TECHNICAL MEMORANDUM X-53678

AUTOMATIC PRESSURE TRANSDUCER CALIBRATION SYSTEM

By

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ABSTRACT

The development of an automatic pressure transducer calibration system is discussed in this report. Evolution from past practices and systems into an automatic calibration system with computerized data handling is described.

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TEST LABORATORY
RESEARCH AND DEVELOPMENT OPERATIONS

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SUMMARY

This report describes evolution and principles of automatic pressure calibration systems. The pressure balance as calibration pressure source and standard, an automatic calibration system for in-place calibration of pressure transducers with data acquisition systems at the test stand, and an automatic fifty-channel pressure transducer calibration system for laboratory evaluation and calibration of pressure transducers are described.

INTRODUCTION

For many years, manufacturers have automated their facilities to increase productivity, reduce cost, and perfect manufacturing of components to closer tolerances. The Instrument Development Branch of the Test Laboratory at MSFC has extended automation into the field of instrument calibration. This report describes an automatic pressure transducer calibration system.

Over the past several years the number of pressure transducers required for testing missiles and space vehicles has increased with the increased size and complexity of the test articles. The transducers generally used in this capacity must be highly accurate and reliable under varying and extreme environmental conditions, necessitating many thorough and complete tests, evaluations, calibrations, and recalibrations during manufacture, acceptance, use, and reuse.

Individual calibration of each transducer at different temperatures, using as a calibration standard the conventional dead weight tester, would require many manhours, large amounts of space, and tremendous duplications of equipment, resulting in great cost per unit calibrated. Calibration output was increased by manifolding a larger number of gages with the same range, but this method required the use of transfer standards, manual pressure regulations, and individual readings. The use of secondary standards is the greatest disadvantage of this method, but manual pressure regulation and the large chance for human errors are also very undesirable.

It was evident, that a more basic standard, automatic operation, and manifolding of a large number of gages would be necessary to increase quantity and accuracy for test, evaluation, and calibration of pressure transducers. These problems were solved with the automatic pressure transducer calibration system described in this report.

BACKGROUND

Around 1950 the author developed a dead weight pressure balance which regulates automatically any desired pneumatic pressure within an accuracy of 0.05 percent of the measured value (Fig. 1). A rotating piston converts the

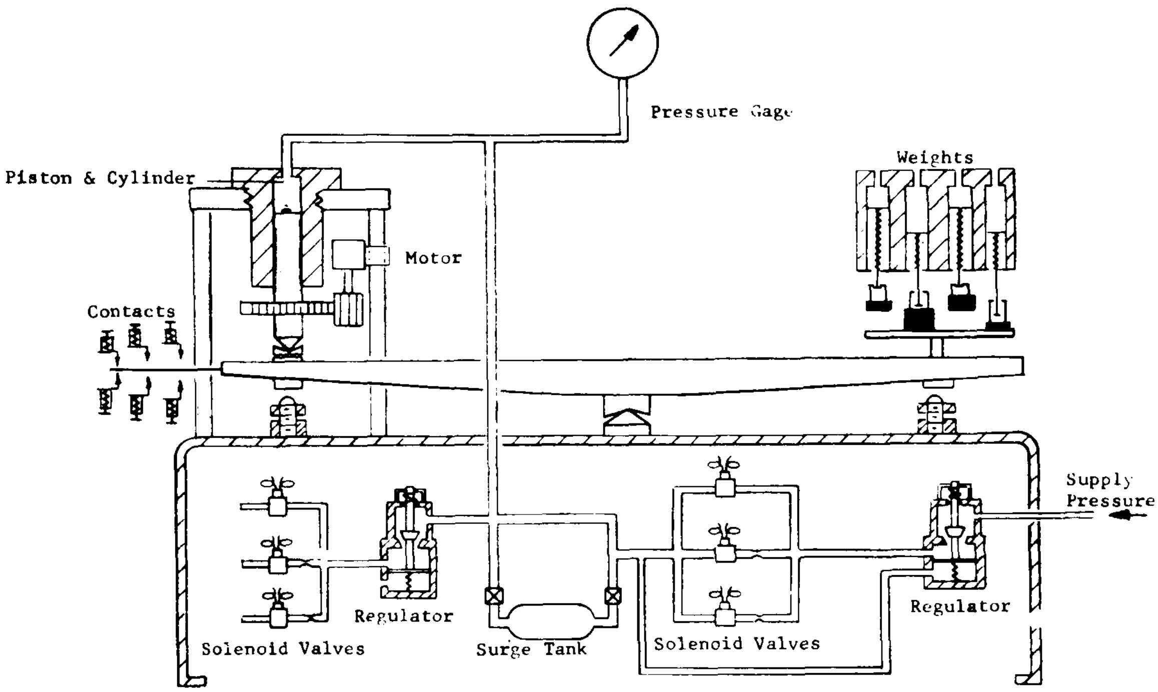

FIGURE 1. AUTOMATIC PRESSURE BALANCE

pressure into force and a mechanical balance compares this force with the force of dead weight. When these forces are unbalanced, an accurate switch system operates solenoid valves and regulates inlet or outlet of compressed air until pressure times effective area equals the force of dead weight on the other arm of the balance. Fast, medium, and slow air flow in or out, and a time delay feature for temperature changes and pneumatic shocks provide a smooth and fast control mechanism.

