Semi-Automated Air Flow Test Stand for Campbell Hausfeld Consumer Air Compressors

by

RICHARD STRACK

Submitted to the
MECHANICAL ENGINEERING TECHNOLOGY DEPARTMENT
In Partial Fulfillment of the
Requirements for the
Degree of
Bachelor of Science
In
MECHANICAL ENGINEERING TECHNOLOGY
at the
OMI College of Applied Science
University of Cincinnati
May 2002

©......Richard Strack

The author hereby grants to the Mechanical Engineering Technology Department permission to reproduce and distribute copies of the thesis document in whole or in part.

Signature of Author

Certified by

Accepted by

Muthar Al-Ubaidi, PhD, Department Head
Mechanical/Engineering Technology
Informative Abstract

Currently, the air compressor market is based on pump output and input current draw. Air compressor companies compete on the retail market with flow and amperage data. The current method to record flow and current data is manually. A new method is needed to collect flow, amps, and voltage data with little human interaction. The test done manually is mindless and should involve a computer data acquisition system. The test is too time consuming. It takes a technician roughly forty-five minutes to complete the flow test. Forty-five minutes is an excess of time that needs to be spent to perform this task. The CH Test Stand collects data from an air compressor with minimal human interaction. This design will have a semi-automatic flow test stand data acquisition system that will record flow, amps, and voltage data at 40, 90, and 120 psi. The test stand will increase production in the lab, and decrease the amount of time it takes to do the test since it is controlled by a computer.
# Table of Contents

- Informative Abstract
- Table of Contents
- List of Figures
- Introduction
- Problem Statement
- Research
- Background
- Project Objectives
- Design Solution
- Customer Survey
- Project Deliveribles
- Proof of Design
- Project Schedule
- Project Budget
- Technical Solution
- Plan for Build and Test
- Conclusion
- Bibliography
- References

## Appendices

- Patents-Copyrights-Trademarks-Inventions-
- U.S. Patent & Trademark Office Search
- Searches for U.S.P.T.O. website
- QFD, House of Quality, Surveys
- Assembly Drawing for First Alternate Design
- Assembly Drawing for Second Alternate Design
- PUGH’s Selection Process Chart
- Employer Letter
- Omega Digital Flow Meter
- Superior Electric Power Supply
- Omega Transducer
- Pressure Transducer
- Parker Pressure Regulator
- Current Test Stand Drawing
- Redesigned Test Stand Drawing
- Itemized Bill of Material
- National Instruments Page
- LabView Performance Flow Test_3 Pressures Program
- LabView Performance Flow Test_13 Pressures Program
- Operations Manual
List of Figures

Figure 1 – Air Compressor Spec Sheet
Figure 2 – Test Stand AutoCAD Sketch
Figure 3 – Digital Picture of Current Air Compressor with Test Stand
Figure 4 – Digital Picture of Current Volt and Amps Meter
Figure 5 – Digital Picture of Typical Smaller Volume Air Compressor
Figure 6 – Digital Picture of Typical Larger Volume Air Compressor
Figure 7 – Project Schedule
Figure 8 – Budget
Figure 9 – CH Test Stand Left Side
Figure 10 – CH Test Stand Front Side
Figure 11 – CH Test Stand Right Side
Figure 12 – National Instruments Field Point Module
Figure 13 – Length of Time at Each Pressure Study
Figure 14.1-14.15 – CH Test Stand Performance Data
Figure 15.1-15.15 – Campbell Performance Test Sheet
Figure 16 – FP2020 Performance Curve Data
Figure 17 – FP5058 Performance Curve Data
Figure 18 – FP6500 Performance Curve Data
Figure 19 – FP6604 Performance Curve Data
Figure 20 – Electrical Transducers Wiring Diagrams
Figure 21 – National Instruments Field Point Wiring Diagram
Introduction

In the air compressor business flow and current are the two most important quantifiable criteria’s. See Figure 1, 5, and 6. The air compressor must produce enough air to run a certain air tool. Types of air tools used are drills, chisels, air nailer’s, etc. For instance, a low-end air chisel requires 6 SCFM at 90 psi to run the tool correctly. In order to run a tool an air compressor needs to produce at least 6 SCFM at 90 psi. This is the main reason why measuring flow is so important. Input current is important because the flow is dependent on the current. A motor that is mounted to the air compressor runs the pump that produces the flow in the air compressor on the tank. If the voltage drops below nominal voltage, which is 120 volts, it decreases the amperage and flow. When the motor is running slower than designed, the pump is turning slower, which results in a lower flow. Also, most homes have 15 or 20 amp breakers in the breaker box. The air compressor must run under 20 amps in order for a homeowner to operate it.

