A Short Term, Accelerated Test Method for Rotary Compressors

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ABSTRACT

Compressor reliability and durability testing has historically required significant time and a variety of test methods, including basic materials and lubricants testing using Falex test methods or equivalent, long term compressor bench tests, end product reliability tests and final field trials before production release. Reducing the total design cycle time to a minimum, while maintaining a high confidence level in reliability test results as they relate to expected compressor quality and reliability, is always a major industry goal.

A short term (200 hour) accelerated test protocol has been developed for rotary compressors used in air-conditioning and small heat pump applications, to provide quick understanding of expected bearing performance and compressor quality. This test procedure can be used to compare bearing performance and manufacturing quality of compressors from different manufacturers, to evaluate new refrigerants, lubricants and materials, and to compare design modifications to base designs.

INTRODUCTION

Qualification of compressors for reliability and durability historically has required many months and often years of material, component, and product tests before production release. From a business perspective, reducing the design cycle time to a minimum while maintaining a high level of confidence in the reliability of the test results, has significant economic advantage.

While it is possible to run parts of a total test program in parallel, most often each test phase, from basic material and lubricant screening, to the final field trial, is conducted in series. Convention compressor bench tests using load stands, generally require from 2000 hours to 4000 hours (12 to 24 weeks).

A short-term (200 hours), accelerated test protocol has been developed for rotary compressors used in air-conditioning and small heat pump applications. This test protocol has been used to compare quality and reliability of different compressors and to evaluate the effect on bearing performance of compressor design changes, new refrigerants such as R407C and R410A, alternative lubricants and lubricant additives, and material modifications.

TEST PROTOCOL

The 200- hour test protocol is designed to heavily stress the vane to vane slot bearing, shaft journal bearings, and the roller o.d. to vane nose bearing. The roller o.d. to vane nose bearing is the most sensitive bearing in the rotary compressor and performance of that bearing is usually indicative of expected mechanical reliability, given the compressor designer has followed good design practice regarding material selection, lubricant selection, and journal bearing loading.

The compressor load condition of 500 psig (35.2 kg/cm^2) discharge pressure and 125 psig (8.80 kg/cm^2) suction pressure for R22, was selected to provide high overall bearing loads (See graph #1). It is desirable to be able to test many different rotary compressor designs from a wide range of manufacturers using a single test protocol. The load condition selected is compatible with generally available motor maximum running torque so that any rotary compressor can be tested with it's designed motor, as manufactured. At operating test pressures, a certain level of liquid floodback is provided and monitored by sight glass observations and by tracking convergence of accumulator-in versus evaporator-mid temperatures.

The level of liquid floodback to provide appropriate test acceleration, within the 200 hour test period, was developed from designed experiments and correlated to actual field return compressor cut-apart analyses, to ascertain that the bearing wear modes were consistent with field experience. Even at the high test pressures, it is the level of liquid floodback which primarily determines the acceleration factor. If the return gas is superheated, gas pressure loading plays the predominant role in bearing stress and wear. A small amount of liquid floodback reduces the quality of lubrication at the vane nose - roller interface and simulates actual field conditions created by dirty evaporator filters, dirty condensers, and some abnormal heat pump operating conditions. A large amount of liquid floodback does not normally duplicate bearing performance observed from field returns, even though the acceleration factor is greatly increased.

To demonstrate the sensitivity of compressor bearing performance to load conditions and level of liquid floodback after 200 hours on test, standard compressors were ran using a marginal lubricant. The results provide an example of sensitivity to test conditions which has been confirmed over many years and several hundred compressor tests. This test series provides a qualitative and quantitative comparison of bearing performance under conditions of superheated return gas, small amount of floodback, and large amount of floodback at the standard test protocol operating pressures of 500 / 125 psig (35.2 / 8.80 kg/cm^2). Within the 200-hour test period, significant differences can be seen and measured in bearing wear at each of the three test conditions. See figure #1 for photo and metrology comparisons.

The compressor tested with superheated return gas showed only polish bands on the roller o.d., no indicated wear on the vane nose, and very light polish on the shaft journals. The compressor tested at the standard test protocol with light, controlled liquid floodback, exhibited moderate roller o.d. wear, moderate shaft journal polish, and vane nose wear evidenced by a 6% increase in wear scar width compared to the superheated return gas compressor test. The compressor tested with excessive floodback showed heavy roller o.d. and vane nose wear and heavy journal bearing polish with some light wear.

