

NISTIR 6387

The NIST Gage Block Calibration Software System User's Manual

Jay H. Zimmerman



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The NIST Gage Block Calibration Software System User's Manual

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National Institute of Standards and Technology

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The NIST Gage Block Calibration Software System User's Manual

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Preface

The purpose of this user documentation is to enhance the knowledge and understanding of managers and technical staff who operate and support the *NIST Gage Block Calibration Software System*. The managers are the administrative or managerial authority in the organization where used is the *NIST Gage Block Calibration Software System*. The technical staff is engineers, scientists, and technicians who use the *NIST Gage Block Calibration Software System* and calibrate and measure gage blocks. This is the first edition published about setting up, operating, and maintaining the *NIST Gage Block Calibration Software System*. For the beginner, they can read this user documentation straight through like a story. For the skilled or knowledgeable through practice of using the *NIST Gage Block Calibration Software System*, they can turn to specific chapters in this user documentation.

More than 70 years, the Engineering Metrology Group and its predecessors at the National Institute of Standards and Technology (NIST) have been documenting many aspects of gage block calibrations and measurements [1]¹. Available to managers and technical staff who

¹ The numbers in brackets refer to *Chapter 8, References*, which provides the references for this user documentation and the *NIST Gage Block Calibration Software System*.

operate and support the *NIST Gage Block Calibration Software System* are internally published documents that together impart the evolution and science of gage block calibrations at NIST. In 1974, Clyde D. Tucker published the techniques to prepare gage blocks for a calibration [2]. In 1973, John S. Beers and Clyde D. Tucker published the methods to measure the flatness and parallelism of gage blocks [3]. John S. Beers and Clyde D. Tucker, in 1976, published the procedures to calibrate gage blocks using electromechanical comparators [4]. In 1978, John S. Beers and James E. Taylor published formulas and nomographs to figure out and instructions to correct for the local deformation to gage blocks' gaging surfaces that spherical probe tips on contact type comparators cause during calibrations [5]. For non-simultaneous comparison calibrations of gage blocks, Joseph M. Cameron and Geraldine E. Hailes, in 1974, and Ted. D. Doiron, in 1993, each published measurement designs that are inherently immune to linear drift [6-7]. Using single wavelength interferometry, John S. Beers, in 1975, published the procedure to measure gage blocks [8] and Ruth N. Varner, in 1977, published the computer software program to figure out the length of gage blocks [9]. For figuring out measurement process uncertainty, Clyde D. Tucker, in 1980, and Carroll Croarkin, John S. Beers, and Clyde D. Tucker, in 1979, each published the measurement assurance program that NIST uses for gage block calibrations [10-11]. Paul E. Pontius published about measurement assurance, traceability, and uncertainty [12-14]. In 1982, Ruth N. Varner published the computer software program to provide for continually a measurement assurance procedure for calibrating gage blocks [15]. This user documentation describes setting up, operating, and maintaining the *NIST Gage Block Calibration Software System*.

In use today at NIST is a custom, integrated software system to calibrate and measure gage blocks, which are length standards having standard features for accuracy, flatness, parallelism, dimensional stability, and surface finish for exceptional wringing characteristics. The gage blocks have nominal lengths defined in the metric system, using millimeters, and in the English system, using the inch that equals 25.4 millimeters. In keeping with the NIST policy of the International System of Units (SI) for reporting length in this manual [16], the nominal lengths of gage blocks identify each by name or size. The gage blocks have flat and parallel opposing surfaces that are rectangular, square (Hoke), and circularly cross-sectional shaped. The American standards for gage blocks, which include the U.S. Federal Specification GGG-G-15C, the American National Standard ANSI/ASME B89.1.9M, and the U.S. Department of Defense Military Standard MIL-STD 45662A, gives suggested dimensions and tolerances for rectangular, square (Hoke), and circular cross-sectional shaped gage blocks [17-19]. This calibration system conducts calibrations and measurements that meet the requirements of the American National Standard ANSI/NCSL Z540-1-1994, the U.S. Department of Defense Military Standard MIL-STD 45662A, and the International Organization for Standardization ISO/IEC Guide 25 [19-21].

This manual, *The NIST Gage Block Calibration Software System User's Manual*, has chapters that feature setting up, operating, and maintaining the *NIST Gage Block Calibration Software System*.

Disclaimer

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Acknowledgments

The Precision Engineering Division at the National Institute of Standards and Technology (NIST) developed the *NIST Gage Block Calibration Software System* and this user documentation to support NIST's gage block calibration and measurement services. Funding for the project to write this user documentation came from the National Institute of Standards and Technology and Department of the Air Force, Air Force Metrology and Calibration (AFMETCAL) Detachment 1, WR-ALC (AFMC) at Heath, Ohio.

Many people have helped me to design, develop, and test the *NIST Gage Block Calibration Software System* and this user documentation. I thank Dr. Theodore D. Doiron, Mr. Dennis S. Everett, Mr. Bryon S. Faust, Dr. Howard H. Harary, Mr. Alan Rannals, Mr. Eric S. Stanfield, and Mr. John R. Stoup, current members of the Engineering Metrology Group, Mr. Edward G. Amatucci, Mrs. Janet L. Land, William B. Penzes, and Mr. Ralph C. Veale, all who shared their ideas and support toward the software and this user documentation.

I share the merits of this user documentation with all these people and others.

Jay H. Zimmerman, August 7, 1998
Computer Scientist
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Chapter 1

Introduction to the User's Manual

The NIST Gage Block Calibration Software System is a complete calibration system with custom, integrated software to calibrate and measure gage blocks, which are length standards having standard features for accuracy, flatness, parallelism, dimensional stability, and excellent surface finish for exceptional wringing characteristics. The gage blocks have nominal lengths defined in the metric system, using millimeters, and in the English system, using the inch that equals 25.4 millimeters. In keeping with the NIST policy of the International System of Units (SI) for reporting length in this manual [16], the nominal lengths of gage blocks identify each by name or size. The gage blocks have flat and parallel opposing surfaces that are rectangular, square (Hoke), and circularly cross-sectional shaped. The American standards for gage blocks, which include the U.S. Federal Specification GGG-G-15C, the American National Standard ANSI/ASME B89.1.9M, and the U.S. Department of Defense Military Standard MIL-STD 45662A, gives suggested dimensions and tolerances for rectangular, square (Hoke), and circular cross-sectional shaped gage blocks [17-19]. The calibration system has software programs that enable the technical user, who calibrates and measures gage blocks, to create and maintain measurement history, statistical process control, and related information on NIST's and its gage block calibration customers' gage blocks. These software programs provide for measuring gage blocks using interferometric techniques and doing intercomparison using an opposed head electro-mechanical comparator with automatic data acquisition. The accessory programs enable the user to configure system resources, calculate or estimate elastic deformations, and edit files. This calibration system conducts calibrations and measurements that meet the requirements of the American National Standard ANSI/NCSL Z540-1-1994, the U.S. Department of Defense Military Standard MIL-STD 45662A, and the International Organization for Standardization ISO/IEC Guide 25 [19-21].

1.1 Objectives of this User Documentation

This user's manual, *The NIST Gage Block Calibration Software System User's Manual*, describes setting up and using the *NIST Gage Block Calibration Software System*.

The comprehensive treatment of the use and operation of the *NIST Gage Block Calibration Software System* is beyond the scope of this manual.

1.2 Documentation Overview

This user's manual, *The NIST Gage Block Calibration Software System User's Manual*, has Chapters 1 through 7 for describing setting up and using the *NIST Gage Block Calibration Software System* and Chapter 8 for providing references. The seven appendices at the end of this user documentation, which are Appendices A through G, provide a supplement to the custom, integrated calibration and measurement software programs and their related files and file folders.

Chapter 1, Introduction to the User's Manual, serves as an introduction to the *NIST Gage Block Calibration Software System*. It identifies the purpose of the documentation and delineates its organization.

Chapter 2, Gage Blocks and Instrumentation Specifications, provides the technical specifications detailing the gage blocks and instrumentation of the *NIST Gage Block Calibration Software System*. These specifications identify the gage blocks and instruments that the NIST technical staff uses to perform gage block calibrations and measurements.

Chapter 3, Microcomputer Hardware and Software Specifications, provides the technical specifications detailing the microcomputer hardware and software components of the *NIST Gage Block Calibration Software System*. These specifications identify the microcomputer hardware and software components critical for interactive programming, instrument control, data acquisition, and information processing.

Chapter 4, The NIST Gage Block Calibration Software System, provides the technical specifications detailing the custom, integrated software components of the *NIST Gage Block Calibration Software System*. These specifications identify the software components to configure system resources, calculate or estimate elastic deformations, edit files, and to calibrate and measure gage blocks, which are length standards having standard features for accuracy, flatness, parallelism, dimensional stability, and excellent surface finish for exceptional wringing characteristics. The gage blocks have nominal lengths defined in the metric system, using millimeters, and in the English system, using the inch that equals 25.4 millimeters. In keeping with the NIST policy of the International System of Units (SI) for reporting length in this manual [16], the nominal lengths of gage blocks identify each by name or size. The gage blocks have flat and parallel opposing surfaces that are rectangular, square (Hoke), and circularly cross-sectional shaped. The American standards for gage blocks, which include the U.S. Federal Specification GGG-G-15C, the American National Standard ANSI/ASME B89.1.9M, and the U.S. Department of Defense Military Standard MIL-STD 45662A, gives suggested dimensions and tolerances for rectangular, square (Hoke), and circular cross-sectional shaped gage blocks

[17-19]. The calibration and measurement software programs provide for measuring gage blocks using interferometric techniques and doing intercomparison using an opposed head electro-mechanical comparator with automatic data acquisition. Other calibration and measurement software programs enable the technical user, who calibrates and measures gage blocks, to create and maintain measurement history and related information and statistical process control about NIST's and its gage block customers' gage blocks.

Chapter 5, The Accessory Software Programs, provides functionality and technical specifications about the *NIST Gage Block Calibration Software System's* accessory software programs. It describes some characteristics and functionality of these software programs.

Chapter 6, The Calibration and Measurement Software Programs, provides functionality and technical specifications about the *NIST Gage Block Calibration Software System's* calibration and measurement software programs. It describes some characteristics and functionality of these software programs.

Chapter 7, Using the NIST Gage Block Calibration Software System, provides general instruction about using the *NIST Gage Block Calibration Software System* as a complete calibration system with custom integrated software to calibrate and measure gage blocks, which are length standards having standard features for accuracy, flatness, parallelism, dimensional stability, and excellent surface finish for exceptional wringing characteristics. The gage blocks have nominal lengths defined in the metric system, using millimeters, and in the English system, using the inch that equals 25.4 millimeters. In keeping with the NIST policy of the International System of Units (SI) for reporting length in this manual [16], the nominal lengths of gage blocks identify each by name or size. The gage blocks have flat and parallel opposing surfaces that are rectangular, square (Hoke), and circularly cross-sectional shaped. The American standards for gage blocks, which include the U.S. Federal Specification GGG-G-15C, the American National Standard ANSI/ASME B89.1.9M, and the U.S. Department of Defense Military Standard MIL-STD 45662A, gives suggested dimensions and tolerances for rectangular, square (Hoke), and circular cross-sectional shaped gage blocks [17-19]. It generalizes the methodical use of the *NIST Gage Block Calibration Software System's* software programs for configuring system resources, creating and maintaining measurement history and related information and statistical process control of NIST's and its gage block customers' gage blocks, and measuring gage blocks using interferometric and mechanical intercomparison techniques.

Chapter 8, References, provides the references for this user documentation and the *NIST Gage Block Calibration Software System*. These references identify the gage blocks, instruments, and documentation that the NIST technical staff uses to perform gage block calibrations and measurements.

The seven appendices at the end of this user documentation, which are Appendices A through G, provide a supplement to the custom, integrated calibration and measurement software programs and their related files and file folders.

Appendix A., The Accessory Software, documents the accessory software programs and their related files.

Appendix B., NIST Gage Block Calibration and Measurement Software, documents the NIST Gage Block Calibration and Measurement software programs and their related files.

Appendix C., NIST Gage Block Calibration and Measurement Software's Configuration Files, documents the configuration files the *NIST Gage Block Calibration Software System* uses.

Appendix D., NIST Gage Block Calibration and Measurement Software's Mecmap Program's Configuration File, documents the configuration file the *NIST Gage Block Calibration and Measurement Software's Mecmap Program* uses.

Appendix E., NIST Gage Block Calibration and Measurement Software's Probe Program's Configuration Files, documents the configuration files the *NIST Gage Block Calibration and Measurement Software's Probe Program* uses.

Appendix F., NIST Gage Block Calibration and Measurement Software's Report Program's NIST Reports' of Calibration Documentation Files, documents the NIST Reports' of Calibration documentation files the *NIST Gage Block Calibration and Measurement Software's Report Program* uses.

Appendix G., NIST Gage Block Calibration and Measurement Software's Spectrum Program's Configuration Files, documents the configuration files the *NIST Gage Block Calibration and Measurement Software's Spectrum Program* uses.

Chapter 2

Gage Blocks and Instrumentation Specifications

*This chapter provides the technical specifications detailing the gage blocks and instrumentation of the **NIST Gage Block Calibration Software System**. These specifications identify the gage blocks and instruments that the NIST technical staff uses to perform gage block calibrations and measurements.*

2.1 Introduction to Gage Blocks and Instrumentation

The fundamental calibration and measurement equipment and instruments are three eleven-piece sets of gage blocks, which the NIST technical staff refers as *step master gage blocks*, four complete sets of gage blocks, which the NIST technical staff refers as *master gage blocks*, electro-mechanical gage block comparators, interferometric measurement instruments, digital voltmeters, thermistor thermometers, barometer, and hygrometer. The technical user, who calibrates and measures gage blocks, uses the electro-mechanical gage block comparators to calibrate and measure gage blocks by mechanical intercomparison and uses the interferometric measurement instruments to calibrate and measure gage blocks by interferometry. The automated calibration and measurement software programs, called the **Probe** and **Gage** programs, which run on standalone microcomputer workstations, each use voltmeters to measure voltage output from the electro-mechanical gage block comparators. The thermometers, barometer, and hygrometer are necessary when making measurement corrections (e.g., thermal expansion, wavelength). Miscellaneous equipment includes several partial sets of gage blocks, many reference flats of various diameters, which the NIST technical staff refers as *optical flats* and *platens*, granite surface plates, soaking plates, and gage block cleaning and preparation equipment. To calibrate and measure gage blocks by mechanical intercomparison, the typical gage block calibration and measurement workstation, as Figure 2.1-1 shows, includes standalone microcomputer workstation with the **NIST Gage Block Calibration Software System**, electro-mechanical gage block comparator, digital voltmeter, and thermistor thermometer.

The gage block cleaning and preparation equipment, as Figure 2.1-2 shows, includes air puffer, anhydrous ethyl alcohol, Arkansas stone, cotton towel, china bristle brush, granite stone,



Figure 2.1-1 Gage Block Calibration and Measurement Workstation

and tongs for every gage block calibration. Anhydrous ethyl alcohol is for cleaning gage blocks. The cotton towel is for cleaning and drying gage blocks. For removing burrs, the Arkansas stone is for chrome carbide gage blocks and the granite is for steel gage blocks. The tongs are equipped with padded tips for handling gage blocks. The air puffer is for removing dust from gage blocks during calibrations.

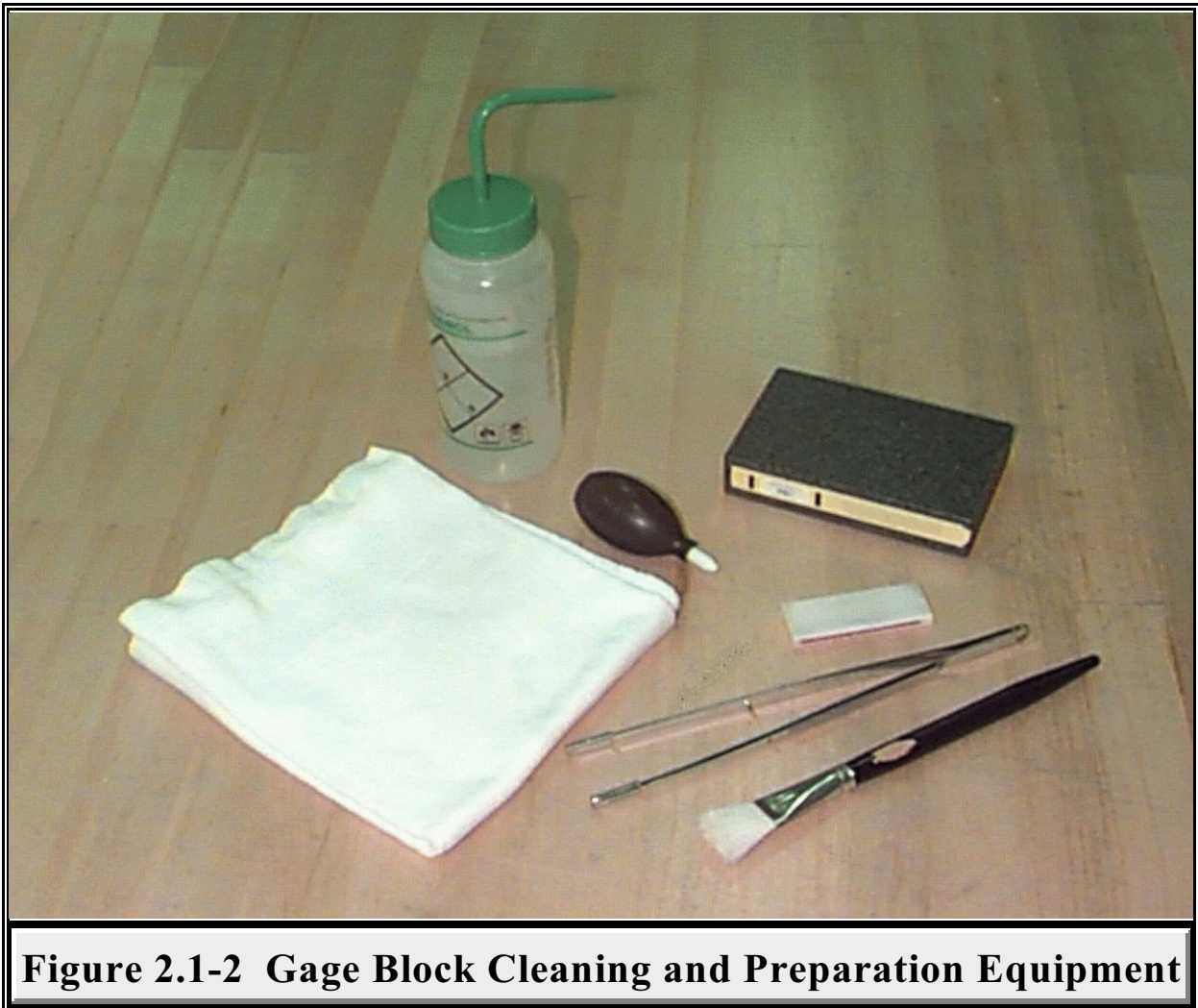


Figure 2.1-2 Gage Block Cleaning and Preparation Equipment

2.2 Gage Blocks

The gage blocks the NIST technical staff uses are three eleven-piece sets of gage blocks, which the NIST technical staff refers as *step master gage blocks*, and four complete sets of gage blocks, which the NIST technical staff refers as *master gage blocks*. The technical user, who calibrates and measures gage blocks, routinely uses the automated software program, called the **Probe** program, and three eleven-piece sets of gage blocks, which the NIST technical staff refers as *step master gage blocks*, to calibrate the electro-mechanical gage block comparators. The three step master gage block sets each are eleven-piece English, or inch, sets, which the user uses exclusively for calibrating the electro-mechanical gage block comparators. The user uses the automated software program, called the **Gage** program, and four complete sets of gage blocks,

which the NIST technical staff refers as *master gage blocks*, to calibrate and measure gage block calibration customers' gage blocks by mechanical intercomparison. The four complete gage block sets are two English, or inch, sets and two metric sets. The user regularly calibrates and measures the gage blocks and check each for parallelism and flatness to be usable for all routine calibrations and measurements, assuring accuracy.

Over the years and currently, the users, who are the technicians who calibrate and measure gage blocks, at NIST have purchased gage blocks from many manufacturers and vendors, including DoAll Company, Ellstrom Company, Fonda Gage Company, Hummel Company, A. A. Jansson, Inc., C. E. Johansson Company, Matrix, Pratt and Whitney Company, Van Keuren Company, Webber Gage Division of the L. S. Starrett Company, and Carl Zeiss Company². Gage block manufacturers commonly inscribe individual identification, or serial, numbers and nominal sizes on all gage blocks to establish proper identification and reference.

The three eleven-piece step master gage block sets, as Figure 2.2-1 shows, each consist of a selection of rectangular gage blocks having nominal gage block sizes from 0.1 through 0.1001 inches, in increments of 0.00001 inches, one each of steel, chrome carbide, and tungsten carbide gage blocks. As a note, everyone uses the actual nominal gage block sizes labeled on these English, or inch, step master gage blocks to identify them and, therefore, using metric equivalents is impractical.

The two English, or inch, master gage block sets each consist of a selection of rectangular gage blocks having nominal gage block sizes from 0.01 inches through 4 inches, one each of steel and chrome carbide gage blocks, and square (Hoke) gage blocks having nominal gage block sizes from 5 inches through 20 inches, two each of steel gage blocks, totaling 178 pieces in each set. Figure 2.2-2 shows a selection of rectangular gage blocks having nominal gage block sizes from 0.01 inches through 4 inches, one each of chrome carbide gage blocks. The principle assortments of nominal gage block sizes are the 0.0001-inch series, the 0.001-inch series, the 0.010-inch series, the 0.020-inch series, the 0.050-inch series, and the 1.000-inch series. The 0.0001-inch series consists of nominal gage block sizes from 0.1001 inches through 0.1009 inches. The 0.001-inch series consists of nominal gage block sizes from 0.101 inches through 0.95 inches. The 0.010-inch series consists of nominal gage block sizes from 0.0101 inches through 0.019 inches. The 0.020-inch series consists of nominal gage block sizes from 0.0201 inches through 0.029 inches. The 1.000-inch series consists of nominal gage block sizes

² This user documentation identifies certain commercial equipment, instruments, materials, products, and the names of companies and products in this user documentation only to properly specify equipment and procedures used. Such identification of commercial equipment, instruments, materials, or products does not imply recommendation or endorsement by the National Institute of Standards and Technology and it does not imply that they are necessarily the best available for the purpose. Refer to the *Disclaimer* section of this user documentation for a complete disclosure.



Figure 2.2-1 Eleven-Piece Step Master Gage Block Sets

from 1 inch through 4 inches. Miscellaneous block series are the 1/64-inch series, which consists of nominal gage block sizes of 1/32, 3/64, 1/16, 5/64, 3/32, and 7/64 inches, and the 0.00005-inch series, which consists of 0.02005 and 0.10005 inches. The two square (Hoke) steel long gage block sets are assemblies of blocks from 5 inches through 20 inches. As a note, everyone uses the actual nominal gage block sizes labeled on these English, or inch, master gage blocks to identify them and, therefore, using metric equivalents is impractical.

The two metric master gage block sets each consist of a selection of rectangular block blocks having nominal gage block sizes from 0.1 millimeters through 100 millimeters, one each of steel and chrome carbide gage blocks, and square (Hoke) gage blocks having nominal gage block sizes from 125 millimeters through 500 millimeters, two each of steel gage blocks, totaling 212 pieces in each set. The principal assortments of nominal gage block sizes are the



Figure 2.2-2 Chrome Carbide English Master Gage Blocks

0.1-millimeter base series, the 0.5-millimeter base series, the 1.0-millimeter base series, the 2.0-millimeter base series, and the 10-millimeter base series. The 0.1-millimeter base series consists of nominal gage block sizes from 0.1 millimeters through 0.9 millimeters in 0.1-millimeter increments. The 0.5-millimeter base series consists of nominal gage block sizes from 1.0 millimeters through 25.0 millimeters in 0.5-millimeter increments. The 1.0-millimeter base series consists of nominal gage block sizes of 1.0005 millimeters, from 1.001 millimeters through 1.009 millimeters in 0.001-millimeter increments, from 1.01 millimeters through 1.49 millimeters in 0.01-millimeter increments, and from 1.6 millimeters through 1.9 millimeters in 0.1-millimeter increments. The 2.0-millimeter base series consists of nominal gage block sizes 2.0005 millimeters, from 2.001 millimeters through 2.009 millimeters in 0.001-millimeter increments, from 2.01 millimeters through 2.49 millimeters in 0.01-millimeter increments, and from 2.6 millimeters through 2.9 millimeters in 0.1-millimeter increments. The 10.0-millimeter

base series consists of nominal gage block sizes from 30.0 millimeters through 100.0 millimeters in 10-millimeter increments and 75.0 millimeters. Miscellaneous metric gage block sizes consist of 0.25, 0.75, 0.405 millimeters. The two square (Hoke) steel long gage block sets are assemblies of blocks from 125 millimeters through 500 millimeters. As a note, everyone uses the actual nominal gage block sizes labeled on these metric master gage blocks to identify them and, therefore, using English, or inch, equivalents is impractical.

2.3 Gage Block Comparators

The *NIST Gage Block Calibration Software System* employs two types of electro-mechanical gage block comparators. The first type of electro-mechanical gage block comparators, as Figure 2.3-1 shows, called *short block comparators*, measures metric gage blocks having nominal lengths from 0.1 millimeters through 100 millimeters and English, or inch, gage blocks having nominal lengths from 0.01 millimeters through 4 inches. The second type of electro-mechanical gage block comparators, as Figure 2.3-2 shows, called *long block comparators*, measures metric gage blocks having nominal lengths from 125 millimeters through 600 millimeters and English, or inch, gage blocks having nominal lengths from 5 inches through 24 inches. In keeping with the NIST policy of the International System of Units (SI) for reporting length in this manual [16], the nominal lengths of gage blocks identify each by name or size. These electro-mechanical gage block comparators provide electronic calibration and measurement of gage blocks and digital readout resolutions of approximately 2.5 nanometers (0.1 microinches). The technical user, who calibrates and measures gage blocks, inserts gage blocks, one-at-a-time and in series, between the electro-mechanical gage block comparators' two opposing spindle probes during the established calibration and measurement processes. The readings, which are the measured displacement of contact between those opposing spindle probes, yield the final calibration and measurement values for the gage blocks.

The short block comparators, which are Federal Products Corporation Model 130B-24 electro-mechanical gage block comparators and manufactured by Federal Products Corporation of Providence, Rhode Island, each are separately interfaced to the *NIST Gage Block Calibration Software System's* microcomputer systems. Components of these electro-mechanical gage block comparator systems each include one Federal Products Corporation Model 130B-24 bench-mounted electro-mechanical gage block comparator, one digital meter with RS-232 output, one Federal Products Corporation Model 130B-24 solid state amplifier, and one Federal Products Corporation Model C-16724 foot switch assembly. The technical user, who calibrates and measures gage blocks, uses these comparators to measure metric gage blocks having nominal lengths from 0.1 millimeters through 100 millimeters and English, or inch, gage blocks having nominal lengths from 0.01 millimeters through 4 inches [22].