The current way of measuring voltage, amperage, & flow at various pressures on an air compressor require a technician to manually collect the data. See Figures 3, 4 and Appendix M. A technician manually recording data from a manual flow meter and a volt & amp meter collects the data. The purpose of this test is to collect amperage and flow measurements at various pressures typically 40, 90, and 120 psi on a typical air compressor. Since the consumer air compressor industry is driven by how much air a particular air compressor produces it is critical to collect a sampling of flow data on every model of air compressors Campbell Hausfeld sells. On an average 25 to 30 air compressor flow tests are done weekly in the Campbell Hausfeld Consumer Engineering Lab. The flow tests normally takes a technician 45-60 minutes to do one
air compressor at the following pressures: 40, 90, and 120 psi. As you can see the process is extremely time consuming.

**Problem Statement**

The problem proposed by Campbell Hausfeld is to find a way to semi-automate the process of collecting voltage, amperage, and flow at certain pressures of a typical air compressor. According to the patent search there is no test stand that will collect amps, watts, and flow of an air compressor then using a computer program automatically pump pressure up to the next set pressure then record data at that pressure (A, B). Eliminate the amount of work a technician is required to complete and concentrate the efforts on more challenging tasks. Employee time spent on more value added tasks only benefits the company. Testing done manually takes away labor hours from cost effective employees and performed mechanically can be done faster. Members of the Consumer Engineering Department like Chris Gruber, Engineering Manager, has complained about the flow test being “mindless” and not a very value added task. The flow test should be semi-automated to increase production of the lab and eliminate non-challenging tasks.

**Research**

Most of the research conducted in this report concentrated on the electro-pneumatic equipment that is used to run the Test Stand. The pressure transducer, volumetric flow meter, & electro-pneumatic regulator had to be within certain accuracy and had to be able to able to communicate with the National Instruments Field Point Module. See Appendices H, J, K, & L. Also, all of the instruments had to use either a 0-20mA or a voltage Input or Output signals. The National Instruments Field Point Module, see Appendix P, uses analog inputs and outputs to communicate between the hardware and the computer software. The challenge in the research
was to find the hardware with the correct input and output signals with good accuracy and within a decent cost.

Considerable amount of time was spent learning National Instruments LabView 6i. Labview 6i is an Icon based measurement software program. Several seminars on LabView 6i are available. The Labview Basics Seminar is an introductory to the capabilities of LabView and what type of measurement automation you could accomplish at your company. The seminar also showed other types of data acquisition systems other than the Field Point Module. The LabView Hands-On Seminar taught basic concepts and techniques on programming the virtual instruments. This second seminar was much more beneficial to me since it showed my how to interface the software with the hardware and how to get actual data points. In addition to the seminars I also have been self-teaching my self-LabView with the help of the following National Instruments Instructional Manuals: 1. LabView Basics I, 2. LabView Basics II, and 3. LabView Advanced I.

The survey and the House of Quality Matrix, see Appendix C, shows that the customer valued the following: type of computer language, including an amperage trip limit in the program, having the ability to input variable pressures, saving man hours, and making something that is cost effective. The computer language was important because it has to be able to use a language that is user friendly. That is partially why we are using LabView, it is icon based, and much easier to program than a line code based program. Safety is another big concern with this project since it is being designed to run without any human supervision. In the event of a pump or motor failure a trip limit will be included into the program. If there is a failure and the amperage exceeds the trip limit the compressor will automatically power off. The ability to input several different pressures is also important to the customer. Typically the data points taken in this test is 40,90, & 120 psi. On occasion other pressure data points are requested and the
program should accommodate that. Since, the Test Stand is virtually unmanned the customer felt that a significant amount of man-hours could be saved from the Test Stand. With the semi-automated test stand the technician is not required to watch the test run, the computer is doing all of the work. The technicians can commit themselves to other tasks while the test is being run. The Test Stand will become cost effective after only a couple of months. Once the initial cost of the test stand is paid off the unit will only make money. The CH Test Stand is performing a service that a human being used to do. More tests can be performed and the technician that used to run the test is busy conducting other value added tasks.

