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A Life Test Study of Refrigerator Compressor Finishes and Fits and Related Machining corrections

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A LIFE TEST STUDY OF REFRIGERATOR COMPRESSOR FINISHES AND FITS AND RELATED MACHINING CORRECTIONS

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"The objective of this study was the development of compressor finishes and related tolerances and to show their advantages by extensive life tests."

INTRODUCTION

Compressor life may be extended by limiting the variations in piston roundness and by using a lubrite, nonmetalic, oil absorptive piston coating for additional surface protection.

It is the purpose in this presentation to discuss several facets of a problem concerning compressor failure caused by piston surface conditions in a 1/3 horse power, 1750 R.P.M. scotch-yoke piston compressor, and the corrective means evolved to satisfy the manufacturer's warranty.

Most refrigerator manufacturers sell their products under a five year guarantee. There is a desire to extend this period to as much as ten years. Life tests of various forms are used to establish assurance that the compressor will perform over an extended period to satisfy the guarantee. They may be used to determine a possible weakness in design or the effect of surface variations on the life of the moving parts. Any tendency to failure which begins to show up during manufacturing quality assurance tests or in field operation needs to be evaluated and corrective means established. The life test program can then be useful to provide confidence in the proposed change.

MEASUREMENT OF COMPRESSOR PARTS

The normally specified microinch surface finish (figure 1) is easily obtained with good practice, and quickly verified by surface indicating instruments. The stylus of such an instrument travels longitudinally of the work with uniform motion (figure 2) so that it gives no indication of roundness. Even though the microfinish is acceptable, the part roundness of a piston, cross-slide, or shaft (figure 3) is most likely to be unacceptable unless measured and controlled as a result of proper instrumentation. Out of roundness can not

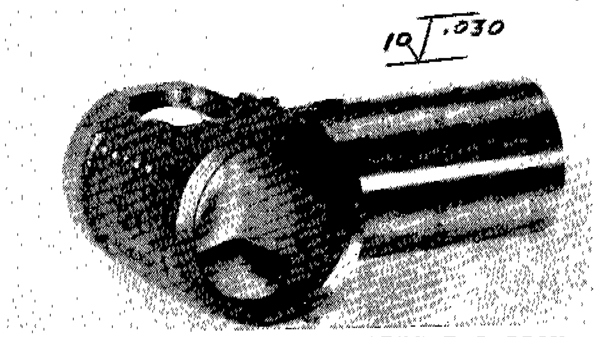

FIGURE 1 MICRO-FINISH SPECIFICATION

FIGURE 2 MICRO INCH FINISH READING

be measured with any certainty by diametric gaging, or vee-block technique.

There are several precision roundness testing instruments on the market which produce accurate polar chart traces of the perifery of the work. Such charts show the type, amount, and location of the departure from roundness which a good machine operator would soon correlate with his setup or adjustments.

Circumferential waviness, described hereafter as fluting in the case of small waves, and as lobing for larger waves, is found on all surfaces of revolution produced by machining and grinding operations. Elastic deformation and deflections due to cutters or wheel pressure are primary causes. Some of the other influences include:
geometry of the part to withstand the grinding forces, condition of feed regulating wheel, infeed rate, feed rest height and support angle, bad spindle bearings, motor bearings and belts, and/or the amount of dynamic unbalance in the grinding wheel assembly. Even environemntal vibration from other machines can be transmitted through floor to cause trouble.

EFFECT OF DYNAMIC BALANCING

Complete elimination of waviness is seldom practical. It is therefore necessary to determine and control the permissible amount of waviness for the application intended. A vibration analizer was a valuable aid in determining the sources of vibration on the centerless grinding machines. This equipment was also used for dynamic, in place balancing of the grinding wheels to make very important contributions to the control of piston lobing and fluting.

(figure 4) shows a piston profile from a grinder which had 160 Mu" (micro-inches) of machine vibration with wheel unbalance. The part was 3 lobed, 120 Mu".