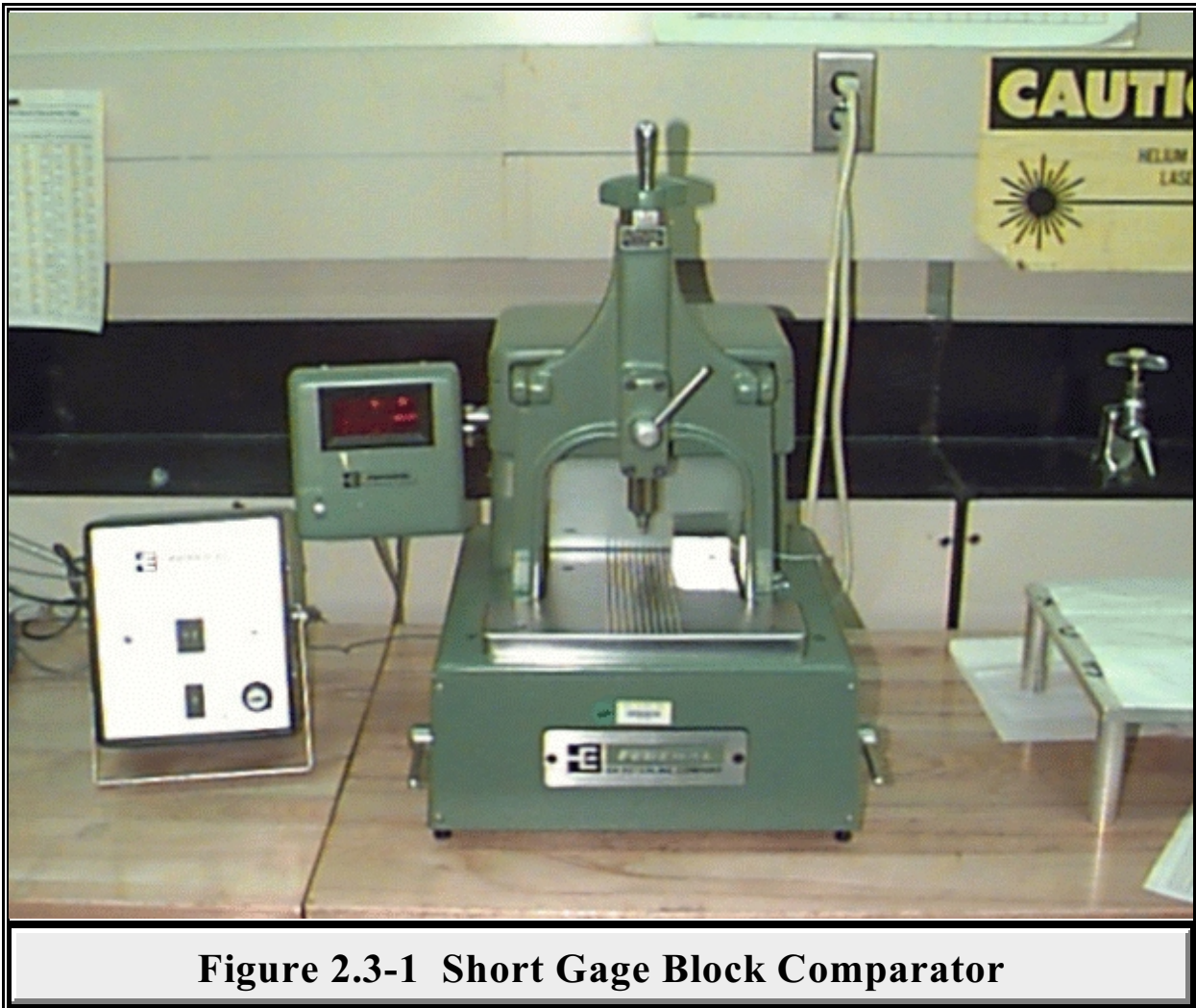


Figure 2.3-1 Short Gage Block Comparator

The long block comparators, which are Federal Products Corporation Model 130B-16 electro-mechanical gage block comparators and manufactured by Federal Products Corporation of Providence, Rhode Island, each are separately interfaced to the *NIST Gage Block Calibration Software System's* microcomputer systems. Components of these electro-mechanical gage block comparator systems each include one Federal Products Corporation Model 130B-16 bench-mounted electro-mechanical gage block comparator, one digital meter with RS-232 output, one Federal Products Corporation Model 130B-16 solid state amplifier, and one Federal Products Corporation Model C-16724 foot switch assembly. The technical user, who calibrates and measures gage blocks, uses these comparators to measure metric gage blocks having nominal lengths from 125 millimeters through 600 millimeters and English, or inch, gage blocks having nominal lengths from 5 inches through 24 inches [23].



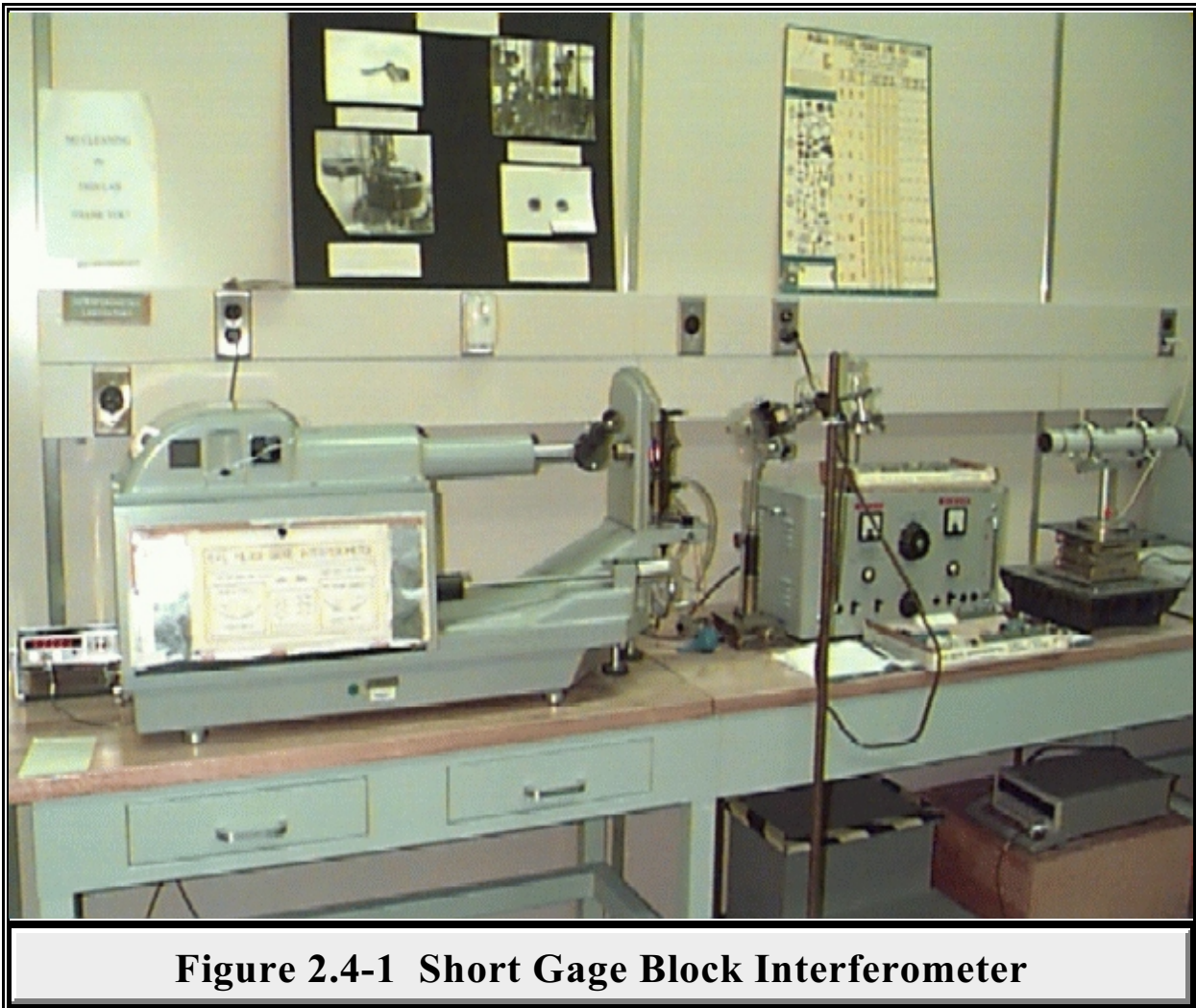
Figure 2.3-2 Long Gage Block Comparator

The short and long block comparators, which are electro-mechanical gage block comparators and manufactured by Federal Products Corporation of Providence, Rhode Island, each feature large, chrome-plated platens of hardened steel to support the gage blocks during gaging. The platen of each comparator is mounted separate from the measuring mechanics and serves to protect gage blocks since it eliminates wringing the blocks into position. The sensitive gage-head contact of each comparator contacts the gage blocks through a slot in the platen. The electro-mechanical gage block comparators' manufacturer suspended the complete gaging mechanism, including the sensitive and reference spindles, within its main measurement structure. According to the manufacturer's specifications, isolating the gaging mechanism reduces effects of local vibration. Finally, the manufacturer says the comparators' design allows for adjusting gaging pressure for both the sensitive and reference contacts [22-23].

2.4 Gage Block Interferometric Measurement Instruments

The *NIST Gage Block Calibration Software System* employs several interferometric measurement instruments to calibrate and measure gage blocks belonging to NIST and its customers. At NIST, the interferometric measurement instruments capacitate the *NIST Gage Block Calibration Software System* to calibrate and measure metric gage blocks, which have nominal lengths from 0.1 through 100 millimeters and from 125 millimeters through 1200 millimeters, and English, or inch, gage blocks, which have nominal lengths nominal lengths from 0.01 through 4 inches and from 5 inches through 48 inches, and measure flatness of the gage blocks to approximately 25 nanometers (one microinch). In keeping with the NIST policy of the International System of Units (SI) for reporting length in this manual [16], the nominal lengths of gage blocks identify each by name or size.

At NIST, the primary interferometer, as Figure 2.4-1 shows, for calibrating and measuring metric gage blocks, which have nominal lengths from 0.1 through 100 millimeters, and English, or inch, gage blocks, which have nominal lengths from 0.01 through 4 inches, was manufactured by Messrs, Hilger and Watts Limited (Hilger Division) of Great Britain. The instrument, a National Physical Laboratory (NPL)-Hilger Gauge Model N180-302/55202 interferometer, was based on NPL design for directly calibrating and measuring batches of gage blocks. The reference standards of measurement are based on the actual wavelengths of cadmium and mercury radiation emitted from the cadmium and mercury lamps and the single frequency wavelength of helium-neon radiation emitted from the Tropel Corporation Model 100 helium-neon laser, which Coherent, a division of Tropel Corporation manufactured. The manufacturer originally supplied the instrument with one baseplate, which the technical user, who calibrates and measures gage blocks, rotates with the instrument's control knob. To interferometrically measure gage blocks, the user suitably wrings gage blocks to the working surface of reference flats of various diameters, which the NIST technical staff refers as *optical flats* and *platens*. Over the field of view, these working plates are within approximately 25 nanometers (one microinch) of perfect flatness to provide suitable optical characteristics.



2.5 Digital Voltmeters

The digital voltmeters are Hewlett-Packard Model HP3478A and Model HP34401A digital multimeters. For automated data transmission, the digital voltmeters are interfaced between the Federal electro-mechanical gage block comparators' RS-232 connection on the back of its digital meter and the microcomputers' PC/IEEE-488 interface hardware. Individual foot switches are separately attached to the digital voltmeters that, when pressed by the users, who are the technicians that calibrate and measure gage blocks, trigger the *NIST Gage Block Calibration Software System's* software programs to gather voltage readings automatically from the electro-mechanical gage block comparators, which the digital voltmeters measure. The digital voltmeters' design features include selectable speed and 3-1/2 to 5-1/2 digit resolution (e.g., 90

readings per second with 3-1/2 digit resolution, 35 readings per second with 4-1/2 digit resolution) and five auto-ranging functions for automated testing. These instruments can measure DCV, true RMS ACV, 2-wire and 4-wire ohms, and DC and AC current. Other design features include switchable front/rear inputs for system connections, complete output and external trigger input that allows synchronization without delay of software commands, a Hewlett-Packard IEEE 488-1978, or Hewlett-Packard Interface Bus (HPIB) input-output interface bus, and nonvolatile memory for storing calibration constants. The digital voltmeters are designed to enable the user to calibrate the instruments manually from the front panel or automatically using the HPIB interface functions [24-25].

2.6 Thermometers

The thermometers are United Systems Corporation Digitec Model 5810 digital thermistor thermometers manufactured by United Systems Corporation of Dayton, Ohio. The thermometers measure directly in degrees Celsius with 0.01 degree Celsius resolutions and operate with United Systems Corporation Series 700A interchangeable probes. Other design features include a 4-1/2 digit display, 0.03 degree Celsius accuracy, two temperature ranges (e.g., -30.00 to +50.00 degrees Celsius, 0.00 to 100.00 degrees Celsius), three probe inputs, line or battery operation, response time of 500 milliseconds, and a sampling rate of four per second nominal [26].

To measure the temperature of gage blocks having nominal gage block sizes from 0.01 inches through 4 inches and from 0.1 millimeters through 100 millimeters, the technical user, who calibrates and measures gage blocks, attaches thermistor probes one each to electro-mechanical gage block comparators' large, chrome-plated platens of hardened steel, which support the gage blocks during gaging. To measure the temperature of long gage blocks having nominal gage block sizes from 5 inches through 20 inches and from 125 millimeters through 500 millimeters, the user attaches thermistor probes one each to electro-mechanical gage block comparators' platens and one each near the bases and tops of these gage blocks during gaging.

2.7 Barometer

The barometer is a PENN-WALT Corporation Model FA-139 aneroid barometer manufactured by Wallace and Tiernan Division, PENN-WALT Corporation of Belleville, New Jersey. The technical user, who calibrates and measures gage blocks, uses this instrument to measure barometric pressure. The measuring range of the barometer is from 710.0 millimeters through 785.0 millimeters of mercury with 0.1-millimeter resolutions. The user measures barometric pressure during interferometric gage block calibrations and measurements.

2.8 Hygrometer

The hygrometer is a Lufft Model AB167 laboratory relative humidity measuring instrument manufactured by Lufft of West Germany and originally certified by Abbeon Cal, Incorporated of Santa Barbara, California. The measuring range of the hygrometer is from zero through 100 per cent relative humidity with one part per hundred resolutions. The technical user, who calibrates and measures gage blocks, measures the laboratory's relative humidity during interferometric gage block calibrations and measurements. To assure proper conditions for storing the gages and doing calibrations and measurements, the user always uses the hygrometer to manage relative humidity levels in the laboratories' spaces.

Chapter 3

Microcomputer Hardware and Software Specifications

*This chapter provides the technical specifications detailing the microcomputer hardware and software components of the **NIST Gage Block Calibration Software System**. These specifications identify the microcomputer hardware and software components critical for interactive programming, instrument control, data acquisition, and information processing.*

3.1 Introduction to Microcomputer Hardware and Software

The **NIST Gage Block Calibration Software System** employs standalone microcomputer workstations. Latest microcomputer hardware and software specifications have each workstation consisting of one independently operating Pentium II microprocessor-based microcomputer with Microsoft Windows 95 operating system, Profession Edition of Microsoft Office 97, TransEra High Tech Basic Language DOS Version 4.3 or higher, the software components of the **NIST Gage Block Calibration Software System**, and one ordinary quality, dot-matrix line printer. To run Microsoft Windows 95 operating system, Profession Edition of Microsoft Office 97, TransEra High Tech Basic Language DOS Version 4.3 or higher, and the calibration and measurement software components of the **NIST Gage Block Calibration Software System**, the microcomputers at NIST each have between 24 and 64 megabytes of random access memory [27-30]. Peripherals shared by all workstations consist of one high-resolution publication-quality laser printer and one graphics plotter. The workstations' hardware and software configuration are virtually compatible, which consists of interchangeable microcomputer hardware components.

3.2 Microcomputer Hardware and Software System

The latest specifications to the **NIST Gage Block Calibration Software System** recommend independently operating Pentium II microprocessor-based microcomputer workstations. The NIST Gage Block Calibration Software is written in TransEra High Tech

Basic (HTBasic) Language System DOS Version 4.3 or higher, which specifically require Intel 486 and Pentium microprocessor-based IBM-compatible personal computers and Microsoft DOS Version 5.0 or higher, Microsoft Windows 3.1, or Microsoft Windows 95 [29-30]. Several calibration and measurement software programs require the microcomputers each to consist of eight megabytes random access memory minimally. To run the Professional Edition of Microsoft Office 97, which requires Microsoft Windows 95, and other Microsoft Windows 95 compatible application software together with the *NIST Gage Block Calibration Software System*, latest recommendations specify Intel Pentium II microprocessor-based IBM-compatible personal computers, 64 megabytes of random access memory, 17-inch color monitor (15.9-inch viewable area), 4-gigabyte hard drive, 12X minimum/32X maximum CD-ROM drive, and 3.5-inch 1.44-megabyte floppy diskette drive [28].

The workstations' microcomputer systems each are equipped with one IOtech PC/IEEE-488 interface board, three IEEE-488 cables, and one RS-232 parallel cable, which connect each workstation's microcomputers to calibration and measurement equipment and computer peripherals. Each workstation's microcomputer system has installed inside its system unit and into an available expansion slot exactly one IOtech PC/IEEE-488 interface board unit according to IOtech's installation specifications. Then, daisy-chained mounted to each workstation's microcomputer system's IOtech PC/IEEE-488 interface board, are three cable connectors, one end only, of the IOtech PC/IEEE-488 cable pair. The leading end of the first cable is mounted to a Hewlett-Packard Model HP3478A or Model HP34401A digital multimeter, which enables the automated calibration and measurement software programs, called the *Probe* and *Gage* programs, use the digital voltmeter to measure voltage output from the electro-mechanical gage block comparators. The leading end of the second cable is mounted to an ordinary dot-matrix desktop line printer. To share the use of the graphics plotter among workstations, the leading end of the third cable is mounted to a graphics plotter, which is disconnected and reconnected to another workstation as needed. The RS-232 parallel cable is mounted, one end to the workstation's parallel printer port, the leading end to a shared parallel printer port, which then connects to the high-resolution, publication-quality laser printer.

3.3 Workstation Digital Voltmeters

The digital voltmeters, which are Hewlett-Packard Model HP3478A and Model HP34401A digital multimeters, provide automated data transmission when adapted by the technical user, who calibrates and measures gage blocks, and interfaced between the Federal electro-mechanical gage block comparators' RS-232 connection on the back of its digital meter and the microcomputers' PC/IEEE-488 interface hardware. This adaptation, which the NIST technical staff calls "debouncing" the digital voltmeters, allows separately attaching individual foot switches to the digital voltmeters that, when pressed by the user trigger the *NIST Gage Block Calibration Software System's* software programs to gather voltage readings automatically from the electro-mechanical gage block comparators, which the digital voltmeters

measure. The agreed upon four-part “debouncing” procedure have the user prepare and add to the digital voltmeters an integrated circuit which debounces incoming signals from the mechanical foot switches [31-32].

The first part of the “debouncing” procedure has the technical user, who calibrates and measures gage blocks, separately attaching the foot switch to the digital voltmeter. Every installation uses the following hardware components:

- One Treadlite foot switch (Type T-91-S, Newark Electronics’ stock number 96F2040)
- One BNC twin connector (Amphenol 31-224)
- One BNC twin connector (Amphenol 31-223)
- One two-meter piece of shielded three-wire cable

In every installation, the user performs the following steps for the first part of the “debouncing” procedure:

- Step 1: Enlarge the existing hole in the digital voltmeter’s rear panel, which is under the plastic template that attaches to the metal, for adapting to the new feed-through connector, performing this action with extreme care to avoid damaging any existing components or allowing metal filings to fall into the digital voltmeter’s circuit board that can cause short circuiting when the digital voltmeter is powered up.
- Step 2: Attach the BNC twin connector (Amphenol 31-224) to one end of the two-meter piece of shielded three-wire cable and attach the BNC twin connector (Amphenol 31-223) to the other end, which is for the feed-through connector that mounts to the digital voltmeter’s rear panel.
- Step 3: Attach the feed-through connector to the digital voltmeter’s rear panel just above the connector labeled “External Trigger.”
- Step 4: Use the two-meter piece of shielded three-wire cable, prepared in the first procedure’s step 2, to duly connect the foot switch to the digital voltmeter’s new trigger input.

The second part of the “debouncing” procedure has the technical user, who calibrates and measures gage blocks, separately interfacing the Federal electro-mechanical gage block comparator’s RS-232 connection, which is on the back of its digital meter, to the “positive-

and-negative” voltage inputs on the digital voltmeter’s rear panel. Every installation uses the following hardware components:

- One 5-pin connector, which the manufacturer of the Federal electro-mechanical gage block comparators normally supplies
- One normal BNC connector (Amphenol 31-30220-12) for 1/8-inch RG-174/U cable
- One BNC-to-double-banana (post-plug) connector
- One two-meter piece of 1/8-inch RG-174/U cable

In every installation, the user performs the following steps for the second part of the “debouncing” procedure:

- Step 1: Check the polarity of the 5-pin connector’s second and third pins and duly attach the 5-pin connector to one end of each two-meter piece of 1/8-inch RG-174/U cable and attach the normal BNC connector (Amphenol 31-30220-12) to the other end.
- Step 2: Plug the BNC-to-double-banana (post-plug) connector into the “positive-and-negative” inputs on the digital voltmeter’s rear panel.
- Step 3: Use the two-meter piece of 1/8-inch RG-174/U cable, prepared in the second procedure’s step 1, to duly connect the Federal electro-mechanical gage block comparator’s RS-232 connection, which is on the back of its digital meter, to the “positive-and-negative” voltage inputs on each digital voltmeter’s rear panel.

The third part of the “debouncing” procedure has the technical user, who calibrates and measures gage blocks, separately adapting the digital voltmeter. Every installation uses the following hardware components:

- One 74LS Type 00 (14-pin) Quad NAND Gate integrated circuit,
- One 14-pin dual-in-line extension socket
- Two 4.7 Kohm resistors
- Two jumpers
- Three pieces of AWG Z8 copper wire, each 15-20 centimeters

Soldering every connection inside the digital voltmeter for every installation, the user performs the following steps for the third part of the “debouncing” procedure:

- Step 1: Trim by half, twelve of the extension socket’s pins, and only leaving the seventh and fourteenth pins intact.

- Step 2: Connect one 4.7 Kohm resistor between the extension socket's first and fourteen pins and connect the other 4.7 Kohm resistor between the extension socket's fifth and fourteenth pins.
- Step 3: Connect one jumper between the extension socket's second and sixth pins and connect the other jumper to the extension socket's third and fourth pins.
- Step 4: Use the three pieces of AWG Z8 copper wire, separately connecting each piece, one end only, to the extension socket's first, third, and fifth pins.
- Step 5: Duly plug the 74LS Type 00 (14-pin) Quad NAND Gate integrated circuit into the extension socket, making sure the integrated circuit's orientation matches the wiring configuration.
- Step 6: Referring to the schematic drawing on page 9-5 of the service guide for the Hewlett-Packard Model HP34401A digital multimeter, find the two 8-pin integrated circuits each respectively numbered U506 and U704, which provides the newly wired integrated circuit its +5 volt supply and ground.
- Step 7: Bend the extension socket's seventh and fourteenth pins, which were left intact, to ensure the 74LS Type 00 (14-pin) Quad NAND Gate integrated circuit correctly seats above both 8-pin integrated circuits each respectively numbered U506 and U704.
- Step 8: Connect the extension socket's pin, which corresponds to the 74LS Type 00 (14-pin) Quad NAND Gate integrated circuit's fourteenth pin, to the second pin of the 8-pin integrated circuit numbered U506.
- Step 9: Connect the extension socket's pin, which corresponds to the 74LS Type 00 (14-pin) Quad NAND Gate integrated circuit's seventh pin, to the eighth pin of the 8-pin integrated circuit numbered U704.
- Step 10: Connect the AWG Z8 copper wire leading from the extension socket's first pin to the feed-through connector, which corresponds as the female connection on the opposite side of the feed-through connector.
- Step 11: Connect the AWG Z8 copper wire leading from the extension socket's fifth pin to the feed-through connector, which corresponds as the male connection on the opposite side of the feed-through connector.
- Step 12: Connect the AWG Z8 copper wire leading from the extension socket's third pin to the center tap of the external trigger connector on the rear face of the digital voltmeter's circuit board just below the feed-through connector.

Referring to the user's guide for the Hewlett-Packard Model HP34401A digital multimeter, the technical user, who calibrates and measures gage blocks, accomplishes the fourth part of the "debouncing" procedure, separately changing the digital voltmeter's programming language selection to the *HP3478A Language* and its hardware address to "23" [25].

3.4 Workstation Peripherals

The workstations' microcomputer systems each are equipped with one ordinary quality dot-matrix line printer. The printers are Hewlett-Packard ThinkJet Model 2225D dot-matrix line printers. These printers print text and graphics, offer 150 characters per second printing capacity, and use disposable print cartridges and 8-1/2 by 11 inch Z-fold paper. The predominant application consists of printing the observation report, which contains the measurements and statistical analyses.

The workstation peripherals shared by all workstations consist of one high-resolution, publication-quality laser printer and one graphics plotter. The workstation printer is a high-resolution, publication-quality Hewlett-Packard LaserJet Model 6PXi laser printer, which prints final reports about calibrations and measurements performed. To run the Professional Edition of Microsoft Office 97 and other Microsoft Windows 95 compatible application software together with the *NIST Gage Block Calibration Software System*, recommendations specify a high-resolution publication-quality laser printer with 6 megabytes of memory, black print color, 600 dots per inch resolution, 12,000-page monthly duty cycle, 350-sheet media capacity, standard media sizes (e.g., letter, legal, A4, executive), standard media types (e.g., plain paper, envelopes, transparencies, labels, and card stock up to 43-lb thickness), and a high-speed interface (e.g., IEEE 1284-compliant parallel) [27-28]. The predominant application consists of printing NIST Reports' of Calibration.

The graphics plotter is an eight-pen Hewlett-Packard ColorPro Model 7440A plotter. The plotter is equipped with a Hewlett-Packard Interface Bus (HPIB) interface and uses Hewlett-Packard Graphics Language (HPGL) instructions, which resides in the plotter. The HPGL software controls plotting functions such as pen movement, labeling, character set selection, and axis placement. The plotter accepts four different media types, which are chart paper, glossy presentation paper, overhead transparency film, and double-matte polyester film. Pen types include fiber-tip pens for paper and overhead transparencies and liquid-ink drafting pens for high-quality drawings on polyester film. Fiber-tip pens are available in ten colors and two tip widths. The drafting pens are refillable and are available in three different tip widths.