Background

The idea of this project originated from Campbell Hausfeld Co. Campbell Hausfeld designs and manufactures air compressors for the Consumer and Commercial Air Compressor Market. The project is for the Consumer Engineering Lab. The Consumer Lab redesigns, conducts research in development, and addresses current production issues. Since a flow test is standard for every compressor that is tested in the lab, a test stand or machine that could collect the data while a technician performed other tasks would be very beneficial to the Lab.

The flow test is performed at 40, 90, and 120 psi (Refer to Figure 1). Some issues to consider are:

1. The pressure readings should be within 2 psi of nominal. (E)
2. The voltage stabilizer should be within 2 volts of nominal. (F)
3. The air compressor should stabilize for about 5-15 minutes at each pressure. (G, H, I)
4. All of the air compressors tested are between 3-16 amps. (F)
5. All of the air compressors tested are between 0.5 – 5 SCFM. (Refer to Figure 1)
6. The testing equipment must meet the above requirements.

Project Objectives
Objectives of this project are solely based on creating a test stand that would do full performance testing with minimal human intervention. The aspects that would benefit the Lab are 20-30 hours a week that a technician would not spend on doing the performance test. The test stand would be extremely cost effective to the company. The technician would spend more time working on more challenging tasks. Another objective of the test stand is that it is computer controlled. Since a machine is controlling it the time interval between data readings will be shorter than a human being manually recording data. It takes 45 to 60 minutes for a human being to complete the test; the CH Test Stand conducts the entire test in 34 minutes.

The formal objectives are as follows:
1. Eliminate the labor time in conducting the airflow test by 20 minutes.
2. Decrease the amount of time to do the complete test from a maximum of 60 minutes to 40 minutes.
3. Increase the production of the entire lab by 15%.
4. The CH Test Stand will be able to test either induction or variable speed air compressor motors. The CH Test Stand is not designed for battery or gas powered air compressors. See Figure 1.
5. The CH Test Stand will be able to test electrical powered air compressors from 4-gallon tanks to 30-gallon tanks. See Figure 1.
6. The CH Test Stand will stop if the air compressor motor draws more amps that the pre-set amperage limits.

Measurable Objectives:
- **Lab Production** – Increase production in the Consumer Engineering Lab by 30%
- **Human Interaction** – After initial setup no human interaction is needed to conduct test. Test stand will free up 25 man-hours per week, which is a –83.3% reduction in labor.
• **Cost Effective** – Initial budget is set to $5000 for Test Stand. The technician’s time spent is being reduced from 30 hours to 5 hours, which makes it very cost effective. The average salary of 1 technician is $28,000 per year. According to that salary the test stand will pay for itself in about 3 months.

**Design Solution**

**Selection of Preferred Design**

**Alternate Design #1 – 3 Poppet Valves Design, See Appendix D**

Remove the manual flow meter and replace it with volumetric flow meter. The design utilizes 3 set of Poppet Valves, one at 40 psi, 90 psi, and 120 psi. A 4-way solenoid valve connects the 3 valves. The 4-way valve opens up to each Poppet valve one at a time when collecting data at that certain pressure. Once the air is being supplied to the specific Poppet valve the flow meter will measure the airflow in the line and send that data back to the computer.

**Alternate Design #2 – Electro Pneumatic Pressure Regulator Design, See Appendix E**

Remove the manual flow meter and replace it with the electro-pneumatic regulator and volumetric flow meter. The design utilizes an electro pneumatic pressure regulator that is controlling the pressure in the line by the computer program. This allows you to actually set the specific pressure that you desire.