(figure 5) shows another piston after vibration was reduced to 20 Mu" by wheel balancing. Here the 3 lobed condition was almost eliminated: the largest deviation being only 60 Mu".

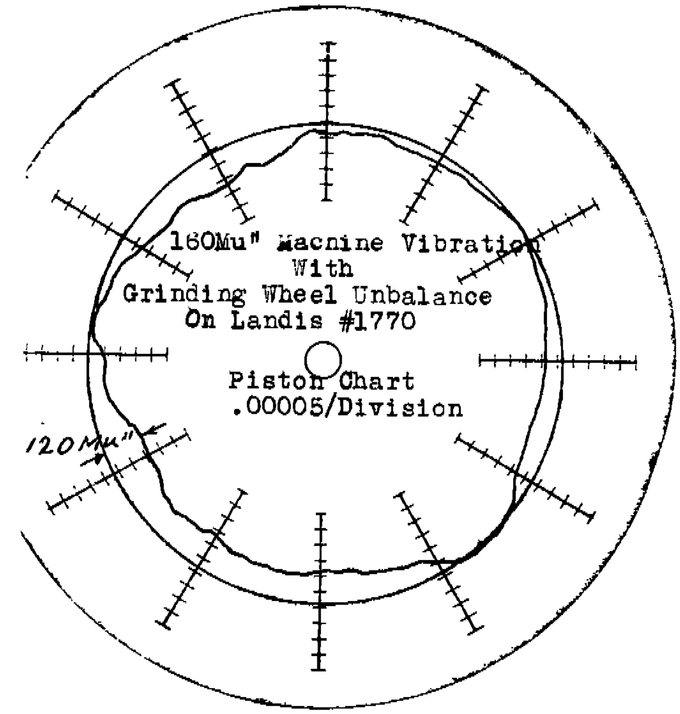

FIGURE 4 PISTON PROFILE WITH GRINDING WHEEL UNBALANCE

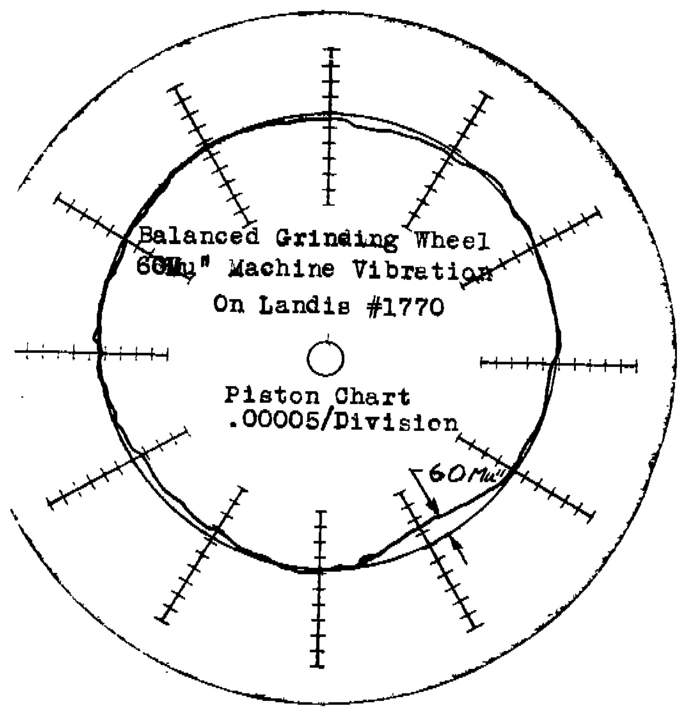

FIGURE 5 PISTON PROFILE WITH GRINDING WHEEL BALANCED

TYPICAL RESULTS

(Figure 6) The perfectly round part shown here is ideal but seldom produced.

