GUIDELINES FOR PERFORMANCE TESTING
CENTRIFUGAL COMPRESSOR

by
Fred L. Van Laningham
Principal Engineer
Union Carbide Corporation
Houston, Texas

Fred Van Laningham is principal engineer, Maintenance Engineering and Services Group, Engineering and Hydrocarbons Division, Union Carbide Corporation. He has more than 35 years of experience with rotating machinery and has been with Union Carbide for over 28 years in several positions in Maintenance, Design and Construction, and Engineering. He is presently in a mechanical reliability oriented group, following the application of large critical process machinery from specification through purchasing, manufacturing, testing, installation and start-up plus. He provides consulting and troubleshooting services to domestic and foreign Union Carbide Chemical Process and Air Separation plants on complex or chronic machinery problems. He is a consultant to the Machinery Application and Machinery Technology Groups on new projects when custom designed and/or critical machinery is required.

ABSTRACT

Performance testing of centrifugal compressors in the field is generally a compromise at best, and shop testing before delivery to the site is usually preferred. There are circumstances that dictate or suggest that the aerodynamic performance be tested after installation in the field. Why field testing is sometimes required or in some cases preferred, the objectives of the test, and a brief description of the procedures used to achieve the objectives are presented. Detailed enumeration of the test instrumentation and the data recorded has not been included, but reference is made to various test codes for such detail.

INTRODUCTION

It is now the practice of some petrochemical companies to perform test new centrifugal compressors that are “custom designed,” prototypes, or critical to the operating continuity of the processing units. Thermodynamic (hydraulic) performance testing of these centrifugal compressors is one of the precautions available to users to enhance the probability that the critical machines in large single-train plants will operate reliably, safely and economically.

In the past, some have felt that thermodynamic performance of compressors in full compliance with specifications was not as important as mechanical performance. Mechanical deficiencies were likely to result in “go” or “no go” situations whereas thermodynamic deficiencies could be compensated for in operation. Moreover, it was felt that most impeller applications were proven well enough that significantly substandard performance was unlikely.

The high cost of energy, added to the already high losses that can result from even small cutbacks of large single-train units, has changed that. Performance testing in the shop is now commonplace, and experience has shown the tests to be justified. While the characteristics of most impellers and stationary parts may be well understood applications, errors do occur. Stability ranges may not be satisfactory, head and capacity may be off specification, and the driver may be too highly loaded. The ability to adjust the speed of the driver may not offer a solution. Rotor maximum continuous or critical speed margins or other considerations may limit speed range changes.

TEST CODES

Most tests are performed by the manufacturers in their factories and make use of established performance test codes. Test codes can help guide the users through a review and acceptance of the test plan for a particular machine, whether the test is performed in the shop or in the field. Options available under the codes, exceptions taken by manufacturers, and the complexity of properly simulating design point operating conditions make the detailed review mandatory. The following are the test codes that are most widely used:

- ASME Power Test Code — 1965: ASME PTC-10 is specifically for centrifugal and axial compressors. PTC-9 covers reciprocating compressors and PTC-11 is for fans.
- VDI 2045 Verein Deutsche Ingenieure (Association of German Engineers): VDI 2045 Acceptance and Performance Test on Dynamic and Positive Displacement Compressors, Part #1, test procedure and comparison with guarantee, is considered by some to be better than PTC-10 since it defines how to handle errors in measurements. It also refers to several DIN, Deutsche Industrie Normen (German Industry Standards), such as DIN 1952, which is a standard for flow measurement and is quite specific with regard to instrumentation.

OBJECTIVES OF TEST

The tests described here, and essentially every performance test, has two basic purposes. First, to determine whether the equipment is properly designed, manufactured, and assembled and thus meets the specifications of the applicable purchase contract; and second, to determine its actual performance characteristics and suitability for service. In other words the objectives of the test are:

1. To verify actual thermodynamic performance.
1. Plan in advance, if possible, including the piping design and control system to assure that they will accommodate a test.

2. Carefully review the applicable test code requirements regarding instrumentation, test conditions and allowable fluctuations of readings during the test.