**Selection of Preferred Design:** I used Pugh’s Selection Process Chart to determine which design I was going to use. According to the chart Alternate Design #1 lacked in the areas of Computer Friendly Program, Multiple Points of Data, and Calibrate Equipment. Alternate Design #2 held a positive mark in the previously mentioned areas. See Appendix F. One of the key downsides to Design #1 is the Poppet Valve. The design is held to 3 pressure points and the valves are only accurate to 2-3 psi. For this application I want to hold my pressure within one psi. Design #2 allows me to input any pressure into the program and is accurate within 1 psi. The one downside
to the regulator is that a pressure transducer is required after the regulator to insure that there is not a pressure drop across the regulator. Both of the alternate designs involved eliminating the current plumbing and manual flow meter. See Appendix M and N. One of the main points of the design is to make the plumbing simpler. The current setup requires 2 flow meter, one for 0-8 cfm and one for 0-17 cfm. In the redesign I am using a flowmeter that will record both cfm ranges, which eliminates most of the plumbing. See Appendix N. Also, both of the alternate designs use a computer program to control the test. In the current test stand setup all of the data is collected manually by a technician. The fact that a computer program is collecting all of the data in the new design eliminates human error.

In conclusion I chose the Alternate Design #2 because it proved to be the better method according to the Pugh Method & it is more accurate.

Design of All Elements of Preferred Design

The actual design of the Test Stand is to replace the existing Test Stand with The Electro-Pneumatic equipment and utilize the National Instruments LabView program to run the test. The components that are the main part of the design are the following:

- Parker Electro-Pneumatic Pressure Regulator – The regulator is in the design to control the pressure that we are measuring in the system. The regulator is wired into the Field Point Module and the module is communicating with the LabView program.

- Omega Pressure Transducer – The transducer is in the design to insure that the pressure after the regulator is correct. I am creating a feedback loop in the program to insure that the correct pressure is being held in the regulator.

- Omega Volumetric Flowmeter – The flowmeter is being used to measure the amount of flow being produced by the air compressor. The flowmeter is wired into the Field Point Module and the module is communicating with the LabView program.
• National Instruments Field Point Module – The Field Point Module is the piece of hardware that is being used to communicate between the software program and the electro-pneumatic devices in the system.

• National Instruments LabView 6I Software – The LabView program is how you tell the hardware what to do. LabView uses an icon-based programming. Appendix Q shows a sample program in LabView.

** Refer to Appendix N for Assembly drawing of Re-Designed Test Stand.

**Customer Survey**

The customer survey is limited to employees of Campbell Hausfeld Co. (C) Since this project is proposed by my employer, the survey by default is limited to that audience. (D) The main focus of the survey is to determine how much the flow test stand will benefit the overall benefit of the company. Another basis of the survey is to determine if the time being spent by a technician performing the flow test can be better spent on more challenging tasks. The proposed survey can be found in Appendix C. The questions in the customer survey are information questions. I am looking for input from the customer. I felt that a scale survey or a true and false survey would not give me enough information concerning the project.

**Project Deliverables**

1. Create a semi-automated airflow test stand for consumer air compressors.

2. A computer program will collect the data at 40, 90, and 120 psi.

3. The program will have an amp limit to protect from any motor failures.

4. The test stand program will take at least 5 minutes less than if done manually.

5. This project will allow a technician at least 45 minutes of time spent on value added tasks instead of manually conducting the flow test on an air compressor.
Proof of Design

1. Technician time to perform the flow test should only be about 5-10 minutes. This time interval should only be for setting up the test.

2. The complete time table for the data acquisition system will be reduced from 60 minutes to 40 minutes.

3. Tests will be completed with data from the new test stand and the manual method of collecting the flow data to insure consistent measurements of the new test stand.

Project Schedule

The approximate schedule proposed is based on the most appropriate list of steps to follow in this project. See Figure 7. The design phase starts in December and should be complete in early March. Testing should then immediately follow in March and April. At the end of May the project will be complete and ready to be presented at the Tech Expo. This schedule is a rough plan but all tasks will be complete by the end of May.