3.5 Microcomputer Software Programming Language

The *NIST Gage Block Calibration Software System* is programmed in TransEra High Tech Basic (HTBasic) Language System DOS Version 4.3 or higher. TransEra HTBasic Language System DOS Version 4.3 or higher is a BASIC interpreter compatible to the Hewlett-Packard Rocky Mountain BASIC Language, which Hewlett-Packard originally developed for the Hewlett-Packard 9000 Series 200/300 scientific and engineering workstations. Hewlett-Packard Rocky Mountain BASIC and TransEra HTBasic Language System DOS Version 4.3 or higher

are powerful scientific and engineering languages that combine the ease-of-use of BASIC, the math capabilities of FORTRAN and the structured-programming of Pascal and C, extensive graphics, instrument control capabilities with IEEE-488 (e.g., Hewlett-Packard Interface Bus (HPIB), General Purpose Interface Bus (GPIB)) or data acquisition plug-in cards, and interactive programming aids [29-30]. Since the former *NIST Gage Block Calibration Software System* was written in Hewlett-Packard Rocky Mountain BASIC, TransEra HTBasic Language System DOS Version 4.3 or higher was approved for its compatibility with Hewlett-Packard's Rocky Mountain BASIC. TransEra HTBasic Language System DOS Version 4.3 or higher utilities enable transferring data and program files between Intel 486 and Pentium microprocessor-based IBM-compatible personal computers running Microsoft Windows or Microsoft DOS and Hewlett-Packard Series 200/300 workstations, Hewlett-Packard Series 700 workstations, or Sun SPARC workstations [29-30]. Once transferred, programs can run virtually unchanged, which avoids time consuming and costly program rewrites.

3.6 Installing the Software Programming Language

The *NIST Gage Block Calibration Software System* needs the installation of TransEra High Tech Basic (HTBasic) Language System DOS Version 4.3 or higher. Installing TransEra HTBasic Language System DOS Version 4.3 or higher on each workstation's microcomputer first comprises copying the language and drivers of TransEra HTBasic Language System DOS Version 4.3 or higher from the distribution floppy diskettes to the *C:\Htb386* folder according to the manufacturer's "Installing and Using" manual. Running TransEra HTBasic Language System DOS Version 4.3 or higher on each workstation's microcomputer next requires fastening an ID module one each to the microcomputers' parallel printer port, which must be plugged into a parallel printer port during the entire time that TransEra HTBasic Language System DOS Version 4.3 or higher is running and the printer should be turned on when attached. The language and drivers of TransEra HTBasic Language System DOS Version 4.3 or higher support different interfaces, input and output (I/O) ports, displays, tablets, plotters, printers, and graphics output files [29-30].

3.7 Running the Software Programming Language

Running TransEra High Tech Basic (HTBasic) Language System DOS Version 4.3 or higher under Microsoft Windows 95 requires following two instructions from the *Readme.1st* file, which the manufacturer supplies with the distribution floppy diskettes for TransEra HTBasic Language System DOS Version 4.3 or higher. The first instruction is copying the *Pharlap.386* file, which the manufacturer supplies with the distribution floppy diskettes for TransEra HTBasic Language System DOS Version 4.3 or higher, from the *C:\Htb386* folder to the *Windows®*

folder. The second instruction is editing the *System.ini* file for Microsoft Windows 95, which is in the *Windows®* folder, and adding the following line in the *[386Enh]* section:

```
Device=C:\Windows\Pharlap.386
```

The *Pharlap.386* file is the Pharlap 386 DOS Extender that enables launching TransEra HTBasic Language System DOS Version 4.3 or higher from within Microsoft Windows 95, which requires restarting the microcomputer.

TransEra HTBasic Language System DOS Version 4.3 or higher uses the *Pharlap* 386 DOS Extender to manage the protected mode of the Intel 386, 486, and Pentium microprocessors. The *Cfig386* program alters the DOS Extender configuration after saving specified settings inside the specified version of TransEra HTBasic Language System DOS Version 4.3 or higher (e.g., *Htb386.exe*, *Htbno387.exe*, *htb386c.exe*, *htbn387c.exe*). The ***NIST Gage Block Calibration Software System*** uses the complex version of TransEra HTBasic Language System DOS Version 4.3 or higher, named *Htb386c.exe*, with the switches as shipped [29-30].

3.8 Optimizing the ***NIST Gage Block Calibration Software System***

Following several instructions can optimize the ***NIST Gage Block Calibration Software System***, which is Microsoft DOS-based and cannot run in a window, to run in a full screen under Microsoft Windows 95. In the *C:\Htb386* folder is a *PIF* file, named *Htb386.pif*, which runs *Htb386.exe* and attempts to allocate 16 megabytes of random access memory both by default. The first instruction to optimization is copying the *PIF* file to the *Windows® Desktop*, *My Computer*, or *Windows Explorer*. The second instruction is editing the program properties of the *PIF* item, which includes entering “***NIST Gage Block Calibration Software System***” for the name of the Microsoft DOS-based program, changing the command line to run the complex version of TransEra High Tech Basic (HTBasic) Language System DOS Version 4.3 or higher, named *Htb386c.exe*, as follows:

```
C:\Htb386\Htb386c.exe -W 8M
```

where the *-W 8M* switch allocates a smaller random access memory work space, changing the working folder to *C:\Gage*, selecting the run mode to *Normal Window*, checking the box to *Close on Exit*, and saving the changes. The third instruction is specifying the icon file, named *Htb386.ico*, for TransEra HTBasic Language System DOS Version 4.3 or higher, which is in the *C:\Htb386* folder, to change the icon that Microsoft Windows 95 displays. Renaming the *PIF* item to “***NIST Gage Block Calibration Software System***” is the last instruction.

Chapter 4

The *NIST Gage Block Calibration Software System*

*This chapter provides the technical specifications detailing the custom, integrated software components of the **NIST Gage Block Calibration Software System**. These specifications identify the software components to configure system resources, calculate or estimate elastic deformations, edit files, and to calibrate and measure gage blocks, which are length standards having standard features for accuracy, flatness, parallelism, dimensional stability, and excellent surface finish for exceptional wringing characteristics. The gage blocks have nominal lengths defined in the metric system, using millimeters, and in the English system, using the inch that equals 25.4 millimeters. In keeping with the NIST policy of the International System of Units (SI) for reporting length in this manual [16], the nominal lengths of gage blocks identify each by name or size. The gage blocks have flat and parallel opposing surfaces that are rectangular, square (Hoke), and circularly cross-sectional shaped. The American standards for gage blocks, which include the U.S. Federal Specification GGG-G-15C, the American National Standard ANSI/ASME B89.1.9M, and the U.S. Department of Defense Military Standard MIL-STD 45662A, gives suggested dimensions and tolerances for rectangular, square (Hoke), and circular cross-sectional shaped gage blocks [17-19]. The calibration and measurement software programs provide for calibrating and measuring gage blocks using interferometric techniques and doing intercomparison using an opposed head electro-mechanical comparator with automatic data acquisition. Other calibration and measurement software programs enable the technical user, who calibrates and measures gage blocks, to create and maintain measurement history and related information and statistical process control about NIST's and its gage block calibration customers' gage blocks.*

4.1 Introduction to the *NIST Gage Block Calibration Software System*

The *NIST Gage Block Calibration Software System* consists of two groups of software files and programs: the accessory software programs and the calibration and measurement software programs and each their related files. The accessory software programs, which the *Htbutil* folder stores, enables the technical user, who calibrates and measures gage blocks, to configure system resources, calculate or estimate elastic deformations, and edit files. The calibration and measurement software programs, which the *Gage* folder stores, enable the user to calibrate and measure gage blocks, which are length standards having standard features for accuracy, flatness, parallelism, dimensional stability, and excellent surface finish for exceptional wringing characteristics. The gage blocks have nominal lengths defined in the metric system, using millimeters, and in the English system, using the inch that equals 25.4 millimeters. In keeping with the NIST policy of the International System of Units (SI) for reporting length in this manual [16], the nominal lengths of gage blocks identify each by name or size. The gage blocks have flat and parallel opposing surfaces that are rectangular, square (Hoke), and circularly cross-sectional shaped. The American standards for gage blocks, which include the U.S. Federal Specification GGG-G-15C, the American National Standard ANSI/ASME B89.1.9M, and the U.S. Department of Defense Military Standard MIL-STD 45662A, gives suggested dimensions and tolerances for rectangular, square (Hoke), and circular cross-sectional shaped gage blocks [17-19]. These software programs provide for calibrating and measuring gage blocks using interferometric techniques and doing intercomparison using an opposed head electro-mechanical comparator with automatic data acquisition. Other calibration and measurement software programs enable the user to create and maintain measurement history and related information and statistical process control about NIST's and its gage block calibration customers' gage blocks. The *Htbutil*, *Gage*, and *Htb386* folders are directly subordinate to the root level folder. The *Htbutil* and *Gage* folders store the custom, integrated calibration and measurement software. The *Htb386* folder stores the programs and drivers of TransEra High Tech Basic Language System DOS Version 4.3 or higher.

4.2 The Accessory Software Programs

The *NIST Gage Block Calibration Software System's* accessory software programs are *Autost*, *Branch*, *Clock*, *Config*, *Edit*, *Elastic*, *Format*, and *Quit*. The *Htbutil* folder stores all the accessory software programs and general software program libraries that complement the calibration and measurement software programs. The *Autost* program, which the *Gage* folder stores, is automatically loaded and executed when TransEra High Tech Basic (HTBasic) Language System DOS Version 4.3 or higher starts in the *Gage* folder. The *Branch* program displays and loads the accessory software programs and the calibration and measurement software programs. The *Clock* program displays and sets the microcomputer date and time

properties. The *Config* program displays and sets the *NIST Gage Block Calibration Software System*'s file folder and device properties. The *Edit* program opens and stores text in any one of three formats, Logical-Interchange-Format binary, Logical-Interchange-Format ASCII, and DOS ASCII text. The *Elastic* program calculates or estimates the compression effects, which normally occur in measuring and using spheres and cylinders in precise metrology. The *Format* program formats floppy diskettes with these formatting options, safe, quick, and destructive. The *Quit* program exits the programming environment of TransEra HTBasic Language System DOS Version 4.3 or higher and returns to the workstations' microcomputer's operating system, which is Microsoft Windows 95. All the accessory software programs and the calibration and measurement software programs use functions and subprograms from the *Main_lib*, *Math_lib*, and *Tech_lib* software program libraries.

4.3 The Calibration and Measurement Software Programs

The *NIST Gage Block Calibration Software System*'s calibration and measurement software programs are *Folder*, *Gage*, *History*, *Intmap*, *Master*, *Mecmap*, *Probe*, *Report*, *Setup*, and *Spectrum*. The *Gage* folder stores the *Autost* program, the *Gage_lib* software program library, and the calibration and measurement software programs and their related files. The *Autost* program is automatically loaded and executed when TransEra High Tech Basic (HTBasic) Language System DOS Version 4.3 or higher starts in the *Gage* folder. The *Folder* program opens, prints, and stores NIST's gage block calibration customers' addresses and test folder information. To calibrate and measure gage blocks by mechanical intercomparison, the technical user, who calibrates and measures gage blocks, uses the *Gage* program to analyze measurements from the electro-mechanical gage block comparators and to print and record the results. The *History* program opens, analyzes, prints, and stores NIST's gage block calibration customers' gage block calibration history. The *Intmap* program opens, analyzes, and prints NIST's master gage block interferometric calibration history. The *Master* program opens, prints, and stores current information about NIST's master gage blocks. The *Mecmap* program opens, analyzes, and prints the mechanical intercomparison control history for all NIST's gage block mechanical intercomparison calibrations and measurements, which the *Gage* program records during its use in calibrations and measurements. The user uses the *Probe* program to calibrate the electro-mechanical gage block comparators. The *Report* program opens, creates, prints, and stores NIST's gage block calibration customers' NIST Reports' of Calibration. The *Setup* program opens, prints, and stores NIST's gage block calibration customers' gage blocks' sizes, identification or serial numbers, and calibration and measurement information. To calibrate and measure gage blocks by interferometry, the user uses the *Spectrum* program to analyze interferometric measurements from the gage block interferometers and to print the results and the *Setup* program is then used to record the results. All the calibration and measurement software programs use functions and subprograms from the *Gage_lib* software program library.

4.4 File Organization of the NIST Gage Block Calibration Software Programs

In the *Gage* folder are the custom, integrated calibration and measurement software programs and their related files and file folders. The **Branch** program uses *Branch.txt*, which is a DOS ASCII text file that resides in the *Gage* folder and stores the program names and descriptions. The **Config** program uses *Config.cfg*, which is a DOS ASCII text file that resides in the *Gage* folder and stores the system configuration. The **Spectrum** program uses *Instrumt.ini*, *Laser.ini*, *Manufact.ini*, *Platen.ini*, and *Spectrum.ini*, which are DOS ASCII text files that reside in the *Gage* folder.

The file folders, which are subordinate to the *Gage* folder, are *Gagemap*, *Historys*, *Intmaps*, *Masters*, *Mecmaps*, *Probes*, *Text*, and *Work* and clearly labeled floppy diskettes store backed-up copies of files stored in these folders. The *Gagemap* folder stores the mechanical intercomparison control history for all NIST's gage block mechanical intercomparison calibrations and measurements, which the **Gage** program records during its use in calibrations and measurements. The *Historys* folder stores NIST's gage block calibration customers' gage block calibration history files. The *Intmaps* folder stores all NIST's master gage block interferometric calibration history files. The **Master** program stores NIST's master gage block database files in the *Masters* folder. The **Master** program stores the English, or inch, the metric, and the step master gage block databases in *Engmstr.gbk*, *Metmstr.gbk*, and *Stepmstr.gbk*, respectively. The **Mecmap** program restores files containing the mechanical intercomparison control history for all NIST's gage block mechanical intercomparison calibrations and measurements in the *Mecmaps* folder. The **Probe** program stores the electro-mechanical gage block comparators' probe calibration measurements and results to files in the *Probes* folder. The *Text* folder stores files containing the text the **Report** program uses to create NIST Reports' of Calibrations. The **Report** program's text files are *Ending.txt*, *Heading.txt*, *Rept1all.txt*, *Rept2all.txt*, *Repteng.txt*, and *Reptmet.txt*, which are DOS ASCII text files. The *Work* folder is the accepted folder to store files with NIST's gage block calibration customers' gage block calibration and measurement results.

4.5 Installing the Accessory Software Programs

The **NIST Gage Block Calibration Software System** needs the installation of the accessory software programs and their related files and the software program libraries. Installing the **NIST Gage Block Calibration Software System's** accessory software programs and software program libraries on each workstation's microcomputer first requires creating the *C:\Htbutil* folder in *My Computer* or *Windows Explorer*. The second instruction is copying all the accessory software programs and their related files and the software program libraries from the distribution floppy diskette, labeled "National Institute of Standards and Technology HTBASIC LAB

SOFTWARE – UTILITY SOFTWARE – Disk 1 of 1,” to the *C:\Htbutil* folder. The accessory software programs are *Autost*, *Branch*, *Clock*, *Config*, *Edit*, *Elastic*, *Format*, and *Quit*. The accessory programs’ related files are *Branch.txt* and *Config.cfg*. The software program libraries are *Main_lib*, *Math_lib*, and *Tech_lib*.

4.6 Installing the Calibration and Measurement Software Programs

The *NIST Gage Block Calibration Software System* needs the installation of the calibration and measurement software programs and their related files and file folders and the software program library. Installing the *NIST Gage Block Calibration Software System’s* calibration and measurement software programs and their related files and file folders and the software program library on workstations’ microcomputers first requires creating the *C:\Gage* folder in *My Computer* or *Windows Explorer* and the subfolders *C:\Gage\Gagemap*, *C:\Gage\Historys*, *C:\Gage\Intmaps*, *C:\Gage\Masters*, *C:\Gage\Mecmaps*, *C:\Gage\Probes*, *C:\Gage\Text*, and *C:\Gage\Work*.

The second instruction is copying all the calibration and measurement software programs and their related files, the *Probe* program’s configuration file, and the software program libraries from the first distribution floppy diskette, labeled “National Institute of Standards and Technology GAGE BLOCK LAB SOFTWARE – SYSTEM SOFTWARE – Disk 1 of 4,” to the *C:\Gage* folder. The calibration and measurement software programs are *Folder*, *Gage*, *History*, *Intmap*, *Master*, *Mecmap*, *Probe*, *Report*, *Setup*, and *Spectrum*. Related files are *Branch.txt* and *Config.cfg*, which are DOS ASCII text files. The *Probe* program’s configuration file is *Probe.ini*, which is a DOS ASCII text file. The software program library is *Gage_lib*. The *Probe* program creates the initial *Probe.ini* configuration file, which the technical user, who calibrates and measures gage blocks, can update using the *Edit* program. Without a probe calibration, the *Gage* program only returns to the *Branch* and *Probe* programs.

The third instruction is copying the English, or inch, the metric, and the step master gage block database files from the second distribution floppy diskette, labeled “National Institute of Standards and Technology GAGE BLOCK LAB SOFTWARE – MASTER FILES – Disk 2 of 4,” to the *C:\Gage\Masters* folder. The English, or inch, the metric, and the step master gage block database files are *Engmstr.gbk*, *Metmstr.gbk*, and *Stepmstr.gbk*, which are DOS ASCII text files. The *Master* program creates the initial English, or inch, and the metric master gage block database files, which the technical user, who calibrates and measures gage blocks, can update using this program and backup to the second distribution floppy diskette. The *Probe* program creates the initial step master gage block database files, which the user can update using the *Edit* program and backup to the second distribution floppy diskette. Without the English, or inch, the

metric, and the step master gage block database files, the calibration and measurement software programs only return to the **Branch** and **Master** programs.

The fourth instruction is copying the **Report** program's text files from the third distribution floppy diskette, labeled "National Institute of Standards and Technology GAGE BLOCK LAB SOFTWARE – REPORT TEXT FILES – Disk 3 of 4," to the *C:\Gage\Text* folder. The **Report** program's text files are *Ending.txt*, *Heading.txt*, *Rept1all.txt*, *Rept2all.txt*, *Repteng.txt*, and *Reptmet.txt*, which are DOS ASCII text files that the technical user, who calibrates and measures gage blocks, can update using the **Edit** program and backup to the third distribution floppy diskette.

The fifth instruction is copying the **Spectrum** program's configuration files from the fourth distribution floppy diskette, labeled "National Institute of Standards and Technology GAGE BLOCK LAB SOFTWARE – SPECTRUM *.INI FILES – Disk 4 of 4," to the *C:\Gage* folder. The **Spectrum** program's configuration files are *Instrumt.ini*, *Laser.ini*, *Manufact.ini*, *Platen.ini*, and *Spectrum.ini*, which are DOS ASCII text files. The **Spectrum** program creates the initial configuration files, which the technical user, who calibrates and measures gage blocks, can update using the **Edit** program and backup to the fourth distribution floppy diskette.

4.7 Running the **NIST Gage Block Calibration Software System**

The user-friendly characteristics of the **NIST Gage Block Calibration Software System** ease its use and operation. The **NIST Gage Block Calibration Software System**, by design, closely adapts and complements the procedures and techniques of the **NIST Gage Block Calibration Software System** that the technical user, who calibrates and measures gage blocks, is familiar. Just clicking the *Windows® Desktop* icon labeled "NIST Gage Block Calibration Software System" starts the whole system of software programs that runs on a Pentium II microprocessor-based microcomputer under Microsoft Windows 95, a computer environment the user has experience. The **Autost** program automatically loads and runs the **Branch** program, which displays the **NIST Gage Block Calibration Software System's** software programs in a menu from which the user selects. The **Branch** program seamlessly loads and runs software programs the user selects. The software programs operate by executing interactive processes the user invokes through responding to various input prompts (e.g., selecting and choosing menu items and options, entering numeric and character data, pressing an auxiliary trigger mechanism). When running a software program is complete, the user can select options when prompted to exit the program, which reloads and runs the **Branch** program. The **Quit** program exits the programming environment of TransEra HTBasic Language System DOS Version 4.3 or higher programming environment and returns to the workstations' microcomputer's operating system, which is Microsoft Windows 95.

Chapter 5

The Accessory Software Programs

*This chapter provides general information about the **NIST Gage Block Calibration Software System**'s accessory software programs. It describes some characteristics and functionality of these software programs.*

5.1 Introduction to the Accessory Software Programs

The **NIST Gage Block Calibration Software System**'s accessory software programs are **Autost**, **Branch**, **Clock**, **Config**, **Edit**, **Elastic**, **Format**, and **Quit** and the software program libraries are **Main_lib**, **Math_lib**, and **Tech_lib**. The *Htbutil* folder stores all the accessory software programs and general software program libraries that complement the calibration and measurement software programs. The **Autost** program, which the *Gage* folder stores, is automatically loaded and executed when TransEra High Tech Basic (HTBasic) Language System DOS Version 4.3 or higher starts in the *Gage* folder. The **Branch** program displays and loads the accessory software programs and the calibration and measurement software programs. The **Clock** program displays and sets the computer date and time properties. The **Config** program displays and sets the **NIST Gage Block Calibration Software System**'s file folder and device properties. The **Edit** program opens, prints, and stores text files in any one of three file storage formats, Logical-Interchange-Format binary, Logical-Interchange-Format ASCII, and DOS ASCII text. The **Elastic** program calculates or estimates the compression effects, which normally occur in measuring and using spheres and cylinders in precise metrology. The **Format** program formats floppy diskettes with these formatting options: safe, quick, and destructive. The **Quit** program exits the programming environment of TransEra HTBasic Language System DOS Version 4.3 or higher and returns to the workstations' microcomputer's operating system, which is Microsoft Windows 95. All the accessory software programs and the calibration and measurement software programs use functions and subprograms from the **Main_lib**, **Math_lib**, and **Tech_lib** software program libraries.

5.2 The *Autost* Program

The *Autost* program, which the *Gage* folder stores, is automatically loaded and executed when TransEra High Tech Basic (HTBasic) Language System DOS Version 4.3 or higher starts in the *Gage* folder. This program loads necessary device drivers, customizes the programming environment of TransEra HTBasic Language System DOS Version 4.3 or higher using programmable statements, and starts the *Branch* program, which is the default application and menu program for the *NIST Gage Block Calibration Software System*.

The *Autost* program shows how to load the serial and General Purpose Interface Bus (GPIB) data acquisition device drivers of TransEra HTBasic Language System DOS Version 4.3 or higher, change keyboard function keys, set various TransEra HTBasic Language System DOS Version 4.3 or higher options, use the DOS command line string, and use the DOS environment strings. The *NIST Gage Block Calibration Software System* needs the GPIB data acquisition device driver of TransEra HTBasic Language System DOS Version 4.3 or higher to access the functions of IOtech PC/IEEE-488 interface board, which TransEra HTBasic Language System DOS Version 4.3 or higher treats as HTBasic devices, from within an HTBasic program. The *Autost* program loads the GPIB driver by using the following programmable statement:

```
LOAD BIN "GPIB;BO PC2A BA 2E1 IN 7"
```

5.3 The *Branch* Program

The *Branch* program, which the *Htbutil* folder stores and the *Autost* program first loads, is the default application and menu program for the *NIST Gage Block Calibration Software System*. This program displays software programs' names and descriptions of the *NIST Gage Block Calibration Software System's* accessory software programs and calibration and measurement software programs on the computer monitor and loads the program that the technical user, who calibrates and measures gage blocks, selects.

The *Branch* program displays on the computer monitor the *NIST Gage Block Calibration Software System's* accessory software programs and calibration and measurement software programs among which the technical user, who calibrates and measures gage blocks, can select. When the user selects a program from the menu, the *Branch* program then loads and executes the program selected. When the user does not use the keyboard and mouse for 30 seconds, the *Branch* program erases the menu of programs and descriptions from the computer monitor and starts the built-in screen saver, which displays what resembles twinkling stars in the midnight sky. Refreshing the menu of programs' names and descriptions to the computer monitor requires the user simply to press any key on the keyboard or the mouse.

The **Branch** program gets the software programs’ names and their descriptions from the DOS ASCII text file, named *Branch.txt*. The *Branch.txt* file resides in the *Gage* folder, which is the current and customary program folder for the **NIST Gage Block Calibration Software System** under normal operations. As Table 5.3-1 shows, the *Branch.txt* file contains software programs’ menu and folder specifications, names, and descriptions. The listing of the *Branch.txt* file, as Table 5.3-2 shows, has the latest **NIST Gage Block Calibration Software System’s** accessory software programs and calibration and measurement software programs.

Table 5.3-1 Configuration of the <i>Branch.txt</i> File	
Column	Field Description
1	This field specifies the software program menu (First Menu: 1, Second Menu: 2, Third Menu: 3, . . . , Ninth Menu: 9).
2	This field specifies the software program menu titles, menu, and folders (Menu Title: 0, Selectable Menu: 1, Accessory Program Folder: 2, Calibration and Measurement Program Folder: 3).
4-80	This field has the menu title.
4-13	This field has the name of software program menus (“1st Menu,” “2nd Menu,” . . . , “9th Menu”) or programs.
17-80	This field has the description of the software program menu or program.

Table 5.3-2 Listing of the <i>Branch.txt</i> File								
Column:	10	20	30	40	50	60	70	80
Row:	1	2	3	4	5	6	7	8
0001:	00	B	R	A	N	C	H	M
0002:	01	2nd	Menu	Second	Menu	of	Programs	
0003:	03	SETUP	File	setup	for	GAGE	Program	
0004:	03	GAGE	Gage	Block	Calibration	Program		
0005:	03	SPECTRUM	Compute	Lengths	from	Interferometric	Fringe	Fractions
0006:	03	MASTER	Laboratory	Master	Gage	Block	Database	Management
0007:	03	PROBE	Probe	Calibration	of	a	Gage	Block
0008:	03	HISTORY	Gage	Block	Customer	History	Program	
0009:	03	FOLDER	Gage	Block	Customer	Test	Folder	Editor
0010:	03	REPORT	Gage	Block	Customer	Report	Program	

Table 5.3-2 Listing of the <i>Branch.txt</i> File									
Column:	10	20	30	40	50	60	70	80	
Row:	1	2	3	4	5	6	7	8	
0011:	03	INTMAP	Interferometric History MAP Statistical Program						
0012:	03	MECMAP	Mechanical History MAP Statistical Program						
0013:	02	CONFIG	Computer System Configuration Program						
0014:	02	CLOCK	Computer System Clock (Display/Reset Date and Time)						
0015:	02	EDIT	HTBasic Text Editor (BDAT, LIF ASCII, and DOS Files)						
0016:	02	FORMAT	Format Floppy Diskettes for Use by the Computer						
0017:	02	ELASTIC	Compute Elastic Compression of Spheres and Cylinders						
0018:	02	QUIT	Quit HTBasic and return to DOS operating system						
0019:	10	B R A N C H	M E N U						
0020:	11	1st Menu	First Menu of Programs						
0021:	12	QUIT	Quit HTBasic and return to DOS operating system						

5.4 The *Clock* Program

The *Clock* program, which the *Htbutil* folder stores, displays and sets the computer date and time properties. This program displays continuously the day of the week, date, and time and a clock face on the display monitor, which shows the computer's current date and time properties. To change the computer's date and time properties, the technical user, who calibrates and measures gage blocks, can press function keys to enter a new date and time, respectively. To switch sound on and off, the user can press alternatively a function key.