The advantage of the pressure balance is its ability to achieve and maintain without constant attention a desired pressure with the accuracy of a pressure standard, and to keep the transducers under test relatively clean by using compressed gas rather than hydraulic fluid as is normally done with dead weight calibrators.

The idea of the automatic pressure balance was originally conceived to provide an accurate reference pressure when pressures are known approximately and have to be measured with extreme accuracy. The pressure balance is set to regulate its pressure to the expected value, and the difference between this reference pressure and the unknown pressure is measured with a differential pressure gage of much smaller range, which increases the accuracy accordingly.

SYSTEM DEVELOPMENT

Successful development of the pressure balance for the reference pressure application led to the realization that the pressure balance was an excellent calibration standard and could be the key to automation in the field of pressure gage calibration. By electrically controlling the placement of weights on the balance pan, the usefulness of the pressure balance could be further expanded since the selection of pressure could then be automatically programmed for an entire calibration operation.

Development specifications were written and a contract was awarded to Gilmore Industries to design a simple device to provide automatic application or removal of the weights and a remote electrical selection of weights required for a certain pressure calibration program. The resulting devices are called "Weight Handler" and "Programmer."

The principle of the weight handler can be seen in Figure 1. Springs hold the weights up above the weight pan. To lower a particular weight onto the pan, the appropriate solenoid valve is energized and compressed air is applied to the proper piston/cylinder assembly, compressing the spring and lowering the weight onto the balance pan. A hook-and-eye arrangement between the weight and piston insures that there is no interaction between weight and weight handler while the weight is in place on the balance pan. Through the use of a binary or binary-coded decimal system of weight combinations, a relatively small number of individual weights provides large pressure ranges in increments of 1 psi ($0.69\ N/cm^2$). Thirteen weights provide 8191 pressure values in the binary system and 16 weights provide 4 decades or 9999 values in the binary coded decimal system. The programmer provides for the automatic operation of the entire calibration. This is accomplished by a punched tape storing the particular program and by a tape reader which converts information on the tape into electric signals to control all required operations.

Automatic Field Calibration System

Figure 2 shows the block diagram for automatic calibration of a complete pressure measuring and data acquisition system while installed in actual place of operation. First, the programmer initiates operation of the proper solenoid valves to connect a selected group of transducers via manifold to the pressure balance. Then it commands the weight handler to place the proper