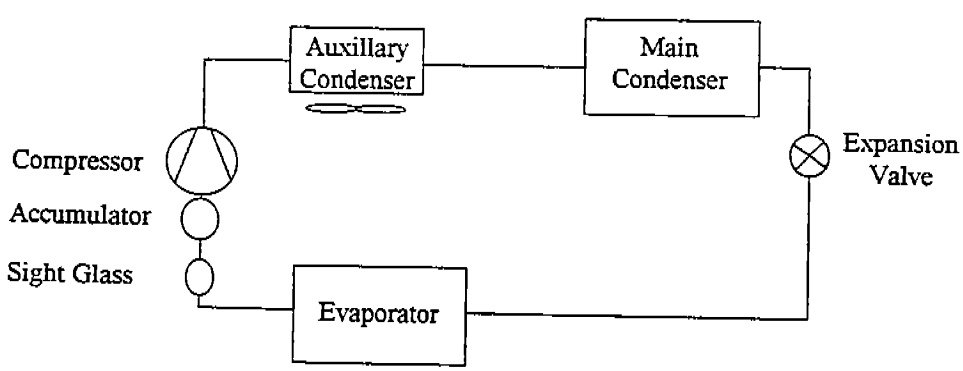
At the standard test floodback level, operating pressures effect wear performance, as can be seen in figure #2. At 400/125 psig (28.2/8.80 kg/cm^2), the roller o.d. shows light polish and the vane wear scar width is appropriate for the shaft eccentricity. At 500/125 psig (35.3/8.80 kg/cm^2) the bearing performance of the roller, vane, and shaft is essentially equivalent to the standard test protocol results as shown in figure #1. Without liquid floodback, compressors show little bearing wear after 200 test hours, at either of the two load points tested.

With superheated return gas, much longer test times are required to provide the same level of acceleration as provided by the standard 200- hour test protocol.

TEST STAND CONSTRUCTION

Test stands are constructed using the primary condenser, evaporator, air flow system, and power controls from a window air conditioner (See schematic below). Modifications of the base unit include an auxiliary condenser with a separate air flow system controlled from a pressure switch installed in the discharge line near the compressor. The capillary is bypassed with a manually controlled restriction valve. Pressure gauges and pressure transducers are installed in the discharge and suction lines of the test stand to monitor running pressures. Thermocouples are positioned at condenser-mid, evaporator-mid, and accumulator-in to monitor system temperatures. An in-line sight glass is installed in the suction line at the accumulator for visual observation of liquid return to the compressor.

To determine the appropriate charge, the evaporator-mid and accumulator-in temperatures are monitored for convergence while observing liquid return in the suction line sight glass. At temperature convergence, a small additional amount of refrigerant, dependent upon the capacity of the compressor on test, is added to provide the appropriate acceleration factor. Once the charge amount has been determined for the compressors on test, each identical load stand and compressor is charged with that same amount of refrigerant.