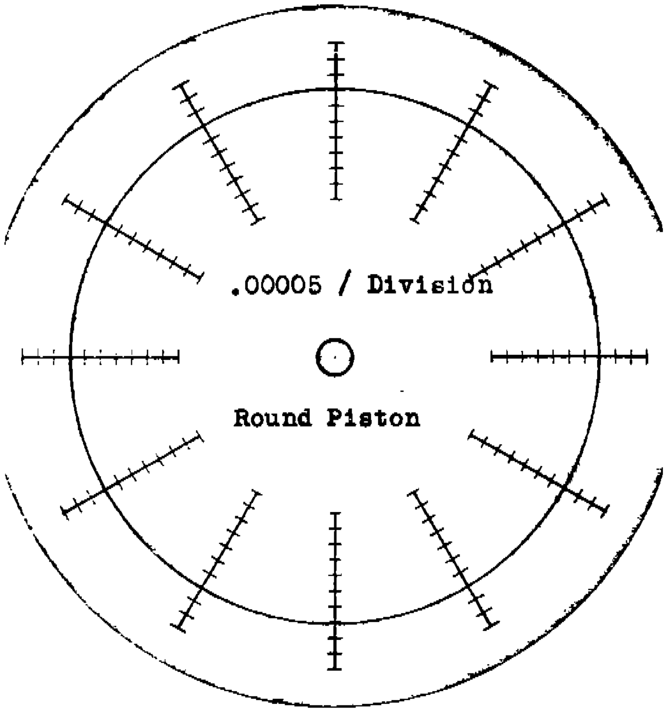

FIGURE 6 THE IDEAL PISTON

(Figure 7) This oval geometry will not often occur unless the part has a fair-sized cross-hole to cause uneven grinding area and varying wheel pressure.

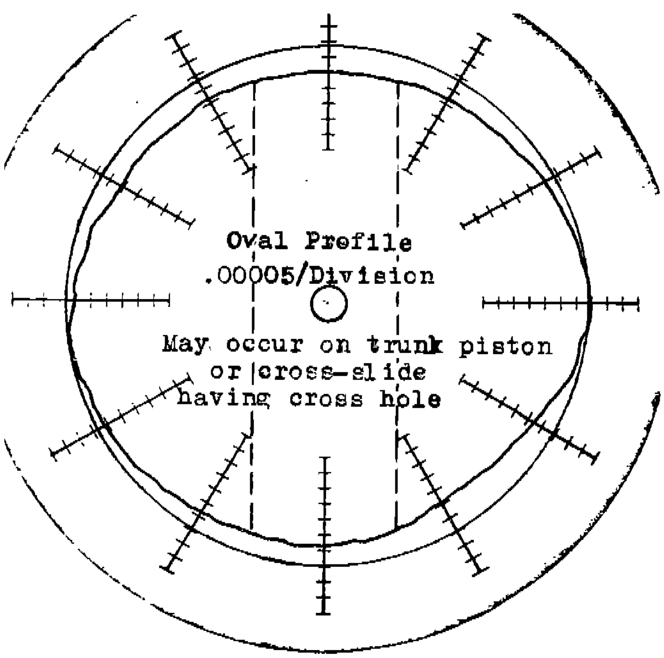

FIGURE 7 THE EFFECT OF PART GEOMETRY ON THE GROUND FINISH PROFILE

This shape (7) is quite prevalent on cross-slides and trunk pistons. It would actually be an advantage on a cross-slide in a scotch-yoke mechanism because it would provide slight relief as the slide moved over the ends of the yoke slots.

(Figure 8 and Figure 9) Parts having 3 or 5 major lobes are usual occurances. The magnitude of the lobes varies directly with wheel unbalance.