Project Budget

The complete budget can be found at Figure 8. Campbell Hausfeld is providing $5000 to complete the entire project. All of the computer equipment, computers, Labview hardware and software, & all flow measuring devices must cost no more than $5000. Campbell Hausfeld will provide all of the air compressors used in this project.
Technical Solution:

A test stand that will let the air compressor run for the duration of the test with some type of computer program that collects all of the data automatically. Typically each compressor is tested at 40, 90, and 120 psi, with a 5-15 minute stabilization time between each pressure change. The program will automatically communicate the information to an Excel spreadsheet. After the data has been collected the compressor will then shut off.

Control Flow Electronically:

The main task in this flow stabilization process is controlling the pressure as the air compressor built up pressure. Parker Inc. makes an Electro-pneumatic Pressure Regulator (I). This pressure regulator will set any pressure that is inputted from the computer program. There are solenoid valves inside the regulator that send electrical inputs to the program when there are differences in pressure to the system. The regulator will also measure volts and amps that will also send an electrical signal back to the computer program. The CH Test Stand controls the pressure to 40, 90, and 120 psi. A digital flow meter (E) is being used to collect data on the actual flow of the air compressor. The flow meter is located after the regulator so that backpressure is not an issue then it sends the air to the atmosphere after it goes through the flow meter.

Automation of Flow Test:

Automation will be achieved by using a computer program called Labview 6i, which is made by Natural Instruments (Ref 10). Labview (Laboratory Virtual Instrument Engineering Workbench) uses plug-in data acquisition boards and inputs the signals from the boards to the program, which is being used on a standard PC. The program is very icon oriented and uses strong graphical representation. The sum of the program is as follows:
1. Plug the flow meter hose into the air outlet of the air compressor being tested. See Figure 2.

2. Plug the power cord to the air compressor into a standard 120-volt plug. **The only compressors tested on this stand will be 120-volt compressors, which can be found in Appendix A.**

3. Initialize program and click on a start icon on the screen.

4. The compressor will turn on automatically from the computer and begin to build pressure up to 40 psi.

5. Once the compressor reaches 40 psi, the pressure regulator will stabilize the pressure and once I have consistent readings at that pressure the regulator will start to close and the pressure will start building back up to 90 psi.

6. Once the compressor reaches 90 psi, the pressure regulator will stabilize the pressure and once consistent readings have been reached the pressure of the regulator will start to close and the pressure will start building back up to 120 psi.

7. Once the compressor reaches 120 psi, the pressure regulator will stabilize the pressure and once consistent readings have been reached the pressure of the regulator will close and the compressor will automatically turn off.

**Plan for Build and Test**

- Purchase all of the electro-pneumatic hardware for test stand.
  - Parker Electro-Pneumatic Pressure Regulator
  - Omega Volumetric Flow Meter
  - Omega Pressure Transducer

**The LabView software, Field Point Module, air compressors, plumbing, personal computer have already been supplied by Campbell Hausfeld.**
• Write and debug the Performance Test program.

• Order Portable Test Stand Table to be used for Tech Expo.

• Conduct testing on Test Stand with several different sizes of air compressors. Also, each compressor tested on redesigned test stand must be tested on current test stand to insure compatibility.

** See Figure 7 & 8 for Projected Schedule and Budget.

Fabrication

Fabrication included machining a aluminum block to fit the flowmeter to the test stand. Two pieces of plexi-glass were custom fit to fit the sides of the cart. A plexi-glass cover for the Field Point Module and the Electrical Transducers were purchased to guard from possible electrical hazards.

ASSEMBLY

Assembly included the following: cart, drilling and sizing the plexi-glass on both sides to fit the flow and electrical transducers, See Figures 9 & 10. All of the plumbing for the flowmeter, pressure gauge, and the Parker Regulator was assembled. See Figure 9. All of the electrical transducers were specially fit on the plexi-glass wall and wired together. See Figures 11 & 20. The National Instruments Field Point Module was specially drilled into the cart and all appropriate wiring was completed. See Figures 12 & 21.

PERFORMANCE TESTING

Before performance testing could begin, the length of time to run each air compressor at each pressure had to be determined. By measuring the airflow with thermocouples before and after the flowmeter while an air compressor is running, the pump thermal stability can be achieved. See Figure 13 – Length of Time at Each Pressure Study. According to the data the
longest time it takes for an air compressor to reach pump stability at a certain pressure is 10 minutes. The CH Test Stand will base its data off of this assumption.