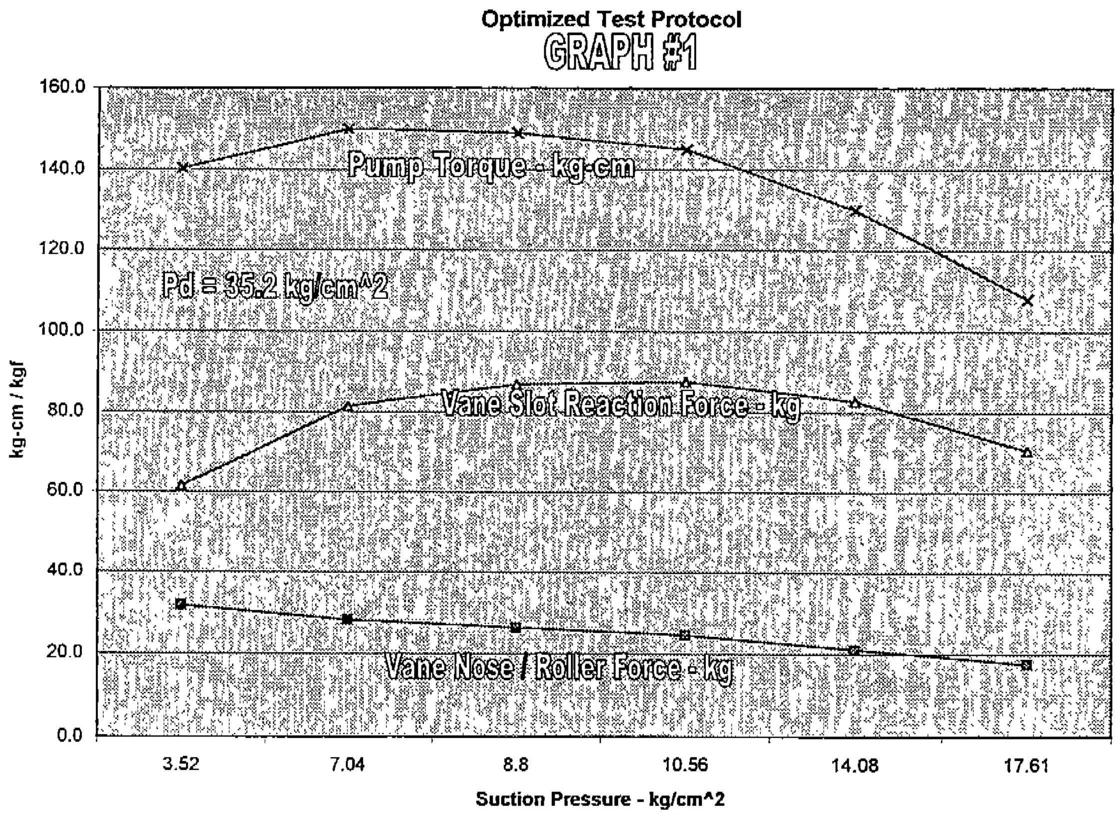
CONCLUSIONS

The 200-hour rotary compressor accelerated test is used to dramatically reduce total design cycle time by as much as three to six months. Hundreds of compressor tests have shown that this test protocol provides consistent, repeatable results, and our goal is to correlate test results, using this protocol, with test results from long term product reliability tests.

It is certainly not intended, nor recommended, that this test protocol should eliminate manufacturer's in-house product reliability tests, or any other tests that are compressor or product specific to a manufacturers product line. This test protocol can, however, provide rapid absolute or comparative evaluation of bearing performance and compressor quality for evaluating compressor design changes, alternate compressor sources, alternate lubricants, refrigerants, and materials.

Used as a screening test, changes from a given base design can be evaluated rapidly in an actual compressor operating environment, to identify those candidates which should be eliminated or carried forward.

While the results from this accelerated test protocol are not yet statistically correlated to end product reliability tests, our experience indicates that such a correlation is promising.



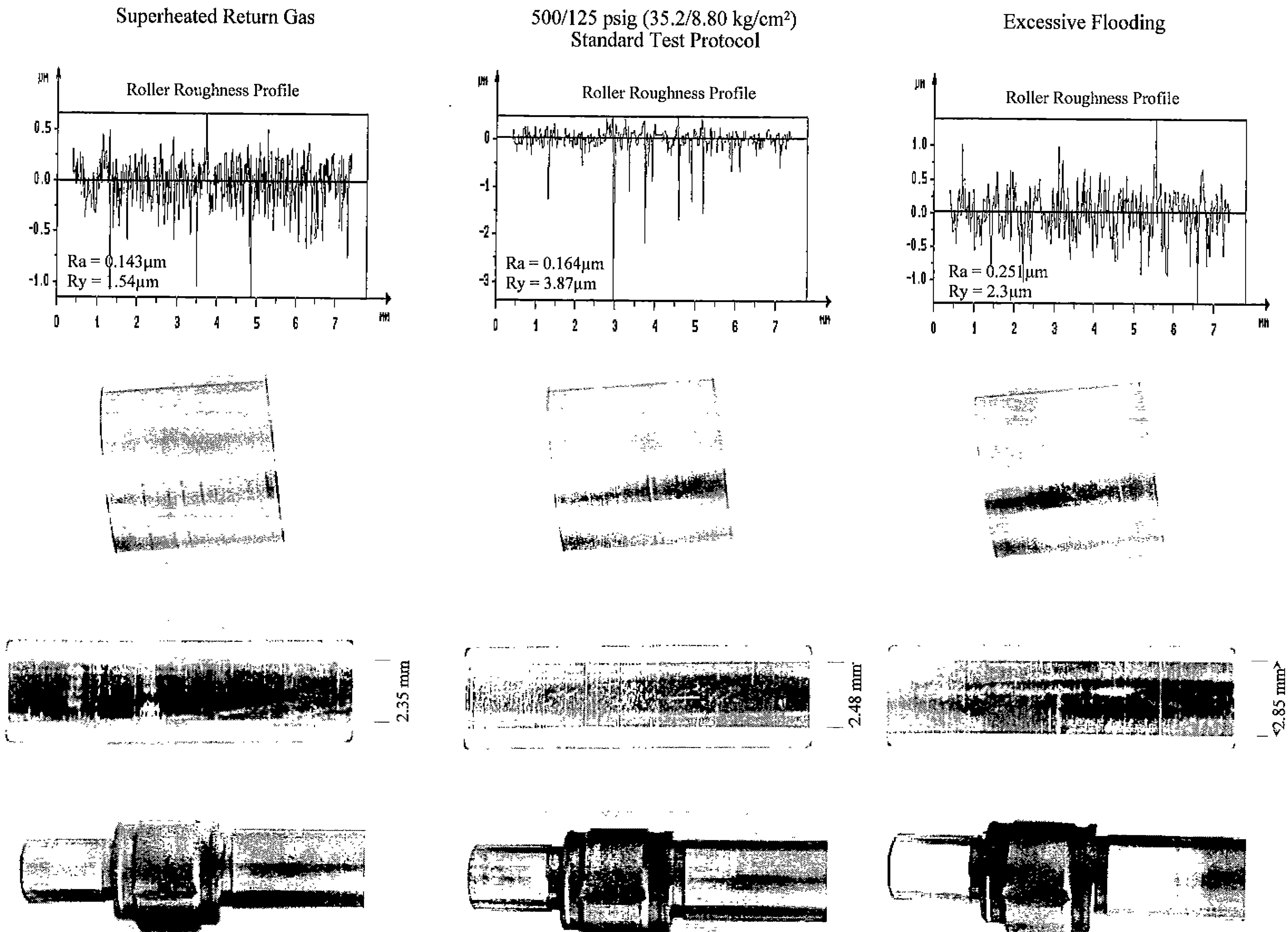
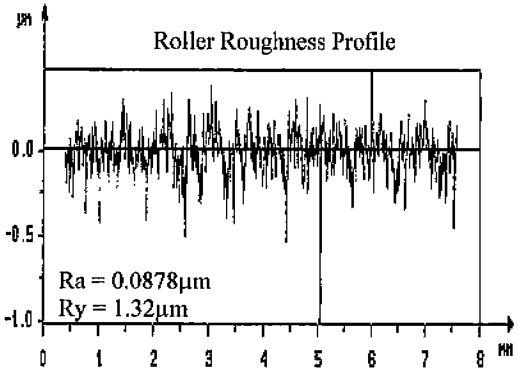
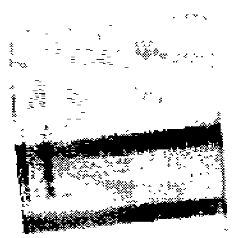