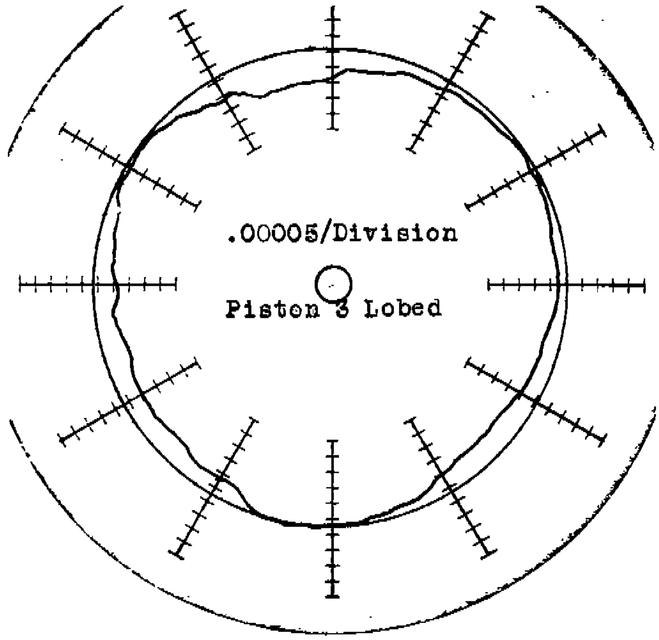

FIGURE 8 A THREE LOBED GROUND PART

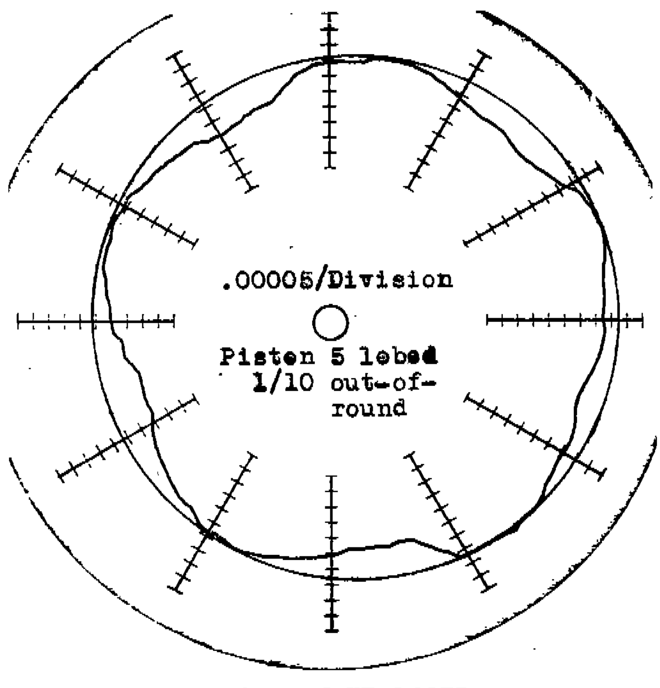

FIGURE 9 A FIVE LOBED GROUND PART

(Figure 10) The finer lobes shown are almost always present to some degree on centerless ground parts. They seem to be more pronounced when plunge grinding, as on the scotch-yoke piston, compared to through feeds, as on cylindrical parts.

Some of the causes of this type of lobing are: part chatter, too rapid an infeed, or unmatched or worn spindle belts. This type of fluting with 75 Mu" maximum height was found acceptable on otherwise round compressor pistons subjected to endurance tests.