The *Clock* program ticks every second, beeps every minute, sounds a short melody every fifteen minutes, and sounds a long melody every hour when sound is on. The short and long melodies fashion Westminster chimes. The *Clock* program counts every hour on the hour. The *Clock* program bases its music note frequencies on the C Major scales for specified music octaves one through seven and reference notes from C to B. This program computes the frequencies on the Equal Tempered Chromatic Scale adopted by the American Standards Association in 1936. The A note in the fourth octave is the reference note and has a value of 440 Hertz. Every increase of one octave doubles the frequency and every decrease of one octave halves the frequency. Twelve half-steps compose an octave and its equal spacing is geometric rather than arithmetic and therefore the ratio of frequencies between any two adjacent notes is a constant.

5.5 The *Config* Program

The *Config* program, which the *Htbutil* folder stores, displays and sets the *NIST Gage Block Calibration Software System's* file folder and peripheral device properties. The installation instructions in Chapter 4 establish the default file folder and device properties for the *NIST Gage Block Calibration Software System's* accessory software programs and calibration and measurement software programs. The technical user, who calibrates and measures gage blocks, should expect to designate the customary software program and working folders and peripheral device configurations.

The *Mass Storage Is (MSI)* functions assign the *NIST Gage Block Calibration Software System's* software program and working folders. The *Utility MSI* function assigns the storage device and folder for the *NIST Gage Block Calibration Software System's* accessory software programs. The default *Utility MSI* storage device and folder is *C:\Htbutil*. The *Utility MSI* function assigns the storage device and folder for the *NIST Gage Block Calibration Software System's* calibration and measurement software programs. The default *Program MSI* storage device and folder is *C:\Gage*. The *Storage MSI* assigns the working storage device and folder for the *NIST Gage Block Calibration Software System's* calibration and measurement software programs. The default *Storage MSI* working storage device and folder is *C:\Gage\Work*.

The *Select Code (SC)* functions assign the *NIST Gage Block Calibration Software System's* computer system peripheral hardware devices. The *Display SC* function assigns the interface select code associated with the computer system's monitor. The default *Display SC* interface select code for the computer system's monitor is "I" or "CRT." The *Printer SC* function assigns the interface select code associated with the computer system's printer. The default *Printer SC* interface select code for the computer system's parallel printer is "10" or "PRT." The *Printer SC* interface select code for the computer system's serial printer "9." Without any printer, the *Printer SC* interface select code for the computer system is "I" or "CRT." The *Plotter SC* function assigns the interface select code associated with the computer system's plotter. The default *Plotter SC* interface select code for the computer system's Hewlett-Packard HPGL language plotter is "3" or "6." Without any plotter, the *Plotter SC* interface select code for the computer system is "I" or "CRT."

The *Mass Storage Is (MSI)* functions assign the *NIST Gage Block Calibration Software System's* software program and working folders and the *Select Code (SC)* functions assign computer system peripheral hardware devices. When the technical user, who calibrates and measures gage blocks, designates or changes customary software program and working folders and peripheral device configurations, selecting the *Okay* function tests the system configuration, restores the confirmed system configuration to the DOS ASCII text file, named *Config.cfg*, that resides in the *Program MSI* storage device and folder, and loads and executes the *Branch* program.

The **Config** program gets the software program and working folders and peripheral device configurations from the DOS ASCII text file, named *Config.cfg*. The *Config.cfg* file resides in the *Gage* folder, which is the current and customary program folder for the **NIST Gage Block Calibration Software System** under normal operations. As Table 5.5-1 shows, the *Config.cfg* file contains software program and working folders and peripheral device configurations.

Table 5.5-1 Configuration of the <i>Config.cfg</i> File	
Record	Software Program and Working Folder and Peripheral Device Description
1	<p>Display SC: Interface Select Code for Monitor (<i>I</i> or <i>CRT</i>)</p> <p>Printer SC: Interface Select Code for Printer (No Printer: <i>I</i> or <i>CRT</i>, Parallel Printer: <i>10</i> or <i>PRT</i>, Serial Printer: <i>9</i>, Default: <i>10</i>)</p> <p>Plotter Sc: Interface Select Code for Hewlett-Packard HPGL Language Plotter (No Plotter: <i>I</i> or <i>CRT</i>, Plotter: <i>3</i> or <i>6</i>, Default: <i>6</i>)</p> <p>Format: <i>Display SC, Printer SC, Plotter SC</i></p>
2	<p>Utility MSI: Storage Device and Folder for Accessory Software Programs (Default: <i>C:\Htbutil</i>)</p> <p>Format: <i>Utility MSI</i></p>
3	<p>Program MSI: Storage Device and Folder for Calibration and Measurement Software Programs (Default <i>C:\Gage</i>)</p> <p>Format: <i>Program MSI</i></p>
4	<p>Storage MSI: Working Storage Device and Folder for Calibration and Measurement Software Programs (Default <i>C:\Gage\Work</i>)</p> <p>Format: <i>Storage MSI</i></p>
5	<p>Plot\$: Plotter Language for the Computer System's Hewlett-Packard HPGL Language Plotter (Monochrome Monitor: "<i>INTERNAL</i>", Color Monitor: "<i>INTERNAL</i>";<i>COLOR MAP</i>)</p> <p>Format: <i>Plot\$</i></p>

Table 5.5-1 Configuration of the <i>Config.cfg</i> File	
Record	Software Program and Working Folder and Peripheral Device Description
6	<p>Frame SC: Software Program Frame Screen (Frames Off: 0, Frames On: 1, Default: 1)</p> <p>Bgpen: Frame Screen Background Color (Black: 0, White: 1, Red: 2, Yellow: 3, Green: 4, Cyan: 5, Blue: 6, Magenta: 7, Black: 8, Olive Green: 9, Aqua: 10, Royal Blue: 11, Maroon: 12, Brick Red: 13, Orange: 14, Brown: 15, and Default: 6)</p> <p>Bgmap(*): Frame Screen Background Positions (Bgmap(1): <i>Left</i>, Bgmap(2): <i>Right</i>, Bgmap(3): <i>Top</i>, Bgmap(4): <i>Bottom</i>, Defaults: 1,80,1,23)</p> <p>Fgpen: Frame Screen Foreground Color (Black: 0, White: 1, Red: 2, Yellow: 3, Green: 4, Cyan: 5, Blue: 6, Magenta: 7, Black: 8, Olive Green: 9, Aqua: 10, Royal Blue: 11, Maroon: 12, Brick Red: 13, Orange: 14, Brown: 15, and Default: 5)</p> <p>Fgmap(*): Frame Screen Foreground Positions (Fgmap(1): <i>Left</i>, Fgmap(2): <i>Right</i>, Fgmap(3): <i>Top</i>, Fgmap(4): <i>Bottom</i>, Defaults: 3,76,3,21)</p> <p>Format: <i>Frame SC, Bgpen, Bgmap(1,2,3,4), Fgpen, Fgmap(1,2,3,4)</i></p>
7	<p>Frame\$: Software Program Frame Screen Style (<i>ALPHANUMERIC</i>, <i>SINGLE</i> Line, <i>DOUBLE</i> Line, <i>MEDIUM</i> Line, <i>BOLD</i> Line, Default: <i>DOUBLE</i>)</p> <p>Format: <i>Frame\$</i></p>
8	<p>Shadow\$: Software Program Frame Screen Shadow Shade (<i>NONE</i>, <i>WHITE</i>, <i>LIGHT</i>, <i>MEDIUM</i>, <i>DARK</i>, <i>BLACK</i>, Default: <i>BLACK</i>)</p> <p>Format: <i>Shadow\$</i></p>
9	<p>Clear SC: Software Program Clear Screen Option (Default: 0 for Off)</p> <p>Pause: Software Program Pause Option (Default: 0 for Off)</p> <p>CRT Saver: Screen Saver Option in Seconds (Default: 0 for Off)</p> <p>Format: <i>Clear SC, Pause, CRT Saver</i></p>

5.6 The *Edit* Program

The *Edit* program, which the *Htbutil* folder stores, is a single, screen display text document editor, which opens, prints, and stores text document files in any one of three file

storage formats: Logical-Interchange-Format binary, Logical-Interchange-Format ASCII, and DOS ASCII text. This text editor's allowable keyboard input includes all standard ASCII characters 32 through 127, ASCII characters 0 through 31, and non-ASCII characters 128 through 255. Among the *Edit* program's many special function keys include backspace, caps-lock, control, clear-display, clear-line, clear-to-end of line, continue, delete-character, delete-line, enter, insert-character, insert-line, pause-program, page-down, page-up, shift, stop-program, tab, the cursor keys, the technical user, who calibrates and measures gage blocks, softkeys, the escape key, and the pointing device or mouse.

By design, the *Edit* program loads and runs best using TransEra High Tech Basic (HTBasic) Language System DOS Version 4.3 or higher minimally configured with 8 megabytes of random access memory. To hold a text document in internal program memory, the *Edit* program sets aside, or allocates, most of the computer's random access memory available to TransEra HTBasic Language System DOS Version 4.3 or higher. The *Edit* program reads text document files and stores, using internal memory, maximum 128 characters per each line of document text.

The *Edit* program, by design, uses screen displays with screen widths, which range from 80 to 120 characters per line, and screen heights, which have 18, 19, 23, or 40 display lines per screen. Currently, the *NIST Gage Block Calibration Software System* operates with 80-character per line screen width and a 23-display line screen height. When the *Edit* program first loads into program memory one copy of a document file and displays the document on the screen display, the technical user, who calibrates and measures gage blocks, may see part of the document that the screen display allows. To view other parts of the document, the user can scroll the document window vertically (e.g., down, up) and horizontally (e.g., left, right). On the display line during document editing is the editing status information, which includes filename, current character position, current line number, and *typeover* mode.

The *Edit* program has a basic wrap feature to display long document text lines, which have from 129 to 256 characters per each line, on multiple screen display lines. When reading text document files and document text lines have from 129 characters to 256 characters per each line, the *Edit* program wraps document text to succeeding screen display lines. At the beginning of each succeeding screen display line, the *Edit* program automatically inserts "»" characters. When storing document files, the *Edit* program concatenates all multiple screen display lines of document text to form continuous records without the "»" characters.

The *Edit* program has many features, as Table 5.6-1, Table 5.6-2, Table 5.6-3, Table 5.6-4, and Table 5.6-5 show. The *Edit* program has three sets of user softkey menus, which include file management and editing functions. The *Edit* program's first menu has file management functions to do the following:

- Create, open, print, and store documents

- Append documents inside another currently in program memory
- Browse storage devices and folders
- Customize the printing device and working file storage device and folder

The *Edit* program’s second menu has editing functions to do the following:

- Search and replace character strings in forwards and reverses directions
- Move, delete, and copy one or complete lines of text
- Insert characters through entering their ASCII or non-ASCII character code
- Clear and set tab stops
- Move the insertion point to specified lines and positions in the document

The *Edit* program’s third menu has miscellaneous functions to do the following:

- Display a help screen with keyboard functions
- Specify file input-output format to any one of three file storage formats (e.g., Logical-Interchange-Format binary, Logical-Interchange-Format ASCII, DOS ASCII text)
- Switch between append on and off
- Specify time between backup operations.

Table 5.6-1 The <i>Edit</i> Program’s User 1 Menu Function Softkeys									
F1	F2	F3	F4	F5	F6	F7	F8	F9	F10
Append Document	New Document	Store Document	Print Document	Catalog Filer	New Printer	New Storage	Exit		

Table 5.6-2 The <i>Edit</i> Program’s User 2 Menu Function Softkeys									
F1	F2	F3	F4	F5	F6	F7	F8	F9	F10
Search Chars	Replace Chars	Move/Del CopyText	Any Char	Clr Tab Set Tab	Goto Line	Goto Position	Exit		

**Table 5.6-3 The *Edit* Program's User 3 Menu
Function Softkeys**

F1	F2	F3	F4	F5	F6	F7	F8	F9	F10
	Help			File I/O Format	Append [On/Off]	Backup [On/Off]	Exit		

**Table 5.6-4 The *Edit* Program's System Menu
Function Softkeys**

F1	F2	F3	F4	F5	F6	F7	F8	F9	F10
Step	Continue	Run	Stop	Clr I/O	DmpAlpha	DmpGraph	Recall	IncLabel	User
			Pause		Alpha	Graphics		Menu	System

Table 5.6-5 The *Edit* Program's Function Softkeys

Function Softkey	Function Description	DOS Keystroke
Append Document	This function opens a copy of an appending file into the current document on the editing screen. When text is already on the editing screen or the insertion point is not in the home position, a prompt first appears about retrieving the appending document into the current document. The function, when the computer user responds affirmatively, causes the function to open a copy of the appending file into the current document on the editing screen, starting on the document line of the insertion point and pushing any portion of the document past the insertion point to make room for the incoming document.	User 1 Menu F1 Softkey

Table 5.6-5 The <i>Edit</i> Program's Function Softkeys		
Function Softkey	Function Description	DOS Keystroke
New Document	This function erases the current document and opens a copy of a new file on the editing screen at the initial editing screen position. When text is already on the editing screen, a prompt first appears about storing the current document and an affirmative response causes the function to store the current document and to open a copy of the new file on the editing screen at the initial editing screen position.	User 1 Menu F2 Softkey
Store Document	This function stores a copy of the current document on the editing screen to a file in any one of three file storage formats: Logical-Interchange-Format binary, Logical-Interchange-Format ASCII, and DOS ASCII text. When a file already exists, a prompt first appears about overwriting the current document to this file or storing the current document to a new file.	User 1 Menu F3 Softkey
Print Document	This function prints from one to nine copies of the current document on the editing screen to the printer.	User 1 Menu F4 Softkey
Catalog Filer	This function copies, deletes, moves, and renames files in the current working file storage device and folder. The function, like the <i>New Document</i> function, erases the current document and opens a copy of a new file on the editing screen at the initial editing screen position. When text is already on the editing screen, a prompt first appears about storing the current document and an affirmative response causes the function to store the current document and to open a copy of the new file on the editing screen at the initial editing screen position.	User 1 Menu F5 Softkey
New Printer	This function assigns the new printing device for the current session of the <i>Edit</i> program. The <i>Edit</i> program always starts with the printing device specified inside the <i>Config.cfg</i> file. Interface select codes for printing devices include <i>1</i> or <i>CRT</i> for no printer, <i>10</i> or <i>PRT</i> for a parallel printer, and <i>9</i> for a serial printer.	User 1 Menu F6 Softkey

Table 5.6-5 The <i>Edit</i> Program's Function Softkeys		
Function Softkey	Function Description	DOS Keystroke
New Storage	This function assigns the new working file storage device and folder for the current session of the <i>Edit</i> program. The <i>Edit</i> program always starts with the working storage device and folder for the calibration and measurement software programs specified inside the <i>Config.cfg</i> , which should be <i>C:\Gage\Work</i> .	User 1 Menu F7 Softkey
Exit	This function stops the <i>Edit</i> program and loads and runs the <i>Branch</i> program. When text is already on the editing screen, a prompt first appears about storing the current document and an affirmative response causes the function to store the current document.	User 1 Menu F8 Softkey
Search Chars	This function searches, forwards or backwards, the current document on the editing screen for a single occurrence of words, characters, or codes.	User 2 Menu F1 Softkey
Replace Chars	This function searches, forwards or backwards, for and replaces a single occurrence of words, characters, or codes in the current document on the editing screen.	User 2 Menu F2 Softkey
Move/Del CopyText	This function moves, deletes, and copies portions of the current document on the editing screen. Defining part of the document to move, delete, or copy requires moving the cursor to the initial document line, pressing the <i>Move/Del/CopyText</i> softkey to start the selecting feature, moving the cursor to the final document line to be selected, and pressing the <i>Move/Del/CopyText</i> softkey again. Upon selecting the document signified by the highlighted document on the editing screen, the features to move, delete, copy, or an abort is selected. The move or copy command respectively moves or copies the selected portion of the document from place to place. The delete command deletes the selected portion of the document. The abort command aborts the process altogether.	User 2 Menu F3 Softkey

Table 5.6-5 The <i>Edit</i> Program's Function Softkeys		
Function Softkey	Function Description	DOS Keystroke
Any Char	This function inserts one character when the computer user enters three digits between 000 and 255, which is the code for all standard ASCII characters 32 through 127, ASCII characters 0 through 31, and non-ASCII characters 128 through 255.	User 2 Menu F4 Softkey
Clr Tab Set Tab	This function switches between two operations, setting a tab stop at the current insertion point or cursor position and clearing an existing tab stop.	User 2 Menu F5 Softkey
Goto Line	This function moves the insertion point or cursor to a new document line when the computer user enters a new document line number.	User 2 Menu F6 Softkey
Goto Position	This function moves the insertion point or cursor to a new document character position when the computer user a new document character position.	User 2 Menu F7 Softkey
Exit	This function stops the <i>Edit</i> program and loads and runs the <i>Branch</i> program. When text is already on the editing screen, a prompt first appears about storing the current document and an affirmative response causes the function to store the current document.	User 2 Menu F8 Softkey
	This softkey is not defined.	User 3 Menu F1 Softkey
Help	This function displays the <i>Edit</i> program's help screen with keyboard functions.	User 3 Menu F2 Softkey
	This softkey is not defined.	User 3 Menu F3 Softkey
	This softkey is not defined.	User 3 Menu F4 Softkey
File I/O Format	This function assigns any one of three file storage formats, Logical-Interchange-Format binary, Logical-Interchange-Format ASCII, and DOS ASCII text.	User 3 Menu F5 Softkey

Table 5.6-5 The <i>Edit</i> Program's Function Softkeys		
Function Softkey	Function Description	DOS Keystroke
Append [On/Off]	This function switches between <i>Append Document On</i> and <i>Append Document Off</i> modes.	User 3 Menu F6 Softkey
Backup [On/Off]	This function switches between <i>Backup Document On</i> and <i>Backup Document Off</i> modes. The function does timed backup operations when the computer user enters the time between backup operations, which switches the function to <i>Backup Document On</i> mode. The backup file, named <i>Edit.bk!</i> , is stored in the storage device and folder for the calibration and measurement software programs.	User 3 Menu F7 Softkey
Exit	This function stops the <i>Edit</i> program and loads and runs the <i>Branch</i> program. When text is already on the editing screen, a prompt first appears about storing the current document and an affirmative response causes the function to store the current document.	User 3 Menu F8 Softkey

The *Edit* program's *New Document* function erases the current document and opens a copy of a new file on the editing screen at the initial editing screen position. When text is already on the editing screen, a prompt first appears about storing the current document and an affirmative response causes the function to store the current document and to open a copy of the new file on the editing screen at the initial editing screen position. The *New Document* function only loads one copy of a document file anytime.

The *Append Document* function opens a copy of an appending file into the current document on the editing screen with *Append Document On* mode. When text is already on the editing screen or the insertion point is not in the home position, a prompt first appears about retrieving the appending document into the current document. The function, when the computer user responds affirmatively, causes the function to open a copy of the appending file into the current document on the editing screen, starting on the document line of the insertion point and pushing any portion of the document past the insertion points to make room for the incoming document. The *Append Document On* mode enables the *Append Document* function to copy additional document files, one at a time, into the current document at the insertion point or cursor position.

The *Store Document* function stores a copy of the current document on the editing screen to a file in any one of three file storage formats: Logical-Interchange-Format binary, Logical-Interchange-Format ASCII, and DOS ASCII text. When a file already exists, a prompt first appears about overwriting the current document to this file or storing the current document to a new file. When storing a document file, the *Store Document* function always stores the current document first to an intermediate file, named *Edit.tmp*, in the current working storage device and folder. Once successfully stored, this function makes a duplicate copy of the intermediate file and names it the filename the technical user, who calibrates and measures gage blocks, specifies, replacing any existing document file.

The *Edit* program's *Backup Document* function does automatic backup operations when the technical user, who calibrates and measures gage blocks, specifies the automatic backup interval, which is minutes between automatic backup operations. Every time the *Edit* program starts, the *Backup Document Off* mode resets no automatic backup operations and begins when the user enters a non-zero value for the automatic backup interval. This function directs the *Edit* program to automatically store, at the time specified, the current document to the DOS ASCII file, named *Edit.bk!*, to the storage device and folder for the calibration and measurement software programs. Turning the *Backup Document* function off requires entering zero for the automatic backup interval or running the program again.

The *NIST Gage Block Calibration Software System's* calibration and measurement software programs share filenames with the *Edit* program. Sharing filenames with the *Edit* program enables these programs to cause the *Edit* program to automatically open a document after loading and running, and completely bypass the *Branch* program. Loading and running the *Branch* program resets filename sharing.

This program illuminates the insertion point or current cursor position, in *character insert* mode, through underscoring the current character and, in *character typeover* mode, through inverse video. Table 5.6-6 shows the DOS keystrokes to move around in the *Edit* program's documents. Showing about inserting and deleting in the *Edit* program's documents are Table 5.6-7 and Table 5.6-8. Lastly, Table 5.6-9 shows the *Edit* program's other editing keystrokes.

Table 5.6-6 The <i>Edit</i> Program's Function Keys About Moving the Insertion Point in the Document		
To Move the Insertion Point to the	Press the DOS Keystroke	Generic Name
<i>Beginning of the Document</i>	Home	BOT
<i>Beginning of the Line</i>	Shift + Left	BOL

Table 5.6-6 The <i>Edit</i> Program's Function Keys About Moving the Insertion Point in the Document		
To Move the Insertion Point to the	Press the DOS Keystroke	Generic Name
<i>Beginning of the Next Line</i>	Enter	ENTER
<i>Beginning of the Screen</i>	Shift + Up	BEGIN
<i>End of the Document</i>	Shift + Home	EOT
<i>End of the Line</i>	Shift + Right	EOL
<i>End of the Screen</i>	Shift + Down	END
<i>Next Character</i>	Right Cursor	RIGHT
<i>Next Line</i>	Down Cursor	DOWN
<i>Next Page (Scroll the Document Upward)</i>	Page Up	PAGE UP
<i>Next Tab</i>	Tab	TAB
<i>Next Word</i>	Alt + Right	NEXT WORD
<i>Previous Character</i>	Left Cursor	LEFT
<i>Previous Line</i>	Up Cursor	UP
<i>Previous Page (Scroll the Document Downward)</i>	Page Down	PAGE DOWN
<i>Previous Tab</i>	Shift + Tab	TAB BACK
<i>Previous Word</i>	Alt + Left	PREV WORD
<i>Specified Character</i>	User 2 Menu–F7 Softkey	K15
<i>Specified Line</i>	User 2 Menu–F6 Softkey	K14

Table 5.6-7 The <i>Edit</i> Program's Function Keys About Inserting in the Document		
To Insert	Press the DOS Keystroke	Generic Name
<i>Any Character (e.g., all standard ASCII characters 32 through 127, ASCII characters 0 through 31, non-ASCII characters 128 through 255.)</i>	Alt + =, Alt + K	ANY KEY
<i>New Line at the Insertion Point</i>	Shift + Insert	INSERT LINE

Table 5.6-8 The <i>Edit</i> Program's Function Keys About Deleting in the Document		
To Delete the	Press the DOS Keystroke	Generic Name
<i>Character to the Left of the Insertion Point</i>	Backspace	BACKSPACE and DELETE LEFT
<i>Current Character at the Insertion Point</i>	Delete	DELETE CHAR
<i>Current Line</i>	Shift + Delete	DELETE LINE

Table 5.6-9 The <i>Edit</i> Program's Function Keys About Other Editing Keystrokes in the Document		
Other Editing Keystrokes	Press the DOS Keystroke	Generic Name
<i>Clear Line</i>	End	CLEAR LINE
<i>Clear Tab at the Insertion Point</i>	Alt + C, Shift + F5 Softkey	CLEAR TAB
<i>Clear to the End of the Line</i>	Shift + End	CLEAR TO END
<i>Dump Alpha Screen</i>	Alt + O	DUMP ALPHA
<i>Increment Menu Labels</i>	Shift + F9 Softkey	INCR LABELS

Table 5.6-9 The <i>Edit</i> Program's Function Keys About Other Editing Keystrokes in the Document		
Other Editing Keystrokes	Press the DOS Keystroke	Generic Name
<i>Pause the Edit Program</i>	System Menu-[F4/F12/F20] Softkey, Alt + F4 Softkey	PAUSE
<i>Set Tab at the Insertion Point</i>	Alt + S, User 2 Menu-F5 Softkey	SET TAB
<i>Softkeys 1 to 8</i>	User 1 Menu F1 . . . F8 Softkeys	K1 . . . K8
<i>Softkeys 9 to 16</i>	User 2 Menu F9 . . . F16 Softkeys	K9 . . . K16
<i>Softkeys 17 to 24</i>	User 3 Menu F17 . . . F24 Softkeys	K17 . . . K24
<i>Stop the Edit Program</i>	Shift + Alt + [F4/F12/F20] Softkey	STOP
<i>Switch Caps Lock On/Off</i>	Caps Lock	CAPS LOCK
<i>Switch Insert/Replace State</i>	Insert	INSERT CHAR
<i>Switch Menu Labels On/Off</i>	F9 Softkey	MENU
<i>System Softkeys</i>	F10	SYSTEM
<i>User Softkeys</i>	Shift + F10 Softkey	USER

5.7 The *Elastic* Program

The *Elastic* program calculates or estimates the compression effects that normally occur in measuring and using spheres and cylinders in precise dimensional metrology. To compute compression effects, or deformations, the *Elastic* program uses proven compression formulae based on mathematical formulas, constants, and methodologies.

The *Elastic* program calculates the elastic deformation between two surfaces based on its physical geometry of the surfaces and other physical properties. This program computes the deformations between two contacting spheres, a sphere contacting a plane, a sphere between two parallel planes, a sphere contacting an internal spherical surface, equal diameter cylinders crossed with their axes at right angles, unequal diameter cylinders crossed with their axes at right angles, unequal diameter cylinders crossed with their axes at any angle, two cylinders contacting with axes parallel, a cylinder contacting a plane, a cylinder between two parallel planes, a sphere contacting an external or internal cylinder, a sphere contacting a symmetrical or asymmetrical cylindrical V-groove, and a cylinder contacting a symmetrical or asymmetrical cylindrical V-groove. To calculate and report compression effects, the *Elastic* program prompts the technical user, who calibrates and measures gage blocks, to enter applied force, surface geometry, and materials.

The *Elastic* program uses the sixteen compression formulae, each directly based on equations derived from Hertz's Law by M. J. Puttock and E. G. Thwaite, to calculate compression effects. In 1969, these scientists published the equations in "Elastic Compression of Spheres and Cylinders at Point and Line Contacts" (National Standards Laboratory Technical Paper No. 25, Commonwealth Scientific and Industrial Research Organization, Australia, 1969) [33]. Referenced by the same case numbers that the publication uses, the following list presents *Elastic's* sixteen compression formulae:

- Case 01: Two Spheres in Contact
- Case 02: Sphere in Contact with Plane
- Case 03: Sphere Between Two Parallel Planes
- Case 04: Sphere in Contact with Internal Spherical Surface
- Case 05: Equal Diameter Cylinders Crossed with Axes at Right Angles
- Case 06: Unequal Diameter Cylinders Crossed with Axes at Right Angles
- Case 07: Unequal Diameter Cylinders Crossed with Axes at Any Angle
- Case 08: Two Cylinders in Contact with Axes Parallel
- Case 09: Cylinder in Contact with Plane
- Case 10: Cylinder Between Two Parallel Planes
- Case 11: Sphere in Contact with External Cylinder
- Case 12: Sphere in Contact with Internal Cylinder
- Case 13: Sphere in Contact with Symmetrical Cylindrical V-Groove
- Case 14: Sphere in Contact with Asymmetrical Cylindrical V-Groove
- Case 15: Cylinder in Contact with Asymmetrical Cylindrical V-Groove
- Case 16: Cylinder in Contact with Symmetrical Cylindrical V-Groove

The compression formulae consider conditions which closely meet with materials and applied forces normally encountered in precise dimensional metrology and with finely lapped surfaces. As identified in Puttock and Thwaite's publication [33], consider the following assumptions about the contact surfaces:

- Assumption 1: Contact surfaces are perfectly smooth
- Assumption 2: Elastic limits of materials are not exceeded
- Assumption 3: Materials are homogeneous
- Assumption 4: No frictional forces between the contact areas

According to Puttock and Thwaite's publication, contact surfaces not finely lapped cause frictional forces and micro-structural surface variations which leads to elastic moduli variations [33]. As a result, expect compression effects, calculated using this program, will likely differ up to 10 percent from actual.

