	-----

*It is not intended that both indentation and hardness shall be made on the same sample of rings since they both measure the same property. Hardness measurements may be made in lieu of indentation at the descretion of the purchaser. Indentation measurements shall be made in all cases of disagreement.

F. METHODS OF SAMPLING, INSPECTION, AND TEST.

F–1. *Sampling.*—Two dozen rings shall be taken at random from each 1,000 gross or fraction thereof.

F–2. *Indentation.*—For purposes of this specification the indentation is that which is produced by a metal circular indentor flange placed concentrically on a jar ring while the jar ring is lying on a flat plate equipped with a center guide. The pressure on the indentor surface shall be 190 ±4 pounds per square inch. This pressure is approximately equal to that which would result from a pressure of 1 atmosphere acting on the area inclosed within the metal indentor flange specified in F–2a and F–2b.

When jar rings to be tested are of such sizes as to preclude the use of the above indentor, other indentor rings shall be provided and the load shall be adjusted so that the pressure on the indentor surface is 190 ± 4 pounds per square inch.

F–2a. *Apparatus.*—The apparatus shown in figure 3 for measuring the indentation of jar rings shall consist of a flat metal bearing plate, *D*, with a center guide, *C*, an indentor plate, *A*, with an integral circular indentor flange, *B*, and a dial gage graduated to 0.0001 inch mounted on the bearing plate in such a way that it will bear in the center of the indentor plate when the indentor plate is placed on the jar ring concentric with the guide on the bearing plate. The bearing plate and the indentor plate shall conform to the following requirements

F–2a (1). *For type I jar rings.*—The bearing plate, except for the center guide, shall not deviate from a flat surface by more than 0.0005 inch. The center guide on the bearing plate shall be 2.187 ±0.005 inches in outside diameter, and shall be approximately 0.075 inch high.

The indentor plate including the indentor flange shall weigh approximately 5.3 oz (150 g). The indentor flange shall be 2.50 ±0.005 inches in mean diameter, 0.046 ±0.001 inch wide, shall have a flat bearing surface, and shall protrude not less than 0.2 inch from the indentor plate.

F–2 a (2). *For type II jar rings.*—The apparatus used for measuring the indentation of type II jar rings shall conform to the requirements given in F–2a, except that the outside diameter of the guide on the bearing plate shall be 2.325 ±0.005 inches; the mean diameter of the indentor flange shall be 2.700 ±0.005 inches, and the width of the flange shall be 0.050 ±0.001 inch.

F–2b. *Procedure.*—The indentor ring shall be wiped with castor oil before each measurement.

Indentation shall be measured by means of a gage accurate to within ±0.0001 inch, and the indentation reading shall be taken 1 minute after the load has been applied.

In making the indentation test, three jar rings shall be cleaned and dried and the indentation measured in accordance with the above instructions. Three additional rings from the same lot shall then be processed in accordance with paragraph F–4 and the measurements repeated.

F–3. *Swelling.*—Three jar rings shall be cleaned, dried, and weighed in air and in water with an accuracy of ±0.001 g. These rings shall be processed as directed in paragraph F–4, and shall again be weighed, first in water, and then in air. The weighing in air shall be made within 30 seconds after the ring has been removed from water and blotted or wiped dry. The drying may also be effected by immersing the rings in alcohol for 5 seconds and quickly shaking off the excess, and allowing the remainder to evaporate within a few seconds.

Calculations of the percentage increase in weight and in volume may be made as follows: Let

w_1 = weight of ring in air before processing
w_2 = weight of ring in water before processing
w_3 = weight of ring in air after processing
w_4 = weight of ring in water after processing.

$$\frac{w_3-w_1}{w_1}\times 100=\text{increase in weight on processing, percent}$$

$$\frac{(w_3-w_4)-(w_1-w_2)}{w_1-w_2}\times 100=\text{increase in volume on processing, percent.}$$

The temperatures of the water used for weighing the rings before and after processing shall not differ by more than 5° C.

F–4. *Processing.*—Jar rings to be processed shall be placed on clean absorbent paper on horizontal racks or grids in a pressure cooker of the type used for home canning. The rings shall be placed above the level of the water and shall be distributed so that steam has access to all surfaces.

The water in the pressure cooker shall be brought to boiling in approximately 15 minutes and steam shall be allowed to escape from the vent for 7 minutes to displace all air from the cooker. The vent shall be closed and the temperature shall be brought to 121° ± 1° C in approximately 15 minutes and held for 2 hours at that temperature. The cooker shall then be cooled to 100° C in approximately 15 minutes.

The rings shall then be removed from the cooker. Those for swelling measurements shall be placed in water at room temperature and those for the measurement of indentation, in water which is kept boiling. The rings shall be kept in water at the respective temperatures until measurements are to be made. All measurements shall be completed within 1 hour after the removal of the rings from the pressure cooker.

Rings for indentation test shall be cooled in water and tested within one minute.

F–5. Hardness shall be measured as directed in ASTM Specification D–676, Indentation of rubber by means of the Durometer.

I. NOTES.

I–1. This specification is intended to give requirements essential to the performance of jar rings, irrespective of the material from which they are made. Consequently, rings furnished under the specification may be made from any material suitable for the intended purpose.

I–2. It has been found that the results of swelling tests are not significantly altered by keeping the rings in water at room temperature for periods up to 1 hour after processing. Similarly, the results of indentation tests are not changed significantly if the rings are kept in boiling water up to 1 hour.

WASHINGTON, April 10, 1945.

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