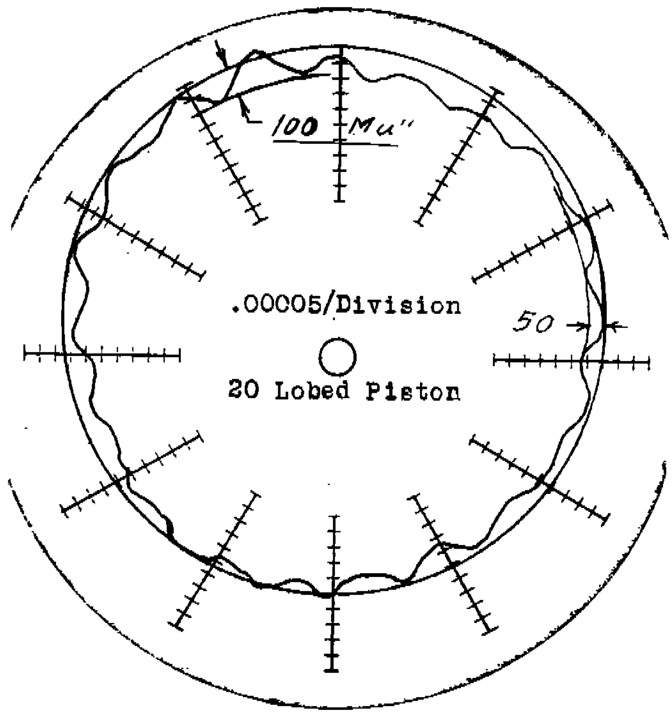

FIGURE 10 A FINE LOBED OR FLUTED PART

(Figure 11) Fluting becomes even more of a problem when superimposed over 3, 5, or 7 major lobes.

Another thing that lobing does is to cause tight clearances unless taken into consideration in the gaging calibration. Air-gaging is normally used as a fast and quite accurate means to classify parts into size groups for selective fitting to achieve specified clearance. The part size is determined by the amount of air flow between the part and the gaging ring. Consequently, with a lobed part, the gaging system would integrate the clearance area and indicate a smaller size than required to encompass the lobe peaks.

LOOP LIFE TESTS

Whenever any one thinks of life testing they usually visualize a long time test. U. S. Testing Laboratories has established that if a unit would run 17 weeks, or 2856 hours at 200F° shell temperature in 110° ambient under high load conditions, it would last 3 to 5 years; and 25 weeks, or 4200 hours would last 10 to 15 years. It was therefore believed that a successful 4000 hour life test might satisfy the Gibson ten year warranty, although, for design criteria, a longer period would be desirable.

Laboratory designed and built test systems (Figure 12) consisted of 8-1/4' of 1/2" O.D. copper tubing as a condenser, through which passed 1/4" evaporator tubing. This assembly was formed into an 8-1/2" diameter coil with both circuits running from top to bottom. The parts list included a bleed type expansion valve, a 0-400# head pressure gage, a 30-0-30--250# retard suction gage, and a #7303 Fenwall switch to control shell temperature with a Morril 5 watt output fan motor. Thus the heat exchange was accomplished without oil