Engineers and scientists at NIST and several other laboratories tested the compression formulae published by Puttock and Thwaite. The compression formulae were determined remarkably accurate when using proper Young's moduli and Poisson's ratios for materials of objects in contact. At NIST, we tested compression effects for spheres in contact with planes and cylinders crossed with axes at right angles. We, at NIST, believe agreement between actual compression effects and calculated compression effects using this program is typically within 0.025 micrometers (1.0 microinches). When we used actual Young's moduli and Poisson ratios for materials that are in contact, this agreement improved to 2.0 nanometers (0.08 microinches) [34-35].

To calculate the compression effects for objects that are in contact, the *Elastic* program will prompt the technical user, who calibrates and measures gage blocks, to:

- Step 1: Select among the sixteen elastic compression cases
- Step 2: Enter the applied force (e.g., newtons, grams, pounds, and ounces)
- Step 3: For each object, enter the geometry dimension (e.g., angle, diameters, and length) in angle degrees, millimeters, inches
- Step 4: For each object, select among common engineering materials (e.g., aluminum, tungsten carbide, chromium carbide, steel, glass, brass, fused silica, and diamond) or enter its elastic constant for the material

The *Elastic* program uses common properties from standard reference books for its elastic moduli of some common engineering materials [34]. As Table 5.7-1 shows, the common engineering materials are aluminum, brass, ceramic, chromium carbide, copper, diamond, glass, gold, invar, platinum, silica, silver, steel, tungsten carbide, and zerodur with their respective

common engineering properties [33-35]. Typically, the Young's moduli and Poisson's ratios for these materials can vary between 10 and 15 percent, which affect the accuracy and precision of calculated compression effects. The Young's moduli and Poisson's ratios of cast iron, for example, can vary more than 20 percent, which Table 5.7-1 does not show [34].

Table 5.7-1 Elastic Constants (V_c) for Common Engineering Materials			
Name of Material	Poisson's Ratio, σ	Young's Modulus, E	Elastic Constant, $V_c = (1 - \sigma^2) / (\pi \cdot E)$
<i>Aluminum</i>	0.345	70 GPa ($10.15 \cdot 10^6$ lbf/in ²)	$4.006 \cdot 10^{-3}$ GPa ($2.762 \cdot 10^{-8}$ lbf/in²)
<i>Brass, 70% Copper, 30% Zinc</i>	0.374	104 GPa ($15.08 \cdot 10^6$ lbf/in ²)	$2.633 \cdot 10^{-3}$ GPa ($1.815 \cdot 10^{-8}$ lbf/in²)
<i>Ceramic, Alumina</i>	0.300	206 GPa ($29.88 \cdot 10^6$ lbf/in ²)	$1.406 \cdot 10^{-3}$ GPa ($0.969 \cdot 10^{-8}$ lbf/in²)
<i>Ceramic, Partially Stabilized Zirconia</i>	0.254	53 GPa ($7.69 \cdot 10^6$ lbf/in ²)	$5.618 \cdot 10^{-3}$ GPa ($3.874 \cdot 10^{-8}$ lbf/in²)
<i>Chromium Carbide, Carmet CA-815G</i>	0.280	340 GPa ($49.31 \cdot 10^6$ lbf/in ²)	$0.863 \cdot 10^{-3}$ GPa ($0.595 \cdot 10^{-8}$ lbf/in²)
<i>Copper, OFHC</i>	0.350	117 GPa ($16.97 \cdot 10^6$ lbf/in ²)	$2.387 \cdot 10^{-3}$ GPa ($1.646 \cdot 10^{-8}$ lbf/in²)
<i>Diamond, Natural</i>	0.200	950 GPa ($137.79 \cdot 10^6$ lbf/in ²)	$0.322 \cdot 10^{-3}$ GPa ($0.222 \cdot 10^{-8}$ lbf/in²)
<i>Diamond</i>	0.200	715 GPa ($103.70 \cdot 10^6$ lbf/in ²)	$0.427 \cdot 10^{-3}$ GPa ($0.295 \cdot 10^{-8}$ lbf/in²)
<i>Diamond, Synthetic</i>	0.200	860 GPa ($124.73 \cdot 10^6$ lbf/in ²)	$0.355 \cdot 10^{-3}$ GPa ($0.245 \cdot 10^{-8}$ lbf/in²)
<i>Glass, Heavy Silicate Flint</i>	0.224	53.50 GPa ($7.76 \cdot 10^6$ lbf/in ²)	$5.651 \cdot 10^{-3}$ GPa ($3.896 \cdot 10^{-8}$ lbf/in²)
<i>Glass, Light Borate Crown</i>	0.274	46.13 GPa ($6.69 \cdot 10^6$ lbf/in ²)	$6.383 \cdot 10^{-3}$ GPa ($4.401 \cdot 10^{-8}$ lbf/in²)

Table 5.7-1 Elastic Constants (V_c) for Common Engineering Materials			
Name of Material	Poisson's Ratio, σ	Young's Modulus, E	Elastic Constant, $V_c = (1 - \sigma^2) / (\pi \cdot E)$
<i>Glass, Pyrex</i>	0.240	62.05 GPa ($9.00 \cdot 10^6$ lbf/in ²)	$4.834 \cdot 10^{-3}$ GPa ($3.333 \cdot 10^{-8}$ lbf/in ²)
<i>Gold</i>	0.440	77.91 GPa ($11.30 \cdot 10^6$ lbf/in ²)	$3.295 \cdot 10^{-3}$ GPa ($2.272 \cdot 10^{-8}$ lbf/in ²)
<i>Invar and Super Invar</i>	0.290	148 GPa ($21.47 \cdot 10^6$ lbf/in ²)	$1.970 \cdot 10^{-3}$ GPa ($1.358 \cdot 10^{-8}$ lbf/in ²)
<i>Platinum</i>	0.377	168.03 GPa ($24.37 \cdot 10^6$ lbf/in ²)	$1.625 \cdot 10^{-3}$ GPa ($1.121 \cdot 10^{-8}$ lbf/in ²)
<i>Ruby, Synthetic Sapphire, Al_2O_3</i>	0.254	53 GPa ($7.69 \cdot 10^6$ lbf/in ²)	$5.618 \cdot 10^{-3}$ GPa ($3.874 \cdot 10^{-8}$ lbf/in ²)
<i>Silica, Fused</i>	0.170	73 GPa ($10.59 \cdot 10^6$ lbf/in ²)	$4.234 \cdot 10^{-3}$ GPa ($2.920 \cdot 10^{-8}$ lbf/in ²)
<i>Silver</i>	0.367	82.74 GPa ($12 \cdot 10^6$ lbf/in ²)	$3.329 \cdot 10^{-3}$ GPa ($2.295 \cdot 10^{-8}$ lbf/in ²)
<i>Steel, 1% Carbon, Stainless</i>	0.290	197 GPa ($28.57 \cdot 10^6$ lbf/in ²)	$1.480 \cdot 10^{-3}$ GPa ($1.020 \cdot 10^{-8}$ lbf/in ²)
<i>Steel, 52100</i>	0.290	210 GPa ($30.46 \cdot 10^6$ lbf/in ²)	$1.388 \cdot 10^{-3}$ GPa ($0.957 \cdot 10^{-8}$ lbf/in ²)
<i>Tungsten Carbide, 10% Cobalt</i>	0.280	724 GPa ($105.01 \cdot 10^6$ lbf/in ²)	$0.405 \cdot 10^{-3}$ GPa ($0.279 \cdot 10^{-8}$ lbf/in ²)
<i>Tungsten Carbide, 10% Cobalt</i>	0.200	600 GPa ($87.02 \cdot 10^6$ lbf/in ²)	$0.509 \cdot 10^{-3}$ GPa ($0.351 \cdot 10^{-8}$ lbf/in ²)
<i>Tungsten Carbide, 16% Cobalt</i>	0.220	525 GPa ($76.14 \cdot 10^6$ lbf/in ²)	$0.577 \cdot 10^{-3}$ GPa ($0.398 \cdot 10^{-8}$ lbf/in ²)
<i>Zerodur</i>	0.240	91 GPa ($13.20 \cdot 10^6$ lbf/in ²)	$3.296 \cdot 10^{-3}$ GPa ($2.273 \cdot 10^{-8}$ lbf/in ²)

When selecting among the common engineering materials, the estimated expanded uncertainty of *Elastic's* calculations is 5 percent using a coverage factor of $k=2$ (95 percent confidence level). This uncertainty is calculated according to "Guidelines for Evaluating and Expressing the Uncertainty of NIST Measurement Results" by Barry N. Taylor and Chris E. Kuyatt (*National Institute of Standards and Technology (U.S.) Technical Note 1297, 1994*) [36].

Besides selecting among common engineering materials, the *Elastic* program gives the technical user, who calibrates and measures gage blocks, the functionality to enter the actual or better-known elastic constants for materials of the objects that are in contact. This can improve the accuracy and precision of *Elastic's* calculated compression effects.

When the technical user, who calibrates and measures gage blocks, enters the elastic constants for materials of the objects, the estimated expanded uncertainty of *Elastic's* calculations will have two components. The first component is the estimated expanded uncertainty for *Elastic's* formulae, which is 0.005 micrometers (0.2 microinches) using a coverage factor of $k=2$ (95 percent confidence level). This uncertainty component is calculated according to "Guidelines for Evaluating and Expressing the Uncertainty of NIST Measurement Results" by Barry N. Taylor and Chris E. Kuyatt (*National Institute of Standards and Technology (U.S.) Technical Note 1297, 1994*) [36]. The second component is the estimated expanded uncertainty for Young's moduli and Poisson's ratios for materials of the objects. To find the estimated uncertainty of *Elastic's* calculations, solve the square root of the sum of the squares of the two estimated expanded uncertainty components. We will refer to this procedure "the root-sum-square method."

The compression formulae of the *Elastic* program calculate as the compression effects for conditions and properties which normally occur in measuring and using spheres and cylinders in precise dimensional metrology. When measuring and using spheres and cylinders in metrology applications and using the *Elastic* program to calculate and correct for compression effects, observe the following basic precautions:

- Precaution 1: Know the actual geometry of the objects that are in contact. Deterioration and wear from use will likely change the dimension and geometry of objects over time. At NIST, for example, we find the spherical diamond contacts in our electro-mechanical gage block comparators become flattened with several months of constant use, which causes compression effect errors of 0.05 micrometers (2 microinches).
- Precaution 2: Apply reasonable measuring forces when measuring and using objects that are in contact. Do not apply large measuring forces that exceed the yield strength for materials of objects and permanently deform or dent the objects, which no longer measure actual length when measuring. Pay special attention for objects having surfaces of contacts that are small

points and line contacts, such as crossed cylinders or sphere in contact with any surface.

5.8 The *Format* Program

The *Format* program formats floppy diskettes with three formatting options: *safe*, *quick*, and *destructive*. This program calls the host operating system Microsoft Windows 95 to format floppy diskettes for use by Microsoft Windows 95 operating system and TransEra High Tech Basic (HTBasic) Language System DOS Version 4.3 or higher. Formatting creates a new root directory and file allocation table for the floppy diskette, checks for bad areas on the floppy diskette, and deletes all data on the floppy diskette. In order for Microsoft DOS Version 5.0 or higher, Microsoft Windows 3.1, or Microsoft Windows 95 to be able to use a new floppy diskette, the technical user, who calibrates and measures gage blocks, must use the Microsoft DOS format command to format the floppy diskette, which the *Format* program does seamlessly.

Formatting a floppy diskette using the *Format* program requires the technical user, who calibrates and measures gage blocks, to specify the floppy diskette device or drive, floppy diskette size, and format method. The *Format* program first requires the user to select the floppy diskette device or drive by entering a floppy diskette device or drive letter (e.g., *A:*, *B:*). Second, the *Format* program requires the user to enter the floppy diskette size. As Table 5.8-1 shows, the floppy diskette size specification matches both the floppy diskette capacity for the floppy diskette device or drive selected and the floppy diskette ready for formatting. Floppy diskette size specifications for 5.25-inch floppy diskettes are 180 kilobytes, 360 kilobytes, and 1.2 megabytes and floppy diskette size specifications for 3.5-inch floppy diskettes are 720 kilobytes and 1.44 megabytes. Last, the *Format* program requires the user to select any one of three file storage formatting methods, as Table 5.8-2 shows.

Table 5.8-1 The <i>Format</i> Program's Floppy Diskette Size Specifications	
Floppy Diskette Size	Floppy Diskette Size Specification
<i>180 KB</i>	One-sided 5.25-inch floppy diskettes. This very low capacity is seldom used.
<i>360 KB</i>	Standard 5.25-inch floppy diskettes. The normal setting to use on 5.25-inch floppy diskettes which are not marked as high density.

Table 5.8-1 The <i>Format</i> Program's Floppy Diskette Size Specifications	
Floppy Diskette Size	Floppy Diskette Size Specification
<i>1.2 MB</i>	High density 5.25-inch floppy diskettes, in a floppy diskette device or drive capable of supporting this format. The standard AT 5.25-inch drive supports this format; however, the floppy diskette must be marked high density.
<i>720 KB</i>	Standard 3.5-inch floppy diskettes. This is the normal setting to use 3.5-inch floppy diskettes which are not marked high density.
<i>1.44 MB</i>	High density 3.5-inch floppy diskettes, in a floppy diskette device or drive capable of supporting this format. Most 3.5-inch drives supports this format; however, the floppy diskette must be marked high density.

Table 5.8-2 The <i>Format</i> Program's Formatting Methods	
Name of Method	Formatting Method
<i>Safe</i>	When reformatting a floppy diskette, this method makes it possible to recover from an accidental floppy diskette format. This method copies information on the floppy diskette to an unused place at the end of the floppy diskette for later recovery. This method works like the Destructive Method for unformatted floppy diskettes fresh from the box.
<i>Quick</i>	This method is a fast way to purge a floppy diskette of all files and folders used only on floppy diskettes already formatted. It simply erases the contents of the file allocation table and root directory. This method does not scan the floppy diskette for bad areas; therefore, you should use this method to format previously formatted floppy diskettes that you know are in good condition.
<i>Destructive</i>	This method performs a standard floppy diskette initialization. Any existing data on the floppy diskette is irretrievably lost. This method formats unformatted floppy diskettes. Be sure you want to do this!

The *Format* program is for formatting floppy diskettes to prepare them to receive data. Therefore, the technical user, who calibrates and measures gage blocks, should be careful to format only floppy diskettes that contain no valuable data to prevent accidental data loss.

5.9 The *Quit* Program

The *Quit* program exits the *NIST Gage Block Calibration Software System* and consequently the programming environment of TransEra High Tech (HTBasic) Language System DOS Version 4.3 or higher and returns to the workstations' microcomputer's operating system, which is Microsoft Windows 95.

5.10 The *Main_lib*, *Math_lib*, and *Tech_lib* Software Program Libraries

The *NIST Gage Block Calibration Software System's* accessory software programs and calibration and measurement software programs use software routines, which are functions and subprograms, from the *Main_lib*, *Math_lib*, and *Tech_lib* software program libraries. The *Main_lib* software program library, as Table 5.10-1 shows, contains 49 routines. The *Math_lib* software program library, as Table 5.10-2 shows, contains five routines. The *Tech_lib* software program library, as Table 5.10-3 shows, contains four routines.

Table 5.10-1 The <i>Main_lib</i> Software Program Library	
Name of Routine	Software Routine Description
<i>Catalog</i>	This subprogram gets file information (e.g., folder and file names, file type, file size, record size, modification date and time, file access permissions) from the complete catalog listing, which is based on the DOS operating system, of the mass storage device and folder passed.
<i>Configuration</i>	This subprogram resets global variables that the <i>NIST Gage Block Calibration Software System's</i> accessory software programs and calibration and measurement software programs use, which includes subprograms and functions called.
<i>FNAdd_zero\$</i>	This function changes the string passed by replacing leading blanks before decimal numbers between -1 and +1, which consequently displaces any minus and plus signs, and returns the string resulting.

Table 5.10-1 The <i>Main_lib</i> Software Program Library	
Name of Routine	Software Routine Description
<i>FNAsk\$</i>	This function gets and returns one alphanumeric character from the keyboard as the computer user's response to the question displayed. When the escape option is set, this function enables the computer user to automatically load and run the Branch program while executing the function.
<i>FNCatalog\$</i>	This function displays the files and folders of the current mass storage device and folder. The function offers the computer user an open dialogue window to enter a filename or wildcards to find or specify files with similar filenames, a menu window to select among files of the current mass storage device and folder, and a menu window to select between other mass storage devices and folders. Depending on what the computer user enters, this function opens a file in the current mass storage device and folder.
<i>FNCenter\$</i>	This function changes the string passed by concatenating with leading and trailing characters, which the length parameter passed restrains what length of string the function returns, and returns the string resulting.
<i>FNCheck_device</i>	This function determines whether the device-selector passed represents a valid device. The function returns true (1) to the calling program when the device-selector is valid; otherwise, the function returns false (0).
<i>FNCheck_storage</i>	This function determines whether the mass storage device and folder passed represents a valid path specifier. The function returns true (1) to the calling program when the mass storage device and folder are valid; otherwise, the function returns false (0).
<i>FNCount_files</i>	This function returns the number of files in the mass storage device and folder passed.
<i>FNCreate_dir</i>	This function creates a new folder, which already does not exist, in the mass storage device and folder passed or the current mass storage device and folder. The function returns true (1) to the calling program when the function creates the folder; otherwise, the function returns false (0).

Table 5.10-1 The <i>Main_lib</i> Software Program Library	
Name of Routine	Software Routine Description
<i>FNCreate_file</i>	This function creates a new file, which already does not exist, in the mass storage device and folder passed or the current mass storage device and folder. The function returns true (1) to the calling program when the function creates the file; otherwise, the function returns false (0).
<i>FNcrt_height</i>	This function returns the screen display height, which is number of lines of the alpha display.
<i>FNcrt_width</i>	This function returns the screen display width, which is number of characters of the alpha display.
<i>FNDate</i>	This function converts the time and date passed from seconds to years, and returns the time and date resulting.
<i>FNDate\$</i>	This function formats a date string using the time and date, in seconds, and the date formatting rule passed, and returns the date string resulting.
<i>FNDir_path\$</i>	This function returns the folder specified within the file specifier passed.
<i>FNEdit\$</i>	This function gets and returns the alphanumeric keyboard input, which the uppercase and lowercase correspondence rule and the string length value passed restrains its character case and length. The function is a single-line text editor that accepts all ASCII characters 32 through 127 and special control keys, which include backspace, clear-line, clear-to-end, cursor keys, the escape key, and the mouse.
<i>FNErrm\$</i>	This function gets and returns the associated error message text from the program's execution error message passed, which excludes the error number and the program's line number on the error occurred.
<i>FNFile\$</i>	This function calls the <i>FNText\$</i> function to get alphanumeric characters from keyboard input and returns the alphanumeric characters, which is a file specifier restrained by the uppercase and lowercase correspondence rule and the file specifier's format rule passed, to the calling program.
<i>FNFile_exist</i>	The function returns true (1) to the calling program when the file specified by the file specifier passed exists in the mass storage device and folder passed or the current mass storage device and folder; otherwise, the function returns false (0).

Table 5.10-1 The <i>Main_lib</i> Software Program Library	
Name of Routine	Software Routine Description
<i>FNFile_name\$</i>	This function returns the filename specified within the file specifier passed.
<i>FNFile_spec\$</i>	This function returns the filename specified by the mass storage device, folder, and filename passed.
<i>FNFormat_string</i>	This function returns true (1) to the calling program when the function can format the string passed using the image specifier passed; otherwise, the function returns false (0).
<i>FNlth\$</i>	This function returns a string representation of the number passed and a suitable archaic inflexional suffix ending (e.g., “th”, “st”, “nd”, “rd”).
<i>FNTrim\$</i>	This function changes the string passed by removing leading blanks and tabs, returning the string resulting.
<i>FNMatpick</i>	This function displays one or more two-dimensional menu windows of items, which the computer user selects from among the items passed, returning the item pointer the computer user selects to the calling program.
<i>FNNumber</i>	This function calls the <i>Readit</i> subprogram to get numeric keyboard input and returns the number, which the relational rule and the numeric limits passed restrains its value, to the calling program.
<i>FNOpen_file</i>	This function sets up an input-output path specified by the file specifier passed. The function returns true (1) to the calling program when assigning the input-output path opens the file; otherwise, the function returns false (0).
<i>FNPassword</i>	This function gets alphanumeric keyboard input as a string and determines its equivalence to the password passed. The function returns true (1) to the calling program when the computer user enters a valid password; otherwise, the function returns false (0).
<i>FNFix</i>	This function truncates the numeric value passed to the specified power of ten, returning the closest integral value between the real value and zero without changing its type. The effect this function has on the value is removing any trailing sub-numeric part of its argument. The numeric value is rounded for numbers having more than 15 digits and the function returns zero for numbers having less than one digit.

Table 5.10-1 The <i>Main_lib</i> Software Program Library	
Name of Routine	Software Routine Description
<i>FNPick</i>	This function displays a one-dimensional menu window of items, which the computer user selects from among the items passed, returning the item pointer the computer user selects to the calling program.
<i>FNProg_heading\$</i>	This function returns the standard program heading having the program's name and today's of the week, date, and time.
<i>FNQuery\$</i>	This function displays a window of items, which the computer user selects from among the items passed to enter alphanumeric keyboard input, returning to the calling program the alphanumeric keyboard input entered. The function restrains items' alphanumeric keyboard input by applying rules passed governing data type (e.g., alphanumeric character, integer, real), uppercase and lowercase correspondence rules and string length limits for alphanumeric keyboard input, value ranges for integers and reals, and image specifiers for formatting alphanumeric keyboard input. The items are single-line text editors that accept all ASCII characters 32 through 127 and special control keys, which include backspace, clear-line, clear-to-end, cursor keys, the escape key, and the mouse.
<i>FNReply</i>	This function gets and returns one alphanumeric character from the keyboard as the computer user's response to the question displayed. When the escape option is set, this function enables the computer user to automatically load and run the Branch program while executing the function.
<i>FNRoman\$</i>	This function returns a string representation of the number passed based on the Roman Numeral system. The function returns Roman numerals for numbers from 1 to 1000 passed to the calling program; otherwise, the function returns Arabic numerals. Roman numerals are written with the seven basic symbols (e.g., I for 1, V for 5, X for 10, L for 50, C for 100, D for 500, M for 1000) and no zero. All other numbers are written by combining these seven symbols from left to right, using the principle of addition.
<i>FNTrim\$</i>	This function changes the string passed by removing trailing blanks and tabs, returning the string resulting.

Table 5.10-1 The <i>Main_lib</i> Software Program Library	
Name of Routine	Software Routine Description
<i>FNSelect\$</i>	This function displays a one-dimensional menu window of items, which the computer user selects from among the items passed, returning the item pointer the computer user selects to the calling program.
<i>FNText\$</i>	This function gets and returns the alphanumeric keyboard input, which the uppercase and lowercase correspondence rule and the string length value passed restrains its character case and length.
<i>FNText_file</i>	This function input and output data to the file specified by the file specifier passed. The function returns true (1) to the calling program for successful input or output operations; otherwise, the function returns false (0).
<i>FNTimeDate\$</i>	This function calls the <i>FNText\$</i> function to get alphanumeric characters from keyboard input and returns the alphanumeric characters, which is the time of day or the date restrained by the time of day or date format rule passed, to the calling program.
<i>FNValid_number</i>	This function returns true (1) to the calling program when the string passed represents a valid number; otherwise, the function returns false (0).
<i>FNVol_spec\$</i>	This function returns the mass storage device specified within the file specifier passed.
<i>Frame</i>	This subprogram prints a frame of alphanumeric characters on the screen display at the positions passed.
<i>Htbasic_reset</i>	This subprogram resets various attributes of the screen display, keyboard, and printer by setting <i>Crt</i> and <i>Kbd</i> registers and executing programmable statements.
<i>Load_program</i>	This subprogram gets a previously stored program into memory and initiates its execution starting at its first line. The subprogram's options features include displaying a message on the screen display and producing an audible tone at the frequency and duration passed.
<i>Number</i>	This subprogram calls the <i>Readit</i> subprogram to get numeric keyboard input and returns the list of numbers, which the relational rule and the numeric limits passed restrains its value, to the calling program.

Table 5.10-1 The <i>Main_lib</i> Software Program Library	
Name of Routine	Software Routine Description
<i>Pause_program</i>	This subprogram pauses program execution. The subprogram's options features include displaying a message on the screen display and producing an audible tone at the frequency and duration passed.
<i>Readit</i>	This subprogram gets numeric keyboard input and returns the list of numbers, which the numeric limits of the programming environment of TransEra High Tech Basic (HTBasic) Language System DOS Version 4.3 or higher restrain its value, to the calling program.
<i>Stop_program</i>	This subprogram stops program execution. The subprogram's options features include displaying a message on the screen display and producing an audible tone at the frequency and duration passed.