Once the program was written all five different models of air compressors were test 3 times each on the CH Test Stand. See Figure 14.1-14.15 for the results of the testing. All of the data showed that after three runs on each air compressor the data is within 1%-2% accurate. This meets the design criteria. The data needed to be compared to the Manual Test Stand. Figure 15.1-15.15 shows a direct comparison between the Manual Test Stand and the CH Test Stand. Again each air compressor was run 3 times on each test stand to insure consistent data. The flow data and regulated pressure showed to have a difference of no more than 3% difference between test stands. The amperage, volts, and wattage show a higher rate of % difference but that is because a voltage stabilizer was not used. Also, the CH Test Stand is 25%-30% faster than the Manual Test Stand. The more important aspect of the time difference is the setup time went from 60 minutes to 5 minutes. This is an 83% reduction in time spent on the Performance Test.

True Performance Curve has never been available until now. An additional program was written that collects data at every 10 psi instead of only at 40, 90, and 120 psi. See Figure 16, 17, 18, and 19. Campbell Hausfeld was intrigued by what the theoretical curve of pressure versus flow looks like in relation to an air compressor. To complete this task manually would take about 6 hours. The CH Test Stand was able to collect this data in about 2.5 hours. Without the CH Test Stand this data would not be available. The graphs on Figures 16, 17, 18, and 19 show the true performance curve for each model of air compressor.
ECONOMIC ANALYSIS

The cost of the CH Test Stand excluding computer hardware and software is about $2800. This is $2200 under the initial budget of $5000. Within 3 months of running about 30 Performance Tests a week the CH Test Stand will pay for itself. See Appendix O.

OPERATIONS MANUAL

Once an operator reads through the Operations Manual, the operator can use the CH Test Stand. See Appendix S. Even though the program is written in LabView, no prior knowledge of the software is necessary to operate the CH Test Stand successfully.
Conclusion

The purpose of this proposal is to create a semi-automated flow test stand for air compressors using a data acquisition computer to record the data. Using this test stand will eliminate work for the employee and generate production for the company in other projects. The flow test stand after being manually setup needs minimal human interaction. The test stand will be a fully functional program and test stand. This project will cost Campbell Hausfeld a minimal amount of money considering that the production in the lab will automatically increase and the testing will be more accurate with computer controlling. The current deliverables are the following:

- **Lab Production** – Increase production in the Consumer Engineering Lab by 30%.
- **Human Interaction** – After initial setup no human interaction is needed to conduct test. Test stand will free up 25 man-hours per week, which is a –83.3% reduction in labor.
- **Cost Effective** – Initial budget is set to $5000 for Test Stand. The technician’s time spent is being reduced from 30 hours to 5 hours, which makes it very cost effective. The average salary of 1 technician is $28,000 per year. According to that salary the test stand will pay for itself in about 3 months.
- **Performance Curve** – An additional program was written to generate data on the true performance curve of an air compressor. This was possible since the CH Test Stand can collect data in a fairly fast operation.

**FUTURE PLANS FOR CH TEST STAND**

A prototype-testing phase of 1-2 months using the CH Test Stand plans to be done at Campbell Hausfeld in the Consumer Engineering Lab. Once the testing-phase is complete
Campbell Hausfeld plans to purchase the parts to assemble 4 more CH Test Stands in the Consumer Lab for everyday use.

**RECOMMENDATIONS**

Other data points that are sometimes collected during a Performance Test are revolutions per minute, and decibels. Both rpm’s and decibel readings should and could be implemented into the CH Test Stand in the near future.
1. “–Patents-Copyrights-Trademarks-Inventions” http://www.invention.com
10. Marsh Bellofram “Electro-Pneumatic I/P & E/P Transducer” www.marshbellofram.com
13. Bis Valves “Pressure relief & safety valves” http://www.bisvalves.co.uk/pressure.htm
References

1. “–Patents-Copyrights-Trademarks-Inventions” http://www.invention.com