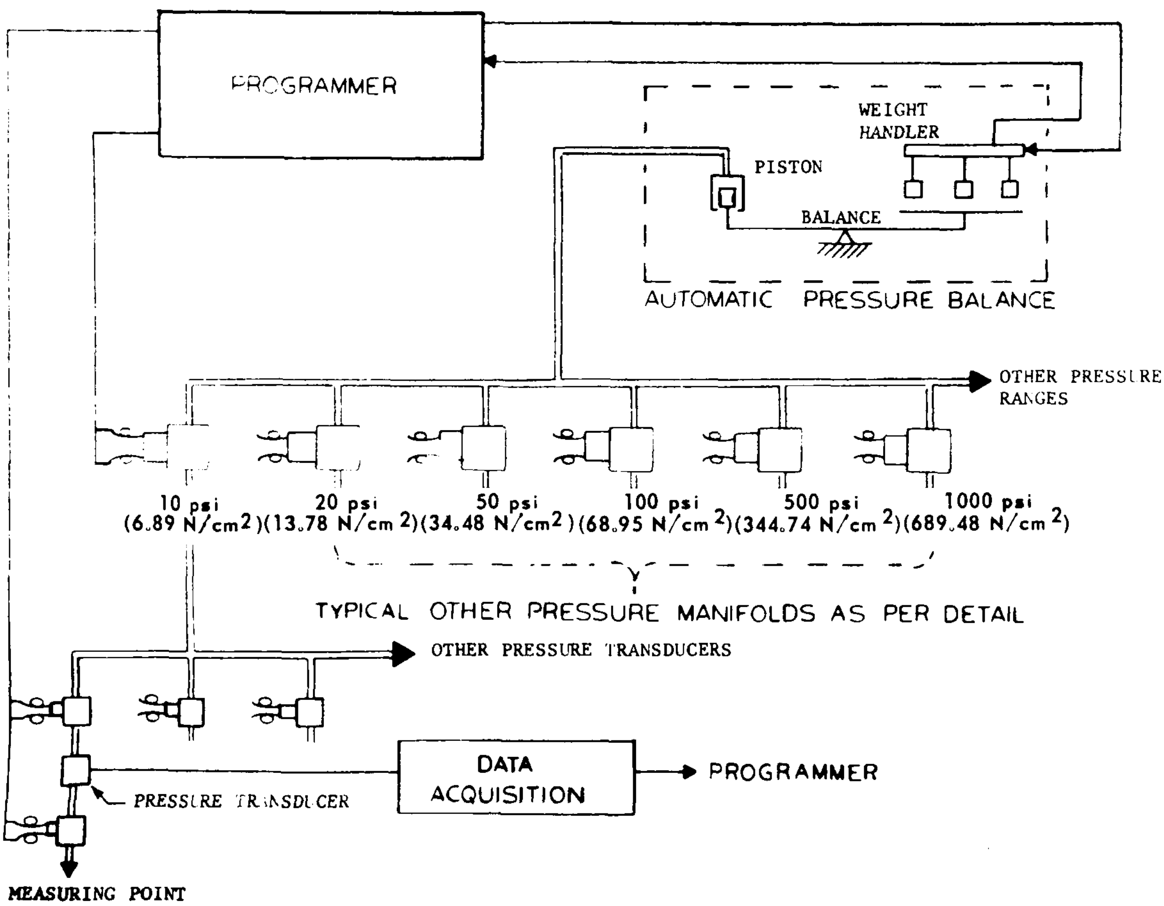

FIGURE 2. BLOCK DIAGRAM, AUTOMATIC CALIBRATION OF COMPLETE MEASURING SYSTEM

set of weights on the balance pan. The resultant force is automatically balanced by the pressure balance, and the regulated pressure is applied to the manifold connecting to the transducers to be calibrated.

After the programmed pressure is stabilized, a "read" command is given to record transducer outputs. Then the programmer initiates the application of other weights for a new pressure step. When all calibration steps for the connected transducers are completed, the programmer operates the solenoid valves to reconnect the calibrated transducer to the system where they are needed and all transducers with another pressure range are connected via manifold to the pressure balance for calibration. Through a "start" command, the calibration console performs all the programmed functions in an unattended operation.

Automatic Laboratory Calibration System

Throughout the years of rocket development it has been an accepted technique to calibrate pressure transducers in actual position at the test stands together with the data acquisition systems. The automatic pressure calibration system just described increased economy and accuracy of these calibrations. However, the increasing numbers of pressure transducers required in testing space vehicles and components resulted in a new policy to use at the test stands. Instead of "end-to-end" pressure calibration, an electrical calibration was used at the test stand and the electric signal/pressure relation was determined in the laboratory. By that time the strain gage pressure transducer had become the leading pressure transducer at MSFC's test stands and the shunt calibration of strain gages is the best and most familiar electrical calibration technique. It consists of switching well determined resistors as shunts parallel to certain arms of the strain gage bridge to produce the same bridge output as the respective pressure would.

Usually shunt calibrations are made at 25, 50, 75, and 100 percent of the pressure range. For these steps the test stands have the proper shunt resistors installed in their data acquisition network, and the laboratory has identical shunt resistors in its calibration network. Specifications for newly purchased strain gage pressure transducers require built-in shunt resistors for 20 and 80 percent of the range, and sufficient accuracy between these two points is assured by linearity specifications which are checked in the laboratory. For this evaluation, test, and calibration work, various modifications and improvements were made on automatic pressure calibration systems. A major improvement was automatic punch card data recording and automatic computer data computation and tabulation. Other major improvements were a programmer with switches instead of punched tape, additional shunt mode capability, automatic shunt-to-pressure calibration, transition between different modes, and automatic programmed application of preset shunts and pressures.

Most of these modifications and improvements resulted from combined efforts of the Instrument Development Branch, Test Laboratory, MSFC, and Vitro Services, prime support contractor of the Test Laboratory.

THE CURRENT SYSTEM

In 1965 and 1966, Vitro Services personnel developed a new and most advanced fully automatic calibration system for simultaneous calibration of 50 pressure transducers. This convenient, accurate, and highly productive 50 channel automatic pressure calibration system is shown in Figure 3.

The pressure transducers to be calibrated are installed in an environmental test chamber and manifolded to connect them to the pressure balance which is the calibration pressure source and standard. The test chamber provides a temperature range of -120° F to +350° F (188.7° K to 449.8° K), and it takes up to two hours to reach temperature stability and equilibrium when the temperature setting is changed.