Table 5.10-2 The <i>Math_lib</i> Software Program Library	
Name of Routine	Software Routine Description
<i>Least_squares</i>	<p>This subprogram uses the least squares' method to compute, in the sense of a minimum variance, the "best" linear, unbiased estimates for a finite number of parameters, including drift, from a finite number of observations, which are the measurements, or differences, and a restraint by means of Gaussian least squares estimators. When observing only differences among objects or groups of objects, the restraint is the designated reference, or standard, to which observations, which are the measurements, they can refer. The designated restraint is a known value that can represent one or more objects in a group, consisting of any combination of objects or all of them. This function uses the differences, or residuals, between the observed and predicted values to compute an estimate of the error, or variance, for the process. In the equations of expected values for the observations, which are the measurements, the computations substitute computed values for the parameters. Mathematical references include "The Use of the Method of Least Squares in Calibration" by J. M. Cameron (<i>National Bureau of Standards (U.S.) NBSIR 74-587</i>, 1974) [37], "Designs for the Calibration of Small Groups of Standards in the Presence of Drift" by J. M. Cameron and G. E. Hailes (<i>National Bureau of Standards (U.S.) Technical Note 844</i>, 1974) [6], and "Drift Eliminating Designs for Non-Simultaneous Comparison Calibrations" by Dr. Theodore D. Doiron (<i>Journal of Research of the National Institute of Standards and Technology 98-2</i>, 1993) [7].</p>

Table 5.10-2 The *Math_lib* Software Program Library

Name of Routine	Software Routine Description
<i>Linear_reg</i>	<p>This subprogram uses the linear regression method to show the straight line used in predicting or estimating values of one variable, known from all coordinate values of X, from a knowledge of another variable, known from Y, for the set of (X,Y) ordered pairs. Predicting values on Y from values on X means calling Y, the variable being predicted or estimated, the dependent variable or criterion while calling X, which provides the information on which bases predictions, the independent variable or predictor. This programmed relation of the form</p> $Y' = b[YX]x + a[YX]$ <p>where Y' is equal to the predicted score on Y, b[YX] is equal to the slope of the line, also called the linear regression coefficient for predicting Y, and a[YX] is equal to the Y-intercept, or the value of Y' when X is equal to zero. The function solves the residuals, or differences between the actual and predicted values of Y, from the linear regression of Y on X, and assigns them to the array variable passed through the argument list. Next, the function assigns statistical information for the linear regression of Y on X to another variable passed through the argument list. Statistics for a linear regression for a specified number of pairs of (X,Y) coordinates for the function include: (1) number of (X,Y) pairs; (2) slope; (3) mean of all Y; (4) mean of all X; (5) y-intercept; (6) mean of all Y's; (7) sum of all Y's squared; (8) variance of mean of all Y's; (9) standard deviation of mean of all Y's; (10) mean of all X's; (11) sum of all X's squared; (12) variance of mean of all X's; (13) standard deviation of mean of all X's; (14) sum of residuals; (15) sum of residuals squared; (16) sum of squares mean; (17) sum of squares slope; (18) variance of residuals; (19) standard deviation of residuals; (20) variance of squares mean; (21) standard deviation of squares mean; (22) variance of slope; (23) standard deviation of slope; (24) variance of Y-intercept; (25) standard deviation of Y-intercept; and (26) F-Test ratio for slope.</p>

Table 5.10-2 The <i>Math_lib</i> Software Program Library	
Name of Routine	Software Routine Description
<i>Ls_fit</i>	This subprogram calls the <i>Least_squares</i> subprogram, which uses the least squares method to compute, in the sense of a minimum variance, the best linear, unbiased estimates for a finite number of parameters, including drift, from a finite number of observations, which are the measurements, or differences, and a restraint by means of Gaussian least squares estimators. When observing only differences among objects or groups of objects, the restraint is the designated reference, or standard, to which observations, which are the measurements, they can refer. The designated restraint is a known value that can represent one or more objects in a group, consisting of any combination of objects or all of them. This function uses the differences, or residuals, between the observed and predicted values to compute an estimate of the error, or variance, for the process. In the equations of expected values for the observations, which are the measurements, the computations substitute computed values for the parameters.
<i>Rsplnp</i>	This subprogram exactly fits a periodic cubic spline to a specified set of (X.Y) ordered pairs where values for the endpoints Y(1) and Y(2) are equal.
<i>Spline_fit</i>	This subprogram exactly fits a nonperiodic cubic spline to a specified set of (X.Y) ordered pairs, specifying values either for the first derivative or the second derivative at the endpoints.

Table 5.10-3 The <i>Tech_lib</i> Software Program Library	
Name of Routine	Software Routine Description
<i>Ambient</i>	This subprogram prompts the computer user to enter values for a set of ambient test conditions. These conditions are object temperature, air temperature, atmospheric pressure, and vapor pressure.

Table 5.10-3 The <i>Tech_lib</i> Software Program Library	
Name of Routine	Software Routine Description
<i>FNRestraint\$</i>	<p>This function translates the accepted material codes (e.g., Steel: 1, Ceramic: 2, Chrome Carbide: 3, Tungsten Carbide: 4, Stainless Steel: 5, and Other: 6) passed from the calling program and returns to the calling program one of three possible string sequences to represent the restraint. The restraint is based upon the material codes for the standard and check standard. The string sequences are “S” for the standard, “C” for the check standard, and “SC” for the standard and check standard.</p>
<i>Material</i>	<p>This subprogram assigns information to designated variables passed through the argument list for defining the accepted material code, the descriptive name, the thermal coefficient of expansion, and the elastic deformation constant of the object. The subprogram automatically assigns descriptive attributes and physical constants or prompts the computer user to select and assign descriptive attributes and physical constants. The value assigned and passed for the thermal coefficient of expansion are in parts per million per Celsius degree. The elastic deformation constants are in foot-pounds per inch squared. To derive the compression constants, use the following formula:</p> $V_c (1 \cdot 10^8) = (1 - \sigma^2) / (\pi \cdot E)$ <p>where σ is Poisson's ratio and E is the Young's modulus, in foot-pounds/inch², of the material of the object. Poisson's ratio is</p> $\sigma = (E / (2 \cdot G)) - 1$ <p>where E is the complete elliptic integral of second class with modulus e and G, in foot-pounds/inch², is the modulus of rigidity of the material of the object. Do not confuse this integral with E, the Young's modulus. Modulus e is the eccentricity of the ellipse of contact and, by definition, is</p> $e = (1 - b^2 / a^2)^{1/2}$ <p>where the quantities a and b are parameters for the materials of the object and the comparator probe, respectively. These quantities are generally unknown and are determined from tables furnished in “Elastic Compression of Spheres and Cylinders at Point and Line Contacts” by Puttock and Thwaite (National Standards Laboratory Technical Paper No. 25, Commonwealth Scientific and Industrial Research Organization, Australia, 1969) [33].</p>

Table 5.10-3 The <i>Tech_lib</i> Software Program Library	
Name of Routine	Software Routine Description
<i>Wavelength</i>	<p>This subprogram computes the quantity for fringes per millimeter from the vacuum wavelength, λ, called Lambda, and the ambient conditions. Ambient conditions are object temperature, air temperature, atmospheric pressure, and vapor pressure. To compute wavelength, the calculations use the fourth derivation of Edlen's equation for the refractive index of air, as the following equations show:</p> $A = P \cdot (8342.22 + 2406057 / (130 - 1/\lambda^2) + 15997 / (38.9 - 1/\lambda^2)) \cdot 10^{-8} / 720.775$ $B = 1 + P \cdot (.801 - 1.30 \cdot 10^{-2} \cdot T) \cdot 10^{-6} / 1 + 3.661 \cdot 10^{-3} \cdot T$ $C = F \cdot (4.9789 - 5.35 \cdot 10^{-2} \cdot 1/\lambda^2) \cdot 10^{-8}$ $L = (1/\lambda^2) / (1 + A \cdot B - C)$ $F = 2000 / L$ <p>where λ is the vacuum wavelength in micrometers, T is the air temperature in Celsius degrees, P is the atmospheric pressure in millimeters, L is the wavelength in microinches at ambient conditions, and F is the fringes per millimeter. The original 1966 Edlen's equation that we, at NIST, now call the first derivation of Edlen's equation appears in "A Gage Block Measurement Process using Single Wavelength Interferometry" by John S. Beers (<i>National Institute of Standards and Technology Monograph 152, 1975</i>) [8]. The fourth derivation of Edlen's equation, which the <i>NIST Gage Block Calibration Software System's</i> calibration and measurement software programs uses, appears in "An Updated NIST Line Scale Interferometer in 1995" by John S. Beers (Non-published Paper) [38].</p>

Chapter 6

The Calibration and Measurement Software Programs

This chapter provides general information about the NIST Gage Block Calibration Software System's calibration and measurement software programs. It describes some characteristics and functionality of these software programs.

6.1 Introduction to the Calibration and Measurement Software Programs

The *NIST Gage Block Calibration Software System's* calibration and measurement software programs are *Folder*, *Gage*, *History*, *Intmap*, *Master*, *Mecmap*, *Probe*, *Report*, *Setup*, and *Spectrum* and the software program library is *Gage_lib*. The *Gage* folder stores the *Autost* program, the *Gage_lib* software program library, and the calibration and measurement software programs and their related files. The *Autost* program is automatically loaded and executed when TransEra High Tech Basic (HTBasic) Language System DOS Version 4.3 or higher starts in the *Gage* folder. The *Folder* program opens, prints, and stores NIST's gage block calibration customers' NIST Reports' of Calibration information, which includes customers' names and addresses. To calibrate and measure gage blocks by mechanical intercomparison, the technical user, who calibrates and measures gage blocks, uses the *Gage* program to analyze measurements from the electro-mechanical gage block comparators, print the results, and record the results to the *Setup Document Files*. The *History* program opens, analyzes, prints, and stores NIST's gage block calibration customers' gage block calibration history. The *Intmap* program opens, analyzes, and prints NIST's master gage block interferometric calibration history. The *Master* program opens, prints, and stores current information about NIST's master gage blocks. The *Mecmap* program opens, analyzes, and prints the mechanical intercomparison control history for all NIST's gage block mechanical intercomparison calibrations and measurements, which the *Gage* program records during its use in calibrations and measurements. The user uses the *Probe* program to calibrate the electro-mechanical gage block comparators. The *Report* program opens, creates, prints, and stores NIST's gage block calibration customers' NIST Reports' of Calibration. The *Setup* program opens, prints, and stores NIST's gage block calibration customers' gage blocks' sizes, identification or serial numbers, and calibration and measurement

information. To calibrate and measure gage blocks by interferometry, the user uses the *Spectrum* program to analyze interferometric measurements from the gage block interferometers and to print the results and the *Setup* program is then used to record the results. All the calibration and measurement software programs use functions and subprograms from the *Gage_lib* software program library.

6.2 The *Folder* Program

The *Folder* program opens, prints, and stores NIST’s gage block calibration customers’ NIST Reports’ of Calibration information, which includes customers’ names and addresses. As part of the process of administering NIST’s gage block calibrations and measurements, NIST assigns official NIST test folders to every gage block calibration and measurement the technical user, who calibrates and measures gage blocks, performs. Called *folder information* by the user, the NIST test folders each contain an NIST test folder number, the NIST’s gage block calibration customer’s name and address, the description of gage blocks calibrated and measured, primary identification or serial number of gage blocks, the purchase order number, internal or group control number, and the date of the NIST Report of Calibration. The user uses the *Folder* program to record the *folder information* in *Folder Document Files*, which are DOS ASCII text files. To create NIST Reports’ of Calibration, the user runs the *Report* program, which uses the folder information from the *Folder Document Files* and the stored gage block calibration and measurement results from the *Setup* and *Gage* programs.

The *Folder* program has a *Control Menu* with nine functions, as Table 6.2-1 shows. The technical user, who calibrates and measures gage blocks, uses the *Control Menu* functions to do the following:

- Create, open, print, store, and archive *Folder Document Files*
- Switch between opened *Folder Document Files*
- View opened *Folder Document Files*

Table 6.2-1 The <i>Folder</i> Program’s Control Menu Functions	
Name of Function	Function Description
<i>Program Preface .</i>	This function displays the <i>Folder</i> program’s introductory statement.
<i>Folders</i>	This function switches between <i>Folder Document Files</i> in respective <i>Folder Document File</i> windows.

Table 6.2-1 The *Folder* Program's Control Menu Functions

Name of Function	Function Description
<i>New</i>	This function opens a copy of a new <i>Folder Document File</i> into a new <i>Folder Document File</i> window.
<i>Open</i>	This function opens a copy of a <i>Folder Document File</i> into a new <i>Folder Document File</i> window. <i>Folder Document Files</i> include working <i>Folder Document Files</i> in the working file storage device and folder, which is <i>C:\Gage\Work</i> , and archived <i>Folder Document Files</i> from the <i>Historys</i> storage device and folder, which is <i>C:\Gage\Historys</i> , and on labeled floppy diskettes. This function copies, deletes, moves, and renames <i>Folder Document Files</i> in file storage devices and folders.
<i>View</i>	This function opens the <i>Folder Document File</i> editing window with the current <i>Folder Document File</i> .
<i>Print</i>	This function prints one copy of the current <i>Folder Document File</i> to the printer.
<i>Store</i>	This function stores a copy of the current <i>Folder Document File</i> in the current <i>Folder Document File</i> window to a working file (e.g., <i>Filename.fdr</i>) in the DOS ASCII text file storage format. When a file already exists, a prompt first appears about overwriting the current <i>Folder Document File</i> to this file or storing the current <i>Folder Document File</i> to a new file.
<i>Archive</i>	This function archives a copy of the current <i>Folder Document File</i> in the current <i>Folder Document File</i> window to an archived file (e.g., <i>Filename.fdh</i>) in the DOS ASCII text file storage format. When a file already exists, a prompt first appears about overwriting the current <i>Folder Document File</i> to this file or storing the current <i>Folder Document File</i> to a new file.
<i>Exit FOLDER</i>	This function stops the <i>Folder</i> program and loads and runs the <i>Branch</i> program. When a <i>Folder Document File</i> is in the current <i>Folder Document File</i> window, a prompt first appears about storing the current <i>Folder Document File</i> and an affirmative response causes the function to store the current <i>Folder Document File</i> and close the current <i>Folder Document File</i> window.

The technical user, who calibrates and measures gage blocks, follows established file naming and storing conventions to manage *Folder Document Files*. The established naming convention for *Folder Document Files* is limited to eight characters for filenames with a three-character extension and a period separating the filename from the extension. The working *Folder Document Files* are to record all *folder information* and the archived *Folder Document Files* to record *folder information* exclusive of an NIST test folder number, the purchase order number, internal or group control number, and the date of the NIST Report of Calibration. When NIST's gage block calibration customers return gage blocks sets for calibrations, the user retrieves the *folder information* from the archived *Folder Document Files* to create new working *Folder Document Files*. Using archived *Folder Document Files* eliminates re-entering all *folder information*, provides information about the gage blocks previously calibrated and measured, and helps with spotting new and missing *folder information*. The user stores all working *Folder Document Files* in the working file storage device and folder, which is *C:\Gage\Work*, and the archived *Folder Document Files* in the *Historys* storage device and folder, which is *C:\Gage\Historys*, and on labeled floppy diskettes. For continuity reasons, the user typically assigns common filenames to *Folder Document Files*, *Report Document Files*, and *Setup Document Files* for every NIST's gage block calibration customers' calibration. The three-character extension for working *Folder Document Files* is "fdr" and for archived *Folder Document Files* is "fdh."

The **Folder** program stores *folder information* in *Folder Document Files*. The configuration of working *Folder Document Files*, as Table 6.2-2 shows, with *folder information*, each totaling ten records. This *folder information* is the NIST test folder number, the description of gage blocks calibrated and measured, the primary identification or serial number of the gage block set, and the NIST's gage block calibration customer's name and address, which includes their division or post office box number, street address, city, state, and U.S. Postal Service ZIP Code+4 within the United States and its territories, the customer's purchase order number, the internal or group control number, and the date of the NIST Report of Calibration. The configuration of archived *Folder Document Files*, as Table 6.2-3 shows, with *folder information*, totaling eight records each, and first records are blank. This *folder information* is one blank first record, the description of gage blocks calibrated and measured, the primary identification or serial number of the gage block set, and the NIST's gage block calibration customer's name and address, which includes their division or post office box number, street address, city, state, and U.S. Postal Service ZIP Code+4 within the United States and its territories. The technical user, who calibrates and measures gage blocks, stores working *Folder Document Files* in the working file storage device and folder, which is *C:\Gage\Work*. The user stores archived *Folder Document Files* in the *Historys* storage device and folder, which is *C:\Gage\Historys*, and on labeled floppy diskettes. The listing of a sample working *Folder Document File*, as Table 6.2-4 shows, has the test *folder information* for an anonymous NIST gage block customer. The listing of a sample archived *Folder Document File*, as Table 6.2-5 shows, has the test *folder information* for an anonymous NIST gage block calibration customer.

Table 6.2-2 Configuration of Working *Folder Document Files*

Record	Record Description
1	This record has the NIST test folder number.
2	This record has the description of the gage blocks calibrated and measured.
3	This record has the primary identification or serial number of the gage block set.
4	This record has the customer's name.
5	This record has the customer's division or post office box number.
6	This record has the customer's street address.
7	This record has the customer's city, state, and U.S. Postal Service ZIP Code+4 within the United States and its territories.
8	This record has the customer's purchase order number.
9	This record has the internal or group control number.
10	This record has the date appearing on the NIST Report of Calibration.

Table 6.2-3 Configuration of Archived *Folder Document Files*

Record	Record Description
2	This record has the description of the gage blocks calibrated
3	This record has the primary identification or serial number of the gage block set.
4	This record has the customer's name.
5	This record has the customer's division or post office box number.
6	This record has the customer's street address.
7	This record has the customer's city, state, and U.S. Postal Service ZIP Code+4 within the United States and its territories.

Table 6.2-4 Listing of a Sample Working <i>Folder Document File</i>	
Column:	10 20 30 40 50 60 70 80
Row:	1234567890123456789012345678901234567890123456789012345678901234567890123456789012
0001:	821/123456-98
0002:	8-Piece Set of Steel English Gage Blocks
0003:	123-456-7890
0004:	Anonymous Company, Incorporated
0005:	Post Office Box 123
0006:	123 Anonymous Street
0007:	Anytown, USA 12345-6789
0008:	AZ-123
0009:	M0001
0010:	June 16, 1998

Table 6.2-5 Listing of a Sample Archived <i>Folder Document File</i>	
Column:	10 20 30 40 50 60 70 80
Row:	1234567890123456789012345678901234567890123456789012345678901234567890123456789012
0001:	
0002:	8-Piece Set of Steel English Gage Blocks
0003:	123-456-7890
0004:	Anonymous Company, Incorporated
0005:	Post Office Box 123
0006:	123 Anonymous Street
0007:	Anytown, USA 12345-6789
0008:	AZ-123

6.3 The *Gage* Program

The technical user, who calibrates and measures gage blocks, calibrates and measures gage blocks at NIST by mechanical intercomparison using the *Gage* program to analyze measurements from the electro-mechanical gage block comparators and to print and record the results. The *Gage* program has two testing modes, the *Gage* mode to calibrate and measure

NIST's gage block calibration customers' gage blocks and the *Test* mode to test the ***NIST Gage Block Calibration Software System*** and train personnel. To calibrate and measure NIST's gage block calibration customers' gage blocks, the user first uses the ***Setup*** program to record the *setup information* in *Setup Document Files*, which are DOS ASCII text files. To calibrate and measure gage blocks by mechanical intercomparison, the user uses the ***Gage*** program in *Gage* mode to analyze measurements from the electro-mechanical gage block comparators, print the results, and record the results to the *Setup Document Files*. As part of the process to ensure quality assurance, the ***Gage*** program estimates short-term and long-term measurement process variability by measuring and recording the differences in length of the two master gage blocks used for every NIST's gage block calibration customers' gage blocks calibrated and measured by mechanical intercomparison and comparing past and present calibration and measurement results. As another part of the process to ensure quality assurance, the user uses the ***History*** program to authenticate past and present calibration and measurement results, which occasionally requisite retests. Once authenticated, the user then merges and records the present calibration and measurement results to the *History Document Files* and creates NIST Reports' of Calibration. To create NIST Reports' of Calibration, the user runs the ***Report*** program, which uses the *folder information* from the *Folder Document Files* and the stored gage block calibration and measurement results from the ***Setup*** and ***Gage*** programs.

The ***Gage*** program has a *Control Menu* with ten functions, as Table 6.3-1 shows. The technical user, who calibrates and measures gage blocks, uses the *Control Menu* functions to do the following:

- Switch between testing modes, the *Gage* mode to calibrate and measure NIST's gage block calibration customers' gage blocks and the *Test* mode to test the ***NIST Gage Block Calibration Software System*** and train personnel
- Switch between master gage block types, the *English* type to calibrate and measure NIST's gage block calibration customers' English gage blocks and the *Metric* type to calibrate and measure NIST's gage block calibration customers' metric gage blocks
- Switch between testing methods, *Interferometric* method that requires running the ***Spectrum*** and ***Setup*** programs and *Mechanical* method that offer fourteen measurement designs for measurement series from the selection menu listing drift eliminating designs
- Enter initials of observer, the user who calibrates and measures NIST's gage block calibration customers' gage blocks
- View opened *Setup Document Files*
- Select gage blocks to calibrate and measure
- Enter measuring temperatures of the comparators and gage blocks
- Enter manually electro-mechanical gage block comparators' readings
- Record automatically the electro-mechanical gage block comparators' readings every time by pressing the auxiliary trigger mechanism

- View and print the gage block calibration and measurement results
- Store the gage block calibration and measurement results to *Setup Document Files*

Table 6.3-1 The <i>Gage</i> Program's Control Menu Functions	
Name of Function	Function Description
<i>Program Preface .</i>	This function displays the <i>Gage</i> program's introductory statement.
<i>Mode</i>	This function switches the testing mode between <i>Gage</i> and <i>Test</i> . The computer user selects <i>Gage</i> mode to calibrate and measure NIST's gage block calibration customers' gage blocks and <i>Test</i> mode to test the <i>NIST Gage Block Calibration Software System</i> and train personnel. Running calibrations and measurements in <i>Gage</i> mode writes results to the screen display and printer, the <i>Setup Document Files</i> , and the <i>Gagemap Document Files</i> that the <i>Mecmap</i> program uses to analyze the mechanical intercomparison control history for all NIST's gage block mechanical intercomparison calibrations and measurements. Running calibrations and measurements in <i>Test</i> mode writes results to the display and printer only.
<i>Masters</i>	This function switches the master gage block types between <i>English</i> and <i>Metric</i> types of master gage blocks. The computer user selects <i>English</i> type to calibrate and measure NIST's gage block calibration customers' English gage blocks and <i>Metric</i> type to calibrate and measure NIST's gage block calibration customers' metric gage blocks.
<i>Method</i>	This function switches the testing methods between <i>Interferometric</i> and <i>Mechanical</i> methods of calibrations. Since the <i>Gage</i> program is to calibrate and measure gage blocks by mechanical intercomparison, the computer user who selects <i>Interferometric</i> testing method is prompted to select running the <i>Setup</i> or <i>Spectrum</i> programs or select between testing methods. When the computer user selects <i>Gage</i> mode and <i>Mechanical</i> testing method, a prompt appears about entering the number of <i>Setup Document Files</i> for the measurement series. When the computer user selects <i>Test</i> mode and <i>Mechanical</i> testing method, the selection menu listing drift eliminating designs appear about selecting the measurement design for the measurement series.

Table 6.3-1 The *Gage* Program's Control Menu Functions

Name of Function	Function Description
<i>Observer</i>	This function prompts the computer user to enter the observer's initials, one to three characters allowed. The observer is the technical user, who calibrates and measures gage blocks, which includes NIST's gage block calibration customers' gage blocks. Running calibrations and measurements in the <i>Gage</i> mode writes the observers' initials to the <i>Setup Document Files</i> and the <i>Gagemap Document Files</i> that the <i>Mecmap</i> program uses to analyze the mechanical intercomparison control history for all NIST's gage block mechanical intercomparison calibrations and measurements.
<i>Instrument</i>	This function switches the electro-mechanical gage block comparator assigned to calibrate and measure NIST's gage block calibration customers' gage blocks. When the computer user selects electro-mechanical gage block comparators with comparator probe calibrations stored to <i>Probe Calibration Files</i> , a prompt appears about selecting the measurement method, <i>Automatic</i> for the <i>Gage</i> program to record the electro-mechanical gage block comparator's readings every time the computer user presses the auxiliary trigger mechanism or <i>Manual</i> for the computer user to enter the electro-mechanical gage block comparator's readings when prompted by the <i>Gage</i> program. When the computer user selects electro-mechanical gage block comparators without comparator probe calibrations stored to <i>Probe Calibration Files</i> , a prompt appears about running the <i>Probe</i> program to calibrate the comparator selected; otherwise, this function stops the <i>Gage</i> program and loads and runs the <i>Branch</i> program. Running calibrations and measurements in <i>Gage</i> mode writes the electro-mechanical gage block comparators assigned to the <i>Gagemap Document Files</i> that the <i>Mecmap</i> program uses to analyze the mechanical intercomparison control history for all NIST's gage block mechanical intercomparison calibrations and measurements.
<i>New</i>	This function opens the <i>Setup Document Files</i> that the computer user generated beforehand using the <i>Setup</i> program for the measurement series. The <i>Setup Document Files</i> are working <i>Setup Document Files</i> from the same working file storage device and folder, which is <i>C:\Gage\Work</i> , and not archived <i>Setup Document Files</i> from the <i>Historys</i> storage device and folder, which is <i>C:\Gage\Historys</i> , and on labeled floppy diskettes.

Table 6.3-1 The <i>Gage</i> Program's Control Menu Functions	
Name of Function	Function Description
<i>Run</i>	This function runs NIST's gage block mechanical intercomparison calibrations and measurements and measurements. The function enables the computer user to view opened <i>Setup Document Files</i> , select gage blocks to calibrate and measure, enter measuring temperatures of the comparators and gage blocks, enter manually electro-mechanical gage block comparators' readings, record automatically the electro-mechanical gage block comparators' readings every time by pressing the auxiliary trigger mechanism, view and print store the calibration and measurement results, and store the calibration and measurement results to <i>Setup Document Files</i> .
<i>Backup</i>	This function backs up the current calendar years' <i>Gagemap Document Files</i> that the <i>Mecmap</i> program uses to analyze the mechanical intercomparison control history for all NIST's gage block mechanical intercomparison calibrations and measurements. Since this function replaces, or overwrites, existing current calendar years' files, renaming the current calendar years' files backed up on the labeled floppy diskettes or backing up on separate labeled floppy diskettes gives incremental backups during current calendar years and better protection against accidental overwrites.
<i>Exit GAGE</i>	This function stops the <i>Gage</i> program and loads and runs the <i>Branch</i> program.

The technical user, who calibrates and measures gage blocks, follows established file naming and storing conventions to manage *Folder Document Files*, *Setup Document Files*, *History Document Files*, and *Report Document Files*. The established naming convention for *Folder Document Files*, *Setup Document Files*, *History Document Files*, and *Report Document Files* is limited to eight characters for filenames with a three-character extension and a period separating the filename from the extension. The working *Folder Document Files* are to record all *folder information* and the archived *Folder Document Files* to record *folder information* exclusive of an NIST test folder number, the purchase order number, internal or group control number, and the date of the NIST Report of Calibration. The working *Setup Document Files* are to record *setup information* and calibration and measurement results and the archived *Setup Document Files* to record only *setup information*. The *History Document Files* are to record calibration and measurement results, which are NIST's gage block calibration customers' gage block calibration history. When customers return gage blocks sets for calibrations, the user

retrieves the *folder information* from the archived *Folder Document Files* to create new working *Folder Document Files* and the *setup information* from the archived *Setup Document Files* to create new working *Setup Document Files*. The user stores all working *Folder Document Files*, *Setup Document Files*, and *Report Document Files* in the working file storage device and folder, which is *C:\Gage\Work*, and the archived *Folder Document Files*, *Setup Document Files*, *History Document Files*, and *Report Document Files* in the *Historys* storage device and folder, which is *C:\Gage\Historys*, and on labeled floppy diskettes. For continuity reasons, the user typically assigns common filenames to *Folder Document Files*, *Setup Document Files*, *History Document Files*, and *Report Document Files* for every NIST's gage block calibration customers' calibration. The three-character extension for working *Folder Document Files* is "fdr" and for archived *Folder Document Files* is "fdh," for working *Setup Document Files* is "ids" and for archived *Setup Document Files* is "idh," for *History Document Files* is "his," and for working *Report Document Files* is "rpt" and for archived *Report Document Files* is "rph."