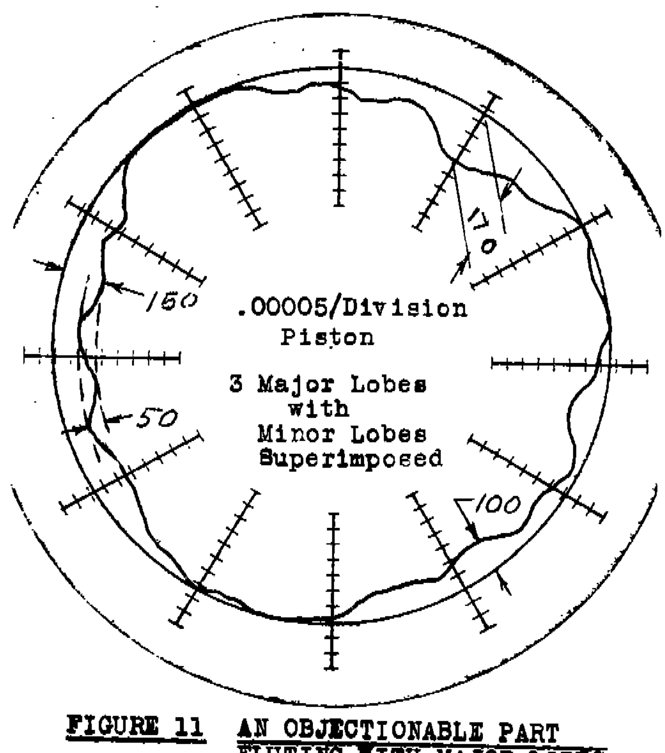

FIGURE 11 AN OBJECTIONABLE PART FLUTING WITH MAJOR LOBES

trapping, or a condensate problem except for a short length of 1/4" copper tubing between expansion valve and coil, which needed to be wrapped with cork mastic insulation. The Fenwall thermostat was immersed in oil, in a 3/4" diameter copper tube soldered to the side of the compressor dome. A 2 gram dryer was installed in the discharge line. A lagged thermocouple was soldered to compressor top shell.

Pistons were preselected for compressor tests after roundness polar chart recording, together with proper cylinders to obtain the various clearances to be evaluated. Other units were assembled to explore the benefits of lubrite coated pistons and yokes. A desirable addition would be to weigh the moving parts to the nearest 1/10th gram before and after test to supplement visual wear evaluations. Dehydrated units and systems were charged to operate as follows: 20 $\pm$ 2# ga. suction pressure, 230-250# discharge pressure, 200° shell temperature in 90 $\pm$ 10° ambient, controlled by inlet and exhaust fans to out of doors. Extra care must be exercised with life test units to be sure that all parts conform to manufacturing specifications. It is most important that the complete life test system be practically moisture free in order to prevent electrolysis and consequent copper plating to thereby avoid aggravation of the basic wear problem.

Wattage readings, temperatures and pressures were recorded twice each working day, to be sure that test conditions prevailed. Any marked change in the trend of the wattage on a given unit was used as a warning of a change on the working surfaces due to wear.

PULL DOWN TESTS

Test setups and procedures are usually tailored for a specific problem. For instance, we began to experience a failure of compressors to pull down during one of the regular laboratory tests. Investigation showed that this was caused by a tendency toward excess wear on the piston O.D. and Yoke I.D.

Cast iron dust, practically colloidal, generated by wear or in machining operations has been known to circulate in the oil and be re-introduced into the bearings, where it became in effect, a lapping compound to erode the surfaces.

In order to obtain adequate compressor life, it is necessary to obtain types of finish on the mating parts, together with proper clearances so that they will run-in rapidly with a minimum of wear. Any wear particles should be of a nature or size so that they become isolated in the oil and thus not