Superheated Return Gas
500/125 psig (35.2/8.80 kg/cm²)
Standard Test Protocol
Excessive Flooding
Roller Roughness Profile
Ra = 0.143μm
Ry = 1.54μm
Roller Roughness Profile
Ra = 0.164μm
Ry = 3.87μm
Roller Roughness Profile
Ra = 0.251μm
Ry = 2.3μm
2.35 mm
2.48 mm
2.85 mm

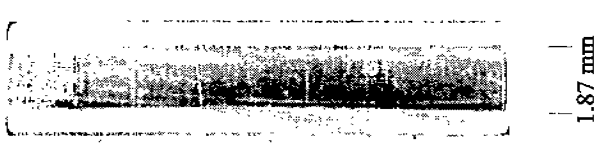
Figure No.1

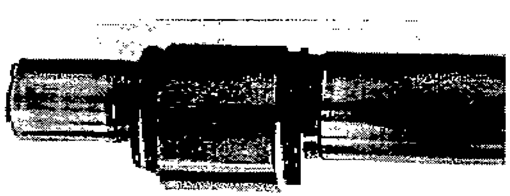
Standard Test
Floodback Protocol

400/125 psig (28.2/8.80 kg/cm²)

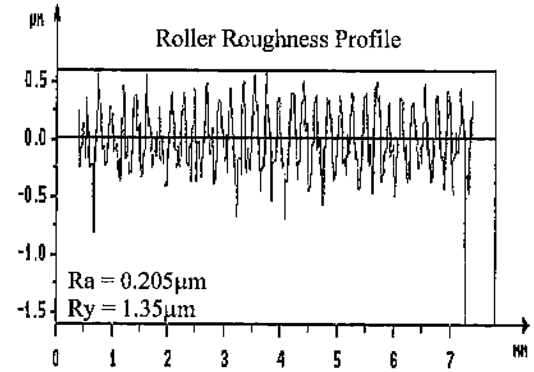


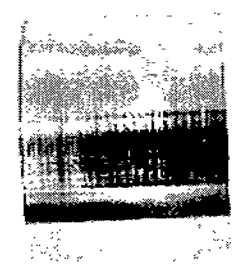


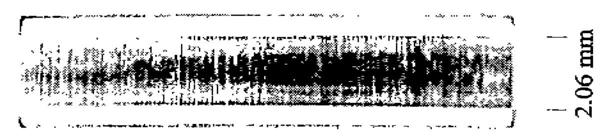




500/125 psig (35.2/8.80 kg/cm²)







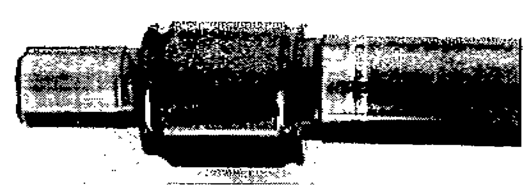


Figure No.2