The **Gage** program has two testing modes: *Gage* and *Test*. The technical user, who calibrates and measures gage blocks, runs the *Gage* program in *Gage* mode to calibrate and measure NIST's gage block calibration customers' gage blocks and in *Test* mode to test the **NIST Gage Block Calibration Software System** and train personnel. Running the **Gage** program in *Gage* mode to calibrate and measure gage blocks writes results to the screen display and printer, the *Setup Document Files*, and the *Gagemap Document Files* that the **Mecmap** program uses to analyze the mechanical intercomparison control history for all NIST's gage block mechanical intercomparison calibrations and measurements. The results the **Gage** program writes to the *Gagemap Document Files* that the **Mecmap** program uses to analyze the mechanical intercomparison control history for all NIST's gage block mechanical intercomparison calibrations and measurements the user refers as *gagemap information*. Running the **Gage** program in *Test* mode to calibrate and measure gage blocks writes results to the display and printer only.

The **Gage** program enables the technical user, who calibrates and measures gage blocks, to calibrate and measure two master gage block types, *English* and *Metric* gage blocks. The user selects *English* type to calibrate and measure NIST's gage block calibration customers' English gage blocks and *Metric* type to calibrate and measure NIST's gage block calibration customers' metric gage blocks.

The **NIST Gage Block Calibration Software System's** calibration and measurement software programs offer the technical user, who calibrates and measures gage blocks, many measurement designs to calibrate and measure gage blocks, one measurement design for interferometry and fourteen measurement designs to calibrate and measure one-to-nine NIST's gage block calibration customers' gage blocks simultaneously by mechanical intercomparison, as Table 6.3-2 shows. The symbol denoting NIST's standard gage block is "S," the symbol denoting NIST's check standard gage block is "C," and the symbols denoting NIST's gage block calibration customers' unknown gage blocks are "1," "2," "3," "4," "5," "6," "7," "8," and "9."

The user uses the first measurement design for interferometry and the fourteenth measurement design, named “ABCA Design,” for fast and less-accurate intercomparisons. The second through thirteenth measurement designs allow the user to measure from one-to-nine sets of NIST’s gage block calibration customers’ gage blocks simultaneously, which allow for constant drift among all measurements, providing for one or more process control measurements [7]. The names of these twelve measurement designs refer first to the number of gage blocks measured, two NIST’s master gage blocks and one-to-nine NIST’s gage block customers’ gage blocks, and second to the number of measurements per gage block. Since Dr. Theodore D. Doiron developed the second through thirteenth measurement designs in 1989 and published them in “Drift Eliminating Designs for Non-Simultaneous Comparison Calibrations” (*Journal of Research of the National Institute of Standards and Technology* 98-2, 1993) [7], seldom used is the fifteenth measurement design, named “4-1 Design,” which J. M. Cameron and G. E. Hailes published in “Designs for the Calibration of Small Groups of Standards in the Presence of Drift” (*National Bureau of Standards (U.S.) Technical Note 844*, 1974) [6] and John. S. Beers and Clyde D. Tucker published in “Intercomparison Procedures for Gage Blocks Using Electromechanical Comparators” (*National Bureau of Standards (U.S.) NBSIR 76-979*, 1976) [4]. To calibrate and measure NIST’s gage block calibration customers’ gage blocks, the user typically uses the fourth measurement design, named “3-6 Design,” and exception to the second measurement design, named “3-2 Design,” and the third measurement design, named “3-4 Design,” for long gage blocks.

Table 6.3-2 Gage Block Measurement Designs		
Number of Design	Name of Design	Design Description
1	Interferometry	1 Unknown, 1 Measurement Each $y_1 = S$
2	3-2 Design	2 Masters and 1 Unknown, 2 Measurements Each $y_1 = S - C$ $y_2 = 1 - C$ $y_3 = S - 1$

Table 6.3-2 Gage Block Measurement Designs		
Number of Design	Name of Design	Design Description
3	3-4 Design	<p>2 Masters and 1 Unknown, 4 Measurements Each</p> $y_1 = S - C$ $y_2 = 1 - S$ $y_3 = C - 1$ $y_4 = C - S$ $y_5 = 1 - C$ $y_6 = S - 1$
4	3-6 Design	<p>2 Masters and 1 Unknown, 6 Measurements Each</p> $y_1 = S - C$ $y_2 = 1 - C$ $y_3 = S - 1$ $y_4 = C - S$ $y_5 = 1 - S$ $y_6 = C - 1$ $y_7 = C - S$ $y_8 = 1 - C$ $y_9 = S - 1$
5	4-4 Design	<p>2 Masters and 2 Unknowns, 4 Measurements Each</p> $y_1 = S - C$ $y_2 = 1 - 2$ $y_3 = 2 - S$ $y_4 = C - 1$ $y_5 = C - S$ $y_6 = 2 - 1$ $y_7 = S - 2$ $y_8 = 1 - C$

Table 6.3-2 Gage Block Measurement Designs		
Number of Design	Name of Design	Design Description
6	4-6 Design	<p>2 Masters and 2 Unknowns, 6 Measurements Each</p> $y_1 = S - C$ $y_2 = 2 - S$ $y_3 = 1 - 2$ $y_4 = C - S$ $y_5 = C - 1$ $y_6 = 2 - C$ $y_7 = S - 1$ $y_8 = C - 2$ $y_9 = S - 2$ $y_{10} = 1 - C$ $y_{11} = 1 - S$ $y_{12} = 2 - 1$
7	5-4 Design	<p>2 Masters and 3 Unknowns, 4 Measurements Each</p> $y_1 = S - C$ $y_2 = 3 - 2$ $y_3 = S - 1$ $y_4 = 3 - C$ $y_5 = 2 - 1$ $y_6 = C - 2$ $y_7 = 1 - S$ $y_8 = 1 - 3$ $y_9 = 2 - S$ $y_{10} = C - 3$

Table 6.3-2 Gage Block Measurement Designs		
Number of Design	Name of Design	Design Description
8	6-4 Design	<p>2 Masters and 4 Unknowns, 4 Measurements Each</p> $y_1 = S - C$ $y_2 = 3 - 2$ $y_3 = 4 - 1$ $y_4 = 4 - 3$ $y_5 = 2 - C$ $y_6 = 1 - 2$ $y_7 = S - 4$ $y_8 = C - 3$ $y_9 = C - 1$ $y_{10} = 3 - S$ $y_{11} = 1 - 4$ $y_{12} = 2 - S$
9	7-4 Design	<p>2 Masters and 5 Unknowns, 4 Measurements Each</p> $y_1 = S - C$ $y_2 = 4 - 2$ $y_3 = 1 - 3$ $y_4 = C - 5$ $y_5 = S - 4$ $y_6 = 3 - 1$ $y_7 = C - 2$ $y_8 = 1 - 5$ $y_9 = 3 - 4$ $y_{10} = 5 - S$ $y_{11} = 4 - C$ $y_{12} = 2 - 1$ $y_{13} = 2 - S$ $y_{14} = 5 - 3$

Table 6.3-2 Gage Block Measurement Designs		
Number of Design	Name of Design	Design Description
<i>10</i>	8-4 Design	<p>2 Masters and 6 Unknowns, 4 Measurements Each</p> $y_1 = S - C$ $y_2 = 4 - 6$ $y_3 = 5 - 2$ $y_4 = 3 - S$ $y_5 = 1 - 4$ $y_6 = 6 - 5$ $y_7 = 2 - 1$ $y_8 = 4 - C$ $y_9 = 5 - 3$ $y_{10} = 2 - S$ $y_{11} = C - 6$ $y_{12} = 3 - 1$ $y_{13} = 4 - S$ $y_{14} = 6 - 2$ $y_{15} = 1 - 3$ $y_{16} = C - 5$

Table 6.3-2 Gage Block Measurement Designs		
Number of Design	Name of Design	Design Description
<i>11</i>	9-4 Design	<p>2 Masters and 7 Unknowns, 4 Measurements Each</p> $y_1 = S - C$ $y_2 = 7 - 5$ $y_3 = C - 1$ $y_4 = 3 - 2$ $y_5 = 4 - 6$ $y_6 = 2 - C$ $y_7 = 1 - 5$ $y_8 = 6 - 7$ $y_9 = 3 - S$ $y_{10} = 1 - 4$ $y_{11} = 7 - S$ $y_{12} = 6 - 3$ $y_{13} = 2 - 4$ $y_{14} = C - 2$ $y_{15} = 5 - 3$ $y_{16} = S - 7$ $y_{17} = 4 - 1$ $y_{18} = 5 - 6$

Table 6.3-2 Gage Block Measurement Designs		
Number of Design	Name of Design	Design Description
12	10-4 Design	<p>2 Masters and 8 Unknowns, 4 Measurements Each</p> $y_1 = S - C$ $y_2 = 5 - 6$ $y_3 = 8 - 2$ $y_4 = 3 - 4$ $y_5 = C - 7$ $y_6 = 1 - 2$ $y_7 = 6 - 7$ $y_8 = 8 - S$ $y_9 = 4 - 5$ $y_{10} = 7 - 8$ $y_{11} = 3 - 5$ $y_{12} = C - 1$ $y_{13} = 2 - 8$ $y_{14} = 7 - 4$ $y_{15} = 1 - 6$ $y_{16} = S - 3$ $y_{17} = 5 - 1$ $y_{18} = 2 - 3$ $y_{19} = 6 - S$ $y_{20} = 4 - C$

Table 6.3-2 Gage Block Measurement Designs		
Number of Design	Name of Design	Design Description
<i>13</i>	11-4 Design	<p>2 Masters and 9 Unknowns, 4 Measurements Each</p> $y_1 = S - C$ $y_2 = 3 - 4$ $y_3 = 6 - 8$ $y_4 = 2 - 7$ $y_5 = C - 1$ $y_6 = 8 - 9$ $y_7 = 7 - 5$ $y_8 = 3 - S$ $y_9 = 1 - 2$ $y_{10} = S - 4$ $y_{11} = C - 6$ $y_{12} = 5 - 1$ $y_{13} = 4 - 5$ $y_{14} = 9 - C$ $y_{15} = 2 - 3$ $y_{16} = 7 - 9$ $y_{17} = 5 - 6$ $y_{18} = 8 - S$ $y_{19} = 1 - 7$ $y_{20} = 6 - 3$ $y_{21} = 9 - 2$ $y_{22} = 4 - 8$
<i>14</i>	ABCA Design	<p>2 Masters and 1 Unknown, 1 - 2 Measurements Each</p> $y_1 = 1 - S$ $y_2 = C - 1$

Table 6.3-2 Gage Block Measurement Designs		
Number of Design	Name of Design	Design Description
15	4-1 Design	<p>2 Masters and 2 Unknowns, 4 Measurements Each</p> $y_1 = S - C$ $y_2 = 2 - S$ $y_3 = 1 - 2$ $y_4 = C - 1$ $y_5 = C - 2$ $y_6 = 2 - S$ $y_7 = S - 1$ $y_8 = 1 - C$

The *NIST Gage Block Calibration Software System's* calibration and measurement software programs afford the technical user, who calibrates and measures gage blocks, the following configurations:

- One-to-nine electro-mechanical gage block comparators to calibrate and measure gage blocks by mechanical intercomparison
- Electro-mechanical gage block comparators' probe calibration cycles, number of days between comparators' probe calibration and number of tests completed using the *Gage* program

With one-to-nine electro-mechanical gage block comparators configured, the technical user, who calibrates and measures gage blocks, switches among the electro-mechanical gage block comparators when running the *Probe* program to calibrate the comparators' measuring probes and the *Gage* program to calibrate and measure NIST's gage block calibration customers' gage blocks. The user selects electro-mechanical gage block comparators with comparator probe calibrations stored to *Probe Calibration Files*, selecting the measurement method, *Automatic* for the *Gage* program to record the electro-mechanical gage block comparator's readings every time the computer user presses the auxiliary trigger mechanism or *Manual* for the computer user to enter the electro-mechanical gage block comparator's readings when prompted by the *Gage* program. With the electro-mechanical gage block comparators' probe calibration cycles configured, when the user exceeds probe calibration cycles, last comparator calibrations or the gage blocks calibrated and measured, or they store no probe calibrations to *Probe Calibration Files*, the *Gage* program alerts the user to run the *Probe* program to calibrate the comparator

selected. Running calibrations and measurements in *Gage* mode writes the electro-mechanical gage block comparators assigned to the *Gagemap Document Files* that the *Mecmap* program uses to analyze the mechanical intercomparison control history for all NIST's gage block mechanical intercomparison calibrations and measurements.

The *Gage* program, running in *Gage* mode to calibrate and measure gage blocks, writes results, which the technical user, who calibrates and measures gage blocks, refers as *gagemap information*, to the *Gagemap Document Files* that the *Mecmap* program uses to analyze the mechanical intercomparison control history for all NIST's gage block mechanical intercomparison calibrations and measurements. To the DOS ASCII text file, named *Gbkupmap.ini*, the *Gage* program, running in *Gage* mode, automatically stores the filename storing the last backup of NIST's gage block mechanical intercomparison calibration history, the date of last backup, and the number of records that the *Gage* program stored since the last backup. The *Gage* program affords the user two ways to back up current calendar years' mechanical intercomparison control history files the *Gage* program writes. The first method, when first running the *Gage* program in *Gage* mode, the *Gage* program checks information stored to the *Gbkupmap.ini* file, prompting the user to back up the current calendar years' mechanical intercomparison control history files when the last backup was done more than one quarter of one calendar year or more than 100 records have been added to the file since the last backup. The second method, the user uses the Control Menu's backup function. Since this function replaces, or overwrites, existing current calendar years' files, renaming the current calendar years' files backed up on the labeled floppy diskettes or backing up on separate labeled floppy diskettes gives incremental backups during current calendar years and better protection against accidental overwrites.

The *Gbkupmap.ini* file resides in the *Gage* folder, which is the current and customary program folder for the *NIST Gage Block Calibration Software System* under normal operations. As Table 6.3-3 shows, the *Gbkupmap.ini* file contains the filename storing the last backup of NIST's gage block mechanical intercomparison calibration history, the date of last backup, and the number of records that the *Gage* program stored since the last backup. The latest listing of a *Gbkupmap.ini* file, as Table 6.3-4 shows, has the filename storing the last backup of NIST's gage block mechanical intercomparison calibration history, the date of the last backup, and the number of NIST's gage block mechanical intercomparison calibration history records that the *Gage* program stored since the last backup.

Table 6.3-3 Configuration of the <i>Gbkupmap.ini</i> File	
Row	Record Description
1	This record has the filename storing the last backup of NIST's gage block mechanical intercomparison calibration history.

Table 6.3-3 Configuration of the <i>Gbkupmap.ini</i> File	
Row	Record Description
2	This record has the date of the last backup of NIST's gage block mechanical intercomparison calibration history.
3	This record has the number of NIST's gage block mechanical intercomparison calibration history records that the <i>Gage</i> program stored since the last backup of NIST's gage block mechanical intercomparison calibration history.

Table 6.3-4 Latest Listing of a <i>Gbkupmap.ini</i> File								
Column:	10	20	30	40	50	60	70	80
Row:	12345678901234567890123456789012345678901234567890123456789012345678901234567890123456789012							
0001:	A:GAGE1998.MAP							
0002:	02 Jul 1998							
0003:	10							

The *Gage* program stores *gagemap information* in *Gagemap Document Files*. The configuration of *Gagemap Document Files*, as Table 6.3-5 shows, with *gagemap information*, each totaling fourteen fields and extending 80 characters. This *gagemap information* is the remark status, NIST's master gage blocks' nominal sizes, identification or serial numbers, master type, material codes, accepted master gage block mechanical intercomparison controls, accepted master gage block mechanical intercomparison within standard deviations, testing method codes, electro-mechanical gage block comparators' identification codes, observed temperatures, observers' initials, testing dates, statistical process control codes, observed master gage block mechanical intercomparison controls, and observed master gage block mechanical intercomparison within standard deviations. The technical user, who calibrates and measures gage blocks, stores working *Gagemap Document Files* in the working file storage device and folder, which is *C:\Gage\Gagemap*. The user stores backed up *Gagemap Document Files* in the working file storage device and folder, which is *C:\Gage\Mecmaps*, and on labeled floppy diskettes. The listing of a sample working *Gagemap Document File*, as Table 6.3-6 shows, has information that the *Gage* program wrote when running in *Gage* mode to calibrate and measure gage blocks at NIST's first gage block calibration workstation.

Table 6.3-5 Configuration of Gagemap Document Files	
Column	Field Description
<i>1</i>	This field has the testing status (Yes: <i>Blank</i> , No: <i>Asterisk</i> , Remark: <i>Exclamation Point</i>).
<i>2-11</i>	This field has the gage block nominal size (English: <i>in inches</i> , Metric: <i>in millimeters</i>).
<i>13-18</i>	This field has the standard gage block identification or serial number (zero to six characters accepted, "NONE" for no identification or serial number is recommended).
<i>20-25</i>	This field has the check standard gage block identification or serial number (zero to six characters accepted, "NONE" for no identification or serial number is recommended).
<i>27</i>	This field has the master gage block type (English: <i>1</i> , Metric: <i>2</i>).
<i>28-35</i>	This field has the accepted master gage block mechanical intercomparison control, in nanometers.
<i>37-41</i>	This field has the accepted master gage block mechanical intercomparison within standard deviation, in nanometers.
<i>43-44</i>	This field has the testing method code (Exempt: <i>0</i> , Interferometry: <i>1</i> , 3-2 Design: <i>2</i> , 3-4 Design: <i>3</i> , 3-6 Design: <i>4</i> , 4-4 Design: <i>5</i> , 4-6 Design: <i>6</i> , 5-4 Design: <i>7</i> , 6-4 Design: <i>8</i> , 7-4 Design: <i>9</i> , 8-4 Design: <i>10</i> , 9-4 Design: <i>11</i> , 10-4 Design: <i>12</i> , 11-4 Design: <i>13</i> , ABCA Design: <i>14</i> , 4-1 Design: <i>15</i>).
<i>45-46</i>	This field has the electro-mechanical gage block comparators' identification code (Workstation One: <i>F1</i> , Workstation Two: <i>F2</i> , Workstation Three: <i>F3</i> , Workstation Four: <i>F4</i> , Workstation Five: <i>F5</i> , Workstation Six: <i>F6</i> , Workstation Seven: <i>F7</i> , Workstation Eight: <i>F8</i> , and Workstation Nine: <i>F9</i>).
<i>48-53</i>	This field has the observed temperature, in degrees Celsius.
<i>55-57</i>	This field has the observer's initials, one to three alphanumeric characters accepted, all initials recommended. The observer is the technical user, who calibrates and measures gage blocks, which includes NIST's gage block calibration customers' gage blocks.
<i>58-61</i>	This field has the year for the testing date, four numeric digit characters with leading zeros displayed, century mandatory.

Table 6.3-5 Configuration of Gagemap Document Files	
Column	Field Description
62-63	This field has the month for the testing date, two numeric digit characters with leading zeros displayed (January: 01, February: 02, March: 03, April: 04, May: 05, June: 06, July: 07, August: 08, September: 09, October: 10, November: 11, December: 12).
64-65	This field has the day of the month for the testing date, two numeric digit characters with leading zeros displayed (1 st Day of Month: 01, 2 nd Day of Month: 02, 3 rd Day of Month: 03, . . . , 31 st Day of Month: 31).
66	This field has the statistical process control codes (Test Passed: 0, Test Failed on the F-test: 1, Test Failed on the T-test: 2, Test Failed on both the F-test and the T-test: 3).
67-74	This field has the observed master gage block mechanical intercomparison control, in nanometers.
76-80	This field has the observed master gage block mechanical intercomparison within standard deviation, in nanometers.

Table 6.3-6 Listing of a Sample Gagemap Document File from NIST's First Gage Block Calibration Workstation											
	Column:	10	20	30	40	50	60	70	80		
		▼	▼	▼	▼	▼	▼	▼	▼		
Row:		12345678901234567890123456789012345678901234567890123456789012345678901234567890123456789012									
0001:		0.010050	4527	VJV5	1	33.0	6.2 04F1	20.020	EMT199801050	20.3	4.1
0002:		0.010200	5116	W7W17	1	36.5	5.7 04F1	20.050	EMT199801050	50.5	6.9
0003:		0.010600	5108	VJV5	1	113.8	5.7 04F1	20.070	EMT199801050	96.9	6.7
0004:		0.010800	5105	VJV5	1	1.1	5.7 04F1	20.070	EMT199801050	11.2	8.1
0005:		0.013000	6110	VJV5	1	145.3	5.7 04F1	20.080	EMT199801050	143.9	4.5
0006:		0.015000	6216	VJV5	1	110.3	5.7 04F1	20.090	EMT199801051	93.2	14.9
0007:		0.018000	1108	VJV5	1	68.7	5.7 04F1	20.100	EMT199801050	71.8	7.5
0008:		0.020300	2358	VJV5	1	-44.2	7.0 04F1	20.110	EMT199801050	-29.2	9.0
0009:		0.020500	2807	VJV5	1	32.9	7.0 04F1	20.130	EMT199801050	23.3	9.1
0010:		0.020900	2638	VJV5	1	-66.2	7.0 04F1	20.130	EMT199801050	-64.0	5.5
0011:		0.022000	2226	VJV5	1	-84.8	7.0 04F1	20.140	EMT199801050	-81.8	10.9
0012:		0.026000	2528	VJV5	1	-1.9	7.0 04F1	20.140	EMT199801050	2.8	4.2
0013:		0.028000	2252	VJV5	1	25.3	7.0 04F1	20.160	EMT199801050	32.2	5.2

Table 6.3-6 Listing of a Sample <i>Gagemap Document File</i> from NIST's First Gage Block Calibration Workstation											
Column:	10	20	30	40	50	60	70	80			
Row:	123456789012345678901234567890123456789012345678901234567890123456789012										
0014:	0.040000	2435	VJV5	1	64.7	6.2	04F1	20.160	EMT199801050	56.5	1.6
0015:	0.050000	D4249	VJV5	1	-9.4	6.2	04F1	20.180	EMT199801051	-5.8	15.3
0016:	0.078125	040	VJV5	1	-136.2	6.2	04F1	20.190	EMT199801051	-134.9	23.8
0017:	4.000000	4361	1UN6	1	-348.3	10.1	04F1	19.810	EMT199801060	-346.4	11.8
0018:	2.000000	2110	1UN6	1	-159.2	9.4	04F1	19.830	EMT199801060	-144.8	10.4
0019:	0.850000	4793	1UN6	1	-52.8	5.3	04F1	20.110	EMT199801060	-51.2	5.9
0020:	0.750000	5019	1UN6	1	-14.6	5.3	04F1	20.120	EMT199801060	-19.3	5.1
0021:	0.550000	4225	1UN6	1	-3.5	5.3	04F1	20.120	EMT199801061	-12.0	10.8
0022:	0.550000	4225	1UN6	1	-3.5	5.3	04F1	20.120	EMT199801060	-10.9	2.1
0023:	0.450000	6318	1UN6	1	-29.3	4.7	04F1	20.120	EMT199801061	-23.4	11.4
0024:	0.450000	6318	1UN6	1	-29.3	4.7	04F1	20.120	EMT199801060	-30.2	3.1
0025:	0.300000	5835	1UN6	1	-0.5	4.7	04F1	20.130	EMT199801060	-6.2	2.2
.
.
.
1649:	0.550000	4225	1UN6	1	-3.9	5.3	04F1	19.940	SRF199807090	-10.1	5.5
1650:	0.500000	6185	1UN6	1	-49.8	4.7	04F1	19.950	SRF199807090	-56.2	4.1
1651:	0.450000	6318	1UN6	1	-29.2	4.7	04F1	19.950	SRF199807090	-34.9	1.5
1652:	0.400000	5398	1UN6	1	-133.1	4.7	04F1	19.950	SRF199807090	-134.1	7.3
1653:	0.350000	3389	1UN6	1	57.2	4.7	04F1	19.960	SRF199807090	51.2	3.2
1654:	0.300000	5835	1UN6	1	-0.2	4.7	04F1	19.960	SRF199807090	0.9	7.7
1655:	0.250000	6592	1UN6	1	30.3	4.7	04F1	19.970	SRF199807091	17.8	18.3
1656:	0.250000	6592	1UN6	1	30.3	4.7	04F1	19.970	SRF199807090	24.3	7.5
1657:	0.200000	4766	1UN6	1	-205.5	4.7	04F1	19.980	SRF199807090	-212.6	5.9
1658:	0.109375	1029	1UN6	1	12.1	5.0	04F1	19.990	SRF199807090	10.5	6.1

6.4 The *History* Program

The *History* program opens, analyzes, prints, and stores NIST's gage block calibration customers' gage block calibration history. To calibrate and measure NIST's gage block calibration customers' gage blocks, the technical user, who calibrates and measures gage blocks, first uses the *Setup* program to record the *setup information* in *Setup Document Files*, which are DOS ASCII text files. To calibrate and measure gage blocks by mechanical intercomparison, the user uses the *Gage* program in *Gage* mode to analyze measurements from the electro-mechanical

gage block comparators, print the results, and record the results to the *Setup Document Files*. As part of the process to ensure quality assurance, the user uses the **History** program to authenticate past and present calibration and measurement results, which occasionally requisite retests. Once authenticated, the user then merges and records the present calibration and measurement results to the *History Document Files* and creates NIST Reports' of Calibration. To create NIST Reports' of Calibration, the user runs the **Report** program, which uses the *folder information* from the *Folder Document Files* and the stored gage block calibration and measurement results from the **Setup** and **Gage** programs.

The use of the **History** program is the third of three parts of NIST's gage block measurement assurance program. The first part is the continuous calibration and measurement of NIST's master gage blocks by interferometry under process control. The technical user, who calibrates and measures gage blocks, together through using the **Spectrum**, **Edit**, and **Intmap** programs, analyzes and records NIST's master gage block interferometric measurement results from the gage block interferometers and NIST's master gage block interferometric calibration history. After accumulating NIST's master gage block interferometric measurement results, the user plots control charts to individually check the variability of NIST's master gage blocks' interferometric calibration history. When the user uses NIST's master gage blocks to calibrate and measure NIST's gage block calibration customers' gage blocks by mechanical intercomparison, NIST Reports' of Calibration report, for every calibration and measurement, the interferometric measurement uncertainty combined in quadrature with the mechanical intercomparison uncertainty. The second part of NIST's gage block measurement assurance program the user accomplishes together through running the **Gage** program in *Gage* mode to calibrate and measure NIST's gage block calibration customers' gage blocks by mechanical intercomparison and using the **Mecmap** program to analyze NIST's gage block mechanical intercomparison calibration history. Providing process control parameters for the mechanical intercomparison process and estimating measurement process variability is NIST's gage block mechanical intercomparison calibration history, which records the measured differences between the NIST's two master gage blocks used in every calibration and measurement and the derived standard deviations of every calibration and measurement. As the third part of NIST's gage block measurement assurance program, the user uses the **History** program to authenticate past and present calibration and measurement results.