The programmer controls the binary coded signals for all steps of the operation and it has the following four sub-units:

1. Pressure control matrix,
2. Shunt control matrix,
3. System or logic control matrix,
4. Computer.

Four selector switches serve to dial the full-scale pressure desired for the calibration, and additional push-button switches program the computer to perform calibrations in the desired steps and increments. For shunt calibration, the programmer connects the transducer bridges either with the shunt calibration resistors in the programmer box or with the shunt resistors built into the transducers.

The scanner sequentially connects all transducers to the ratiometer, which includes analog-to-digital conversion. The digital volt ratiometer compares the output signals of the connected transducer with the voltage of a reference power supply and gives the millivolt/volt output-input ratio in digital form to the card punch or magnetic tape recorder. A standby power supply provides normal excitation of the transducers, and when the scanner connects a transducer to the ratiometer, the excitation of the transducer is switched to the reference voltage. The reference power supply is periodically checked when the scanner connects it to a calibration standard which provides precision dc voltage.

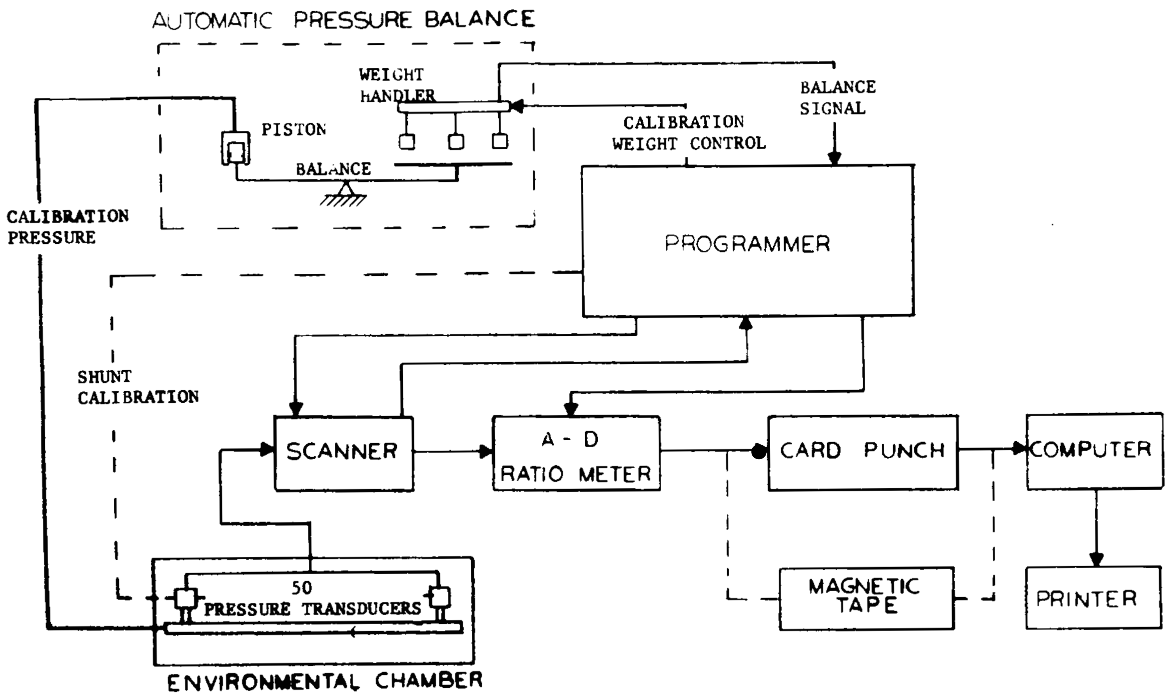

FIGURE 3. BLOCK DIAGRAM, 50 CHANNEL AUTOMATIC PRESSURE CALIBRATION SYSTEM

The output of the digital ratiometer is recorded on punch cards together with temperature, barometric pressure, and programming instructions. A coded formula identifies channel numbers and pressure steps or shunt calibration steps. The IBM 526 printing summary punch is used. This machine has a programming drum and is a multipurpose machine suitable for various recording and controlling applications. It is planned to use magnetic tapes for recording in the future to reduce storage problems.

The punched cards are sorted and printed out locally for checks and raw data files. The Computation Laboratory performs calculations to determine sensitivity, linearity, hysteresis, temperature characteristics, and deviation limits. A summary sheet of these data provides quick-look information about the usefulness of a transducer for a special application. Then shunt calibrations are made with the real data acquisition systems at the test stands or wherever the transducers are used. The combination of pressure and shunt calibrations in the laboratory, and the shunt calibrations in the field satisfy all calibration requirements and provide very reliable calibration data for evaluation of the field measurement.

APPROVAL

AUTOMATIC PRESSURE TRANSDUCER CALIBRATION SYSTEM

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The information in this report has been reviewed for security classification. Review of any information concerning Department of Defense or Atomic Energy Commission programs has been made by the MSFC Security Classification Officer. This report, in its entirety, has been determined to be unclassified.

This document has also been reviewed and approved for technical accuracy.

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