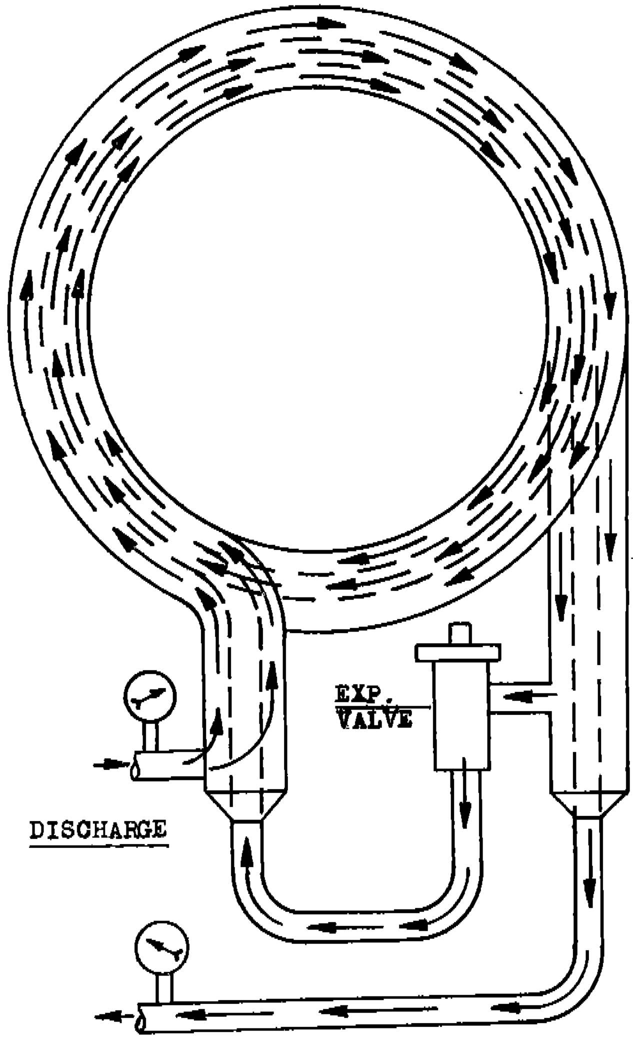

FIG. 12 LOOP LIFE TEST--HEAT EXCHANGE

cause working surface damage.

It was decided therefore, to test several units having special piston and yoke finishes in normal 110° ambient no load refrigerator pull downs. This type of test, where the original failures occured, was thereby used to quickly show whether a 'fix' had been achieved.

The lubite chemical is formulated by producing on the bearing surfaces a non-metalic, dense, black, medium crystaline, oil absorptive coating which is composed chiefly of iron and manganese phosphates. It permits rapid break-in without scuffing or welding by preventing metal to metal contact. It also increases lubrication, removes light scratches during application and retards corrosion.

Units which had the lubrited pistons ran 120 successive pull downs, approximately 1000 test hours, without a tendency to score. Plain pistons had failed in 1 to 6 pull downs, as a result of scoring, tight parts, or high wattage.

Subsequent observations and analysis showed that even with lubrite, lack of piston roundness and poor taper control were the main contributors to wear and scoring. Units were then built up with various magnitudes of 3 and 5 lobes, others with fine lobes or fluting, and still others having 3 and 5 lobes with superimposed fluting. These tests established acceptance limits as to piston surface geometry and corresponding clearance limits.

A correlation between the pulldown and loop life tests was accomplished by running one unit 31 pull down days, 248 hours, followed by 5496 hours on loop life test without failure. It would therefore be feasible to use the pull downs to solve wear problems, and then follow with a reduced time period on loop life tests, without detracting from the value of the final results.

RESULTS

Two methods of data summary were arranged for evaluation and from which to draw conclusions. The first tabulation placed the data in preferential order as to parts appearance.

Of the 10 units tested, the test hours of the two best units were averaged to establish a 100% base for a 10 year warranty acceptability, namely 5734 hours.

The second tabulation then carried the percentage hour rating together with the type of geometry; 3 lobed-plain, 3 lobed plus fluting, etc. Remarks were recorded as to visual wear: no appreciable wear, lubrite worn off pressure side, heavy wear and light scores, etc.

Thus two types of testing have been discussed which have been used to solve a critical wear problem. The 110^{o} ambient no load pull downs were easy for the refrigerator manufacturer to set up with materials available to run 10 or 15 refrigerators at a time. The loop life test cell was developed during that time to handle 45 units for final approval tests.

CONCLUSIONS

1. The addition of lubrite to the piston and yoke surfaces was considered to be the most important improvement to compressor life, which with adequate clearances, would exceed the 10 year warranty requirements.

2. A .0003 increase in piston diametral clearnace from .0006/.0008 to .0009/.0011 would increase the compressor life by compensating for a tolerable departure from roundness of the piston, with negligable effect on performance.

3. Fine waviness (or fluting) of 75 Mu" Maximum on an otherwise round piston would last through 10 year warranty.

4. Three plain lobes of 120 to 150 Mu" depth on the piston would pass the 10 year warranty.

5. Five plain lobes of 100 Mu" depth would be Marginal.

6. Any combination of lobing beyone 100 Mu" depth with superimposed waviness (or fluting) of 50 Mu" maximum was found to be dangerous from the life test standpoint.

7. A 5500 hour loop life test was considered by the author as necessary to satisfy a ten year warranty requirement.

The same results could be obtained by running thirty 8 hour pull down tests, followed by 3000 hours in loop life tests on the same units.