3. Consult with and include the manufacturer in reaching an agreement on the test procedure and the basis for calculation of the gas thermodynamic properties. Improve and calibrate instrumentation for the critical parameters, such as suction and discharge pressures and temperatures, gas flow and gas analysis, to the point that agreement can be reached with the manufacturers on the validity of the results.

4. Work closely with operating personnel to identify and log data, which although remote from the test, may assist in evaluation of test data.

5. Arrange with operating personnel to regulate production as necessary to achieve stable performance and provide sufficient assistance and/or automatic logging to permit simultaneous readings of all points.

6. Confirm stable operation. Record no less than three sets of data at each point.

LIMITATIONS OR DISADVANTAGES TO FIELD TESTING

The most careful planning for the field test may not yield optimum results. The test may be limited by:

1. Piping straight runs that are less than specified by the codes, resulting in errors.

2. Plan operating flexibility that will not permit the machine to operate from surge to overload.

3. The control valves installed in the piping not permitting proper or safe throttling of the suction or discharge.

4. Anti-surge bypass flows and "pop-overs" that may not be accounted for.

5. Liquid injection for cooling or anti-fouling that may be difficult to account for.

PROBLEMS ENCOUNTERED DURING A FIELD TEST

Two large identical motor driven multi-stage compressors with multiple side streams installed in a chemical process unit appeared to be low in capacity and efficiency. They did not receive a shop performance test. A flange-to-flange field test was agreed to with the manufacturer. Nearly all of the foregoing precautions were taken and the test was performed. The permanently installed instrumentation was calibrated for use. Gas samples were taken during the test. However, a single test gage with a face diameter of approximately 15 in. was connected through a manifold to take pressure readings. A preliminary check of the readings from the permanently installed instrumentation, temporary temperature indicators and pressure gages did not correlate with the readings from this huge test gage. The suction pressure ranged from subatmospheric to about 5 psig and the final discharge pressure was about 270 psia. Even though the gage had a large, easy to read dial, it was not accurate enough for this test over its full range. When making a test, be sure that the test gages are calibrated for the
range expected at the point to be measured. The test was rerun using microscopes and calibrated gages.

The manufacturer altered the wheel lineup and changed some stationary parts, but the performance (capacity and efficiency) still was not per the original purchase specification. Another test was performed after all parties again agreed to the plan. Before this test, the casing upper half was drilled and tapped in ten places, two at each of the diffuser return bends for total pressure and temperature probes. These combination probes, inserted through compression fittings and gate valves, measured static and velocity pressure, plus temperature. The manufacturer had originally requested 20 taps, 4 taps in each return bend 90° apart. Because of constrains agent sparking or ignition sources in the operating unit, only the upper casing half was drilled since it could be removed from the hazardous area for drilling and seal welding. This test was flange-to-flange per the applicable code, plus the wheel-by-wheel test that additionally measured the mixed temperatures of the gas inside the machine that result from side stream flows. Separate calibrated gages were used for each pressure measurement. This same test set-up was used to recheck the final and proper design, which performed as originally specified.

Since these compressors were driven by synchronous motors through speed increasing gears, the power required during the testing was measured using both the heat balance methods and the measurement of power input by electric motors, covered in PTC-10, Section 4. On more recent field performance tests, the shaft power input was measured with torque measuring couplings as well as strain gages attached to the coupling spacer and telemetering systems.

CONCLUSION

Whenever possible, it is suggested that thermodynamic performance testing be done in the shop. On the other hand, when the performance test must be carried out in the field, careful and detailed planning will help assure test results as accurate as those obtained in the shop.

ACKNOWLEDGMENTS

Most of the information presented here is not new, and in addition to the test codes, the information published earlier provides excellent guidelines for field and shop testing; as given in References [4], [5], and [6].

REFERENCES

2. VDI-Association of German Engineers VDI 2045, Acceptance and Performance Test on Dynamic and Positive Displacement Compressors, Part #1 Test Procedure and Comparison with Guarantee.