The **History** program simplifies efforts by the technical user, who calibrates and measures gage blocks, to manage and statistically analyze NIST's gage block calibration customers' gage block calibration history. To reduce risks of reporting inaccurate measurements and improve complete measurement confidence, the **History** program helps the user to routinely monitor the following:

- NIST's gage block calibration customers' gage block calibration history
- Individual gage blocks' history in NIST's gage block calibration customers' gage block calibration history

- Offsets of individual gage blocks' history, which are between the latest and all previous calibrations and measurements, in NIST's gage block calibration customers' gage block calibration history
- Gage block sets' offset, which is between averages of the latest and all previous calibrations and measurements, in NIST's gage block calibration customers' gage block calibration history

The **History** program has a *Control Menu* with thirteen functions, as Table 6.4-1 shows. The technical user, who calibrates and measures gage blocks, uses the *Control Menu* functions to do the following:

- Open working *Folder Document Files* and *Setup Document Files*
- Open archived *History Document Files*
- Assemble *New History Document Files* by generating anew or updating NIST's gage block calibration customers' gage block calibration history, merging complete records from opened working *Folder Document Files* and *Setup Document Files*, indexing and reordering all records by gage blocks' nominal sizes, identification or serial numbers, and calibration and measurement dates
- View and print NIST's gage block calibration customers' gage block calibration history
- View, plot, and print individual gage blocks' history in NIST's gage block calibration customers' gage block calibration history
- View, plot, and print the offsets of individual gage blocks' history, which are between the latest and all previous calibrations and measurements, in NIST's gage block calibration customers' gage block calibration history
- View, plot, and print the gage block sets' offset, which is between averages of the latest and all previous calibrations and measurements, in NIST's gage block calibration customers' gage block calibration history
- Load and run the **Edit** program to automatically open archived *History Document Files*
- Archive *New History Document Files* to archived files stored in the DOS ASCII text file storage format

Table 6.4-1 The History Program's Control Menu Functions

Name of Function	Function Description
<i>Program Preface</i> .	This function displays the <i>History</i> program's introductory statement.

Table 6.4-1 The <i>History</i> Program's Control Menu Functions	
Name of Function	Function Description
<i>Open Folder</i>	This function opens a copy of a <i>Folder Document File</i> . The <i>Folder Document Files</i> are working <i>Folder Document Files</i> in the working file storage device and folder, which is <i>C:\Gage\Work</i> . This function copies, deletes, moves, and renames <i>Folder Document Files</i> in file storage devices and folders.
<i>Open Setup</i>	This function opens a copy of a <i>Setup Document File</i> . The <i>Setup Document Files</i> are working <i>Setup Document Files</i> in the working file storage device and folder, which is <i>C:\Gage\Work</i> . This function copies, deletes, moves, and renames <i>Setup Document Files</i> in file storage devices and folders.
<i>Open History</i>	This function opens a copy of a <i>History Document File</i> . The <i>History Document Files</i> are archived <i>History Document Files</i> from the <i>Historys</i> storage device and folder, which is <i>C:\Gage\Historys</i> , and on labeled floppy diskettes. This function copies, deletes, moves, and renames <i>History Document Files</i> in file storage devices and folders.
<i>Run</i>	This function assembles the <i>New History Document File</i> by generating anew or updates an NIST's gage block calibration customer's gage block calibration history or merging complete records from the opened <i>Setup Document File</i> and opened <i>History Document File</i> , reordering all records by the gage blocks' nominal sizes, identification or serial numbers, and calibration and measurement dates.
<i>View</i>	This function opens the <i>New History Document File</i> viewing window with the <i>New History Document File</i> for examining and printing an NIST's gage block calibration customer's gage block calibration history.
<i>Plot</i>	This function opens the <i>New History Document File</i> plotting window with the <i>New History Document File</i> for examining, plotting, and printing individual gage blocks' history in an NIST's gage block calibration customer's gage block calibration history.
<i>Plot Latest Offset</i>	This function opens the <i>New History Document File</i> latest offset plotting window with the <i>New History Document File</i> for examining, plotting, and printing the offsets of individual gage blocks' history, which are between the latest and all previous calibrations and measurements, in an NIST's gage block calibration customer's gage block calibration history.

Table 6.4-1 The <i>History</i> Program's Control Menu Functions	
Name of Function	Function Description
<i>Plot Set Bias</i>	This function opens the <i>New History Document File</i> set offset plotting window with the <i>New History Document File</i> for examining, plotting, and printing the gage block set's offset, which is between averages of the latest and all previous calibrations and measurements, in an NIST's gage block calibration customer's gage block calibration history.
<i>Edit</i>	This function stops the <i>History</i> program and loads and runs the Edit program. When the <i>New History Document File</i> needs archiving, a prompt first appears about archiving the <i>New History Document File</i> and an affirmative response causes the function to archive the <i>New History Document File</i> , stop the History program, and load and run the Edit program, which automatically opens the archived <i>History Document File</i> .
<i>Print</i>	This function prints one copy of the <i>New History Document File</i> to the printer.
<i>Archive</i>	This function archives a copy of the <i>New History Document File</i> to an archived file, such as <i>Filename.his</i> , and stored in the DOS ASCII text file storage format. When a file already exists, a prompt first appears about overwriting the <i>New History Document File</i> to this file or storing the <i>New History Document File</i> to a new file.
<i>Exit HISTORY . . .</i>	This function stops the History program and loads and runs the Branch program. When a <i>New History Document File</i> needs archiving, a prompt first appears about archiving the <i>New History Document File</i> and an affirmative response causes the function to archive the <i>New History Document File</i> and closes all document files opened, which include the <i>Folder Document File</i> , the <i>Setup Document File</i> , the <i>History Document File</i> , and the <i>New History Document File</i> .

The technical user, who calibrates and measures gage blocks, follows established file naming and storing conventions to manage *Folder Document Files*, *Setup Document Files*, *History Document Files*, and *Report Document Files*. The established naming convention for *Folder Document Files*, *Setup Document Files*, *History Document Files*, and *Report Document Files* is limited to eight characters for filenames with a three-character extension and a period separating the filename from the extension. The working *Folder Document Files* are to record all *folder information* and the archived *Folder Document Files* to record *folder information*

exclusive of an NIST test folder number, the purchase order number, internal or group control number, and the date of the NIST Report of Calibration. The working *Setup Document Files* are to record *setup information* and calibration and measurement results and the archived *Setup Document Files* to record only *setup information*. The *History Document Files* are to record calibration and measurement results, which are NIST's gage block calibration customers' gage block calibration history. When customers return gage blocks sets for calibrations, the user retrieves the *folder information* from the archived *Folder Document Files* to create new working *Folder Document Files* and the *setup information* from the archived *Setup Document Files* to create new working *Setup Document Files*. The user stores all working *Folder Document Files*, *Setup Document Files*, and *Report Document Files* in the working file storage device and folder, which is *C:\Gage\Work*, and the archived *Folder Document Files*, *Setup Document Files*, *History Document Files*, and *Report Document Files* in the *Historys* storage device and folder, which is *C:\Gage\Historys*, and on labeled floppy diskettes. For continuity reasons, the user typically assigns common filenames to *Folder Document Files*, *Setup Document Files*, *History Document Files*, and *Report Document Files* for every NIST's gage block calibration customers' calibration. The three-character extension for working *Folder Document Files* is "fdr" and for archived *Folder Document Files* is "fdh," for working *Setup Document Files* is "ids" and for archived *Setup Document Files* is "idh," for *History Document Files* is "his," and for working *Report Document Files* is "rpt" and for archived *Report Document Files* is "rph."

The **History** program assembles a *New History Document File* by generating anew or updates an NIST's gage block calibration customer's gage block calibration history or merging complete records from the opened *Setup Document File* and opened *History Document File*, reordering all records by the gage blocks' nominal sizes, identification or serial numbers, and calibration and measurement dates. This program uses copies opened of either or both the following: working *Setup Document File* in the working file storage device and folder, which is *C:\Gage\Work*, and archived *History Document File* from the *Historys* storage device and folder, which is *C:\Gage\Historys*, and on labeled floppy diskettes. As part of assembling an NIST's gage block calibration customer's gage block calibration history, the technical user, who calibrates and measures gage blocks, completes running the **History** program with archiving a *New History Document File* for future uses. Archiving a *New History Document Files* stores the archived file, such as *Filename.his*, in the DOS ASCII text file storage format.

The **History** program's *Control Menu* has three plotting functions, as Table 6.4-1 shows, to analyze NIST's gage block calibration customers' gage block calibration history by performing linear regression analysis. The technical user, who calibrates and measures gage blocks, uses the plotting functions to analyze and plot the following:

- Individual gage blocks' calibration history
- Offsets of individual gage blocks' calibration history, which are between the latest and all previous calibrations and measurements

- Gage block set's offset, which is between averages of the latest and all previous calibrations and measurements

The plotting functions are analysis tools that perform linear regression analysis by using the “least squares” method to fit lines through sets of observations, which are the measurements. By using linear regression analysis to examine individual gage blocks' calibration history, the technical user, who calibrates and measures gage blocks, can visualize, in charts, the individual gage blocks' history to show patterns or trends clearly, which describes nominal length variations. The analysis tool assumes straight-line relationships between the independent variable, which are the calibrated and measured nominal lengths, and the dependent variable, which are the calibration and measurement dates. In keeping with the NIST policy of the International System of Units (SI) for reporting length in this manual [16], the nominal lengths of gage blocks identify each by name or size. By using linear regression analysis to examine offsets of individual gage blocks' history, the user can visualize, in charts, the offsets of individual gage blocks' history, which are between the latest and all previous calibrations and measurements, to show patterns or trends clearly, which describes compared nominal length variations. The analysis tool assumes straight-line relationships between the independent variable, which are the calibrated and measured nominal lengths, and the dependent variable, which are the dates of the calibrations and measurements. By using linear regression analysis to examine the gage block set's offset, the user can visualize, in charts, the gage block set's offset, which is between averages of the latest and all previous calibrations and measurements, to show patterns or trends clearly, which describes the gage block set's average compared nominal length variations and average process variations.

6.5 The *Intmap* Program

The *Intmap* program opens, analyzes, and prints NIST's master gage block interferometric calibration history. To calibrate and measure NIST's master gage blocks by interferometry, the technical user, who calibrates and measures gage blocks, uses the *Spectrum* program to analyze interferometric measurements from the gage block interferometers and to print the interferometric measurement results, which the user refers as NIST's master gage block interferometric calibration history. To archive NIST's master gage block interferometric calibration history, the user uses the *Edit* program to record the interferometric measurement results to *Intmap Document Files*, which are DOS ASCII text files. The user uses the *Intmap* program to analyze NIST's master gage block interferometric calibration history from the *Intmap Document Files* and to print the interferometric calibration history results, which the user refers as *intmap information*, and the *Master* program is then used to record the interferometric calibration history results, which the user refers as *master information*. The *intmap information* is the master gage blocks' nominal sizes, identification or serial numbers, material codes, interferometrically-derived nominal deviations, and interferometry standard deviations. The

Intmap Document Files organize into groups NIST's master gage blocks' interferometric calibration history gage blocks with common physical length characteristics, which improves the significance of the statistical analyses. The *master information* is the master gage blocks' nominal sizes, identification or serial numbers, material codes, interferometrically-derived nominal deviations, interferometry standard deviations, master gage block mechanical intercomparison controls, master gage block mechanical intercomparison within standard deviations, and master gage block mechanical intercomparison total standard deviations.

The use of the *Intmap* program is the first of three parts of NIST's gage block measurement assurance program. The first part is the continuous calibration and measurement of NIST's master gage blocks by interferometry under process control. The technical user, who calibrates and measures gage blocks, together through using the *Spectrum*, *Edit*, and *Intmap* programs, analyzes and records NIST's master gage block interferometric measurement results from the gage block interferometers and NIST's master gage block interferometric calibration history. After accumulating NIST's master gage block interferometric measurement results, the user plots control charts to individually check the variability of NIST's master gage blocks' interferometric calibration history. When the user use NIST's master gage blocks to calibrate and measure NIST's gage block calibration customers' gage blocks by mechanical intercomparison, NIST Reports' of Calibration report, for every calibration and measurement, the interferometric measurement uncertainty combined in quadrature with the mechanical intercomparison uncertainty. The second part of NIST's gage block measurement assurance program the user accomplishes together through running the *Gage* program in *Gage* mode to calibrate and measure NIST's gage block calibration customers' gage blocks by mechanical intercomparison and using the *Mecmap* program to analyze NIST's gage block mechanical intercomparison calibration history. Providing process control parameters for the mechanical intercomparison process and estimating measurement process variability is NIST's gage block mechanical intercomparison calibration history, which records the measured differences between the NIST's two master gage blocks used in every calibration and measurement and the derived standard deviations of every calibration and measurement. As the third part of NIST's gage block measurement assurance program, the user uses the *History* program to authenticate past and present calibration and measurement results.

The *Intmap* program simplifies efforts by the technical user, who calibrates and measures gage blocks, to manage and statistically analyze NIST's master gage block interferometric calibration history. In the past, to determine the "best" length for each of NIST's master gage blocks from interferometric calibrations, the user used the most recently-gathered data. Today, with the *Intmap* program, to determine or predict the "best" length for each of NIST's master gage blocks, the user uses all NIST's master gage block interferometric calibration history, which makes optimal use of the available information. To improve complete measurement confidence, the *Intmap* program helps the user to routinely monitor NIST's master gage block interferometric calibration history. For NIST's master gage blocks having less than five years of available interferometric calibration history or exhibiting dimensional stability or negligible

length changes, the user uses the *Intmap* program to average the interferometric calibration history for finding “mean” length, which has lower measurement uncertainty than using only the most recently-gathered data. For NIST’s master gage blocks exhibiting general patterns of length changes, the user uses the *Intmap* program to do linear regression analysis by using the “least squares” method to fit lines through sets of measurements for establishing “predicted” length, which has higher measurement uncertainty.

The *Intmap* program has a *Control Menu* with thirteen functions, as Table 6.5-1 shows. The technical user, who calibrates and measures gage blocks, uses the *Control Menu* functions to do the following:

- Customize the *Intmap* program’s current preferences
- Switch between *Intmap Document Files*
- View and print NIST’s master gage block interferometric calibration history
- View, plot, and print individual gage blocks’ history in NIST’s master gage block interferometric calibration history
- Load and run the *Edit* program to automatically open *Intmap Document Files*
- Backup and restore *Intmap Document Files*

Table 6.5-1 The <i>Intmap</i> Program’s Control Menu Functions	
Name of Function	Function Description
<i>Program Preface</i> .	This function displays the <i>Intmap</i> program’s introductory statement.
<i>Preferences</i>	This function opens the <i>Preferences</i> window with the <i>Intmap</i> program’s current preferences. In this window, the computer user customizes the file storage devices and folders that the <i>Intmap</i> program uses to open, backup, and restore <i>Intmap Document Files</i> . Among other preferences in this window, the computer user customizes the method and date that the <i>Intmap</i> program uses to predict future nominal length variations and perform linear regression analysis.
<i>Select</i>	This function prompts the computer user to select among the working <i>Intmap Document Files</i> with NIST’s master gage block interferometric calibration history stored in the working file storage device and folder, which is <i>C:\Gage\Intmaps</i> by default. When the computer user selects an <i>Intmap Document File</i> , this function opens a copy of a <i>Intmap Document File</i> into the <i>Intmap Document File</i> window.

Table 6.5-1 The *Intmap* Program’s Control Menu Functions

Name of Function	Function Description
<i>Run</i>	This function assembles the <i>Intmap Report Document</i> by generating anew a report about NIST’s master gage block interferometric calibration history from the current <i>Intmap Document File</i> in the <i>Intmap Report Document</i> viewing window, recording from all records the master gage blocks’ nominal sizes, identification or serial numbers, current and predicted nominal deviations and standard deviations, latest calibration and measurement dates, and tests to date.
<i>View Report</i>	This function opens the <i>Intmap Report Document</i> viewing window with the current <i>Intmap Report Document</i> .
<i>Print Report</i>	This function prints one copy of the current <i>Intmap Report Document</i> in the <i>Intmap Report Document</i> viewing window to the printer.
<i>Store Report</i>	This function stores the current <i>Intmap Report Document</i> in the <i>Intmap Report Document</i> viewing window to an <i>Intmap Report Document File</i> stored in the DOS ASCII text file storage format in the file storage device and folder that the <i>Intmap</i> program uses, which is <i>C:\Gage\Intmaps</i> by default.
<i>View</i>	This function opens the <i>Intmap Document File</i> viewing window with the current <i>Intmap Document File</i> for examining and printing an NIST’s master gage block interferometric calibration history.
<i>Plot</i>	This function opens the <i>Intmap Document File</i> plotting window with the current <i>Intmap Document File</i> for examining, plotting, and printing individual master gage blocks’ history in an NIST’s master gage block interferometric calibration history
<i>Edit</i>	This function stops the <i>Intmap</i> program and loads and runs the <i>Edit</i> program, which automatically opens the working file of the current <i>Intmap Document File</i> in the <i>Intmap Document File</i> window.
<i>Backup</i>	This function backs up the working file of the current <i>Intmap Document File</i> in the <i>Intmap Document File</i> window or all working <i>Intmap Document Files</i> from the file storage device and folder that the <i>Intmap</i> program uses, which is <i>C:\Gage\Intmaps</i> by default, to backup files each stored in the DOS ASCII text file storage format on labeled floppy diskettes.

Table 6.5-1 The *Intmap* Program's Control Menu Functions

Name of Function	Function Description
<i>Restore</i>	This function restores the working file of the current <i>Intmap Document File</i> in the <i>Intmap Document File</i> window or all working <i>Intmap Document Files</i> from backup files each stored in the DOS ASCII text file storage format on labeled floppy diskettes to the file storage device and folder that the <i>Intmap</i> program uses, which is <i>C:\Gage\Intmaps</i> by default.
<i>Exit INTMAP</i>	This function stops the <i>Intmap</i> program and loads and runs the <i>Branch</i> program. When an <i>Intmap Document File</i> is in the <i>Intmap Document File</i> window, the function closes the current <i>Intmap Document File</i> and <i>Intmap Report Document File</i> windows.

The technical user, who calibrates and measures gage blocks, follows established file naming and storing conventions to manage *Intmap Document Files*. The established naming convention for *Intmap Document Files* is limited to eight characters for filenames with a three-character extension and a period separating the filename from the extension. The working *Intmap Document Files* are to record current *intmap information* and the backed up *Intmap Document Files* to record minimally the current *intmap information*. When working *Intmap Documents Files* are corrupted or lost, the user restores the *intmap information* from the backed up *Intmap Document Files*, which eliminates re-entering all *intmap information*. The user stores all working *Intmap Document Files* in the working file storage device and folder, which is *C:\Gage\Intmaps*, and the backed up *Intmap Document Files* on labeled floppy diskettes.

The *Intmap* program uses *intmap information* in *Intmap Document Files*. The *Intmap Document Files*, as Table 6.5-2 shows, organize into groups NIST's master gage blocks' interferometric calibration history gage blocks with common physical length characteristics, which improves the significance of the statistical analyses. The configuration of *Intmap Document Files*, as Table 6.5-3a, Table 6.5-3b, and Table 6.5-3c show, with *intmap information*, each respectively totaling six fields and extending up to 35 characters, totaling one field and extending up to 80 characters, and totaling five fields and extending up to 80 characters. Header records have "[*SIZE*=" keywords followed by NIST's master gage blocks' nominal sizes, master gage block length unit keywords, "*ID*=" keywords, identification or serial numbers, "*MATERIAL*=" keywords, and names of the gage blocks' materials, which follow with closing square bracket characters. Remark records have remarked statements, which open with all characters except following characters in the first column: [1234567890. Interferometry measurement records have NIST's master gage blocks' testing dates and interferometrically-derived nominal deviations, which follow with remarked statements. The technical user, who

calibrates and measures gage blocks, stores working *Intmap Document Files* in the working file storage device and folder, which is *C:\Gage\Intmaps*. The user backs up the *Intmap Document Files* on labeled floppy diskettes. The listing of a sample working *Intmap Document File*, as Table 6.5-4 shows, has information that the **Gage** program wrote when running in *Gage* mode to calibrate and measure gage blocks at NIST's first gage block calibration workstation.

**Table 6.5-2 Organization Groups of NIST's
Master Gage Block Interferometric
Calibration History in *Intmap Document Files*
and *Intmap Report Document Files***

Group Name	Master Gage Block Nominal Sizes in Group	Name of <i>Intmap</i> <i>Document File</i>	Name of <i>Intmap Report</i> <i>Document File</i>
<i>GROUP 01</i> <i>English Thins</i>	0.010 to 0.09375 Inches	<i>IMAPGRP.001</i>	<i>IMAPRPT.001</i>
<i>GROUP 02</i> <i>English Gage Blocks</i>	0.100 to 0.107 Inches	<i>IMAPGRP.002</i>	<i>IMAPRPT.002</i>
<i>GROUP 03</i> <i>English Gage Blocks</i>	0.108 to 0.126 Inches	<i>IMAPGRP.003</i>	<i>IMAPRPT.003</i>
<i>GROUP 04</i> <i>English Gage Blocks</i>	0.127 to 0.146 Inches	<i>IMAPGRP.004</i>	<i>IMAPRPT.004</i>
<i>GROUP 05</i> <i>English Gage Blocks</i>	0.147 to 0.500 Inches	<i>IMAPGRP.005</i>	<i>IMAPRPT.005</i>
<i>GROUP 06</i> <i>English Gage Blocks</i>	0.550 to 4.000 Inches	<i>IMAPGRP.006</i>	<i>IMAPRPT.006</i>
<i>GROUP 07</i> <i>English Long Blocks</i>	5.0 to 20.0 Inches	<i>IMAPGRP.007</i>	<i>IMAPRPT.007</i>

**Table 6.5-2 Organization Groups of NIST's
Master Gage Block Interferometric
Calibration History in *Intmap Document Files*
and *Intmap Report Document Files***

Group Name	Master Gage Block Nominal Sizes in Group	Name of <i>Intmap</i> Document File	Name of <i>Intmap Report</i> Document File
<i>GROUP 08</i> <i>English 010 Series</i> <i>Thins</i>	0.01005 to 0.019 Inches	<i>IMAPGRP.008</i>	<i>IMAPRPT.008</i>
<i>GROUP 09</i> <i>English 020 Series</i> <i>Thins</i>	0.02005 to 0.029 Inches	<i>IMAPGRP.009</i>	<i>IMAPRPT.009</i>
<i>GROUP 10</i> <i>English 050 Series</i> <i>Thins</i>	0.05005 to 0.059 Inches	<i>IMAPGRP.010</i>	<i>IMAPRPT.010</i>
<i>GROUP 11</i> <i>English Step Gage</i> <i>Blocks</i>	0.100 to 0.1001 Inches (Formerly 0.200 to 0.2001 Inches)	<i>IMAPGRP.011</i>	<i>IMAPRPT.011</i>
<i>GROUP 13</i> <i>Metric Thins</i>	0.10 to 0.95 Millimeters	<i>IMAPGRP.013</i>	<i>IMAPRPT.013</i>
<i>GROUP 14</i> <i>Metric Gage Blocks</i>	1.00 to 1.09 Millimeters	<i>IMAPGRP.014</i>	<i>IMAPRPT.014</i>
<i>GROUP 15</i> <i>Metric Gage Blocks</i>	1.10 to 1.29 Millimeters	<i>IMAPGRP.015</i>	<i>IMAPRPT.015</i>
<i>GROUP 16</i> <i>Metric Gage Blocks</i>	1.30 to 1.49 Millimeters	<i>IMAPGRP.016</i>	<i>IMAPRPT.016</i>
<i>GROUP 17</i> <i>Metric Gage Blocks</i>	1.50 to 2.09 Millimeters	<i>IMAPGRP.017</i>	<i>IMAPRPT.017</i>
<i>GROUP 18</i> <i>Metric Gage Blocks</i>	2.10 to 2.29 Millimeters	<i>IMAPGRP.018</i>	<i>IMAPRPT.018</i>

Table 6.5-2 Organization Groups of NIST’s Master Gage Block Interferometric Calibration History in <i>Intmap Document Files</i> and <i>Intmap Report Document Files</i>			
Group Name	Master Gage Block Nominal Sizes in Group	Name of <i>Intmap</i> Document File	Name of <i>Intmap Report</i> Document File
<i>GROUP 19 Metric Gage Blocks</i>	2.30 to 2.49 Millimeters	<i>IMAPGRP.019</i>	<i>IMAPRPT.019</i>
<i>GROUP 20 Metric Gage Blocks</i>	2.50 to 10.0 Millimeters	<i>IMAPGRP.020</i>	<i>IMAPRPT.020</i>
<i>GROUP 21 Metric Gage Blocks</i>	10.5 to 20.0 Millimeters	<i>IMAPGRP.021</i>	<i>IMAPRPT.021</i>
<i>GROUP 22 Metric Gage Blocks</i>	20.5 to 50 Millimeters	<i>IMAPGRP.022</i>	<i>IMAPRPT.022</i>
<i>GROUP 23 Metric Gage Blocks</i>	60 to 100 Millimeters	<i>IMAPGRP.023</i>	<i>IMAPRPT.023</i>
<i>GROUP 24 Metric Gage Blocks</i>	125 to 500 Millimeters	<i>IMAPGRP.024</i>	<i>IMAPRPT.024</i>

Table 6.5-3a Configuration of the <i>Intmap Document Files</i> Header Records	
Column	Field Description
1-6	This field has the “[SIZE=” keyword, which begins with the opening square bracket character.
7-16	This field has the master gage block nominal size (English: <i>in inches</i> , Metric: <i>in millimeters</i>).
18-21	This field has the master gage block length unit keyword (English: “ <i>INCH</i> ,” Metric: “ <i>MM</i> ”).

Table 6.5-3a Configuration of the <i>Intmap Document Files</i> Header Records	
Column	Field Description
25-27	This field has the “ <i>ID=</i> ” keyword.
28-33	This field has the master gage block identification or serial number (zero to six characters accepted, “NONE” for no identification or serial number is recommended).
37-45	This field has the “ <i>MATERIAL=</i> ” keyword.
46-62	This field has the name of the master gage block material (e.g., “ <i>STEEL,</i> ” “ <i>CERAMIC,</i> ” “ <i>CHROME CARBIDE,</i> ” “ <i>TUNGSTEN CARBIDE,</i> ” and “ <i>STAINLESS STEEL</i> ”), which follows with the closing square bracket character.

Table 6.5-3b Configuration of the <i>Intmap Document Files</i> Remarked Records	
Column	Field Description
1-80	This field has the remarked statement. Do not use the following characters in the first column: [1234567890.

Table 6.5-3c Configuration of the <i>Intmap Document Files</i> Interferometry Measurement Records	
Column	Field Description
1-4	This field has the year for the testing date, four numeric digit characters with leading zeros displayed, century mandatory.
5-6	This field has the month for the testing date, two numeric digit characters with leading zeros displayed (January: <i>01</i> , February: <i>02</i> , March: <i>03</i> , April: <i>04</i> , May: <i>05</i> , June: <i>06</i> , July: <i>07</i> , August: <i>08</i> , September: <i>09</i> , October: <i>10</i> , November: <i>11</i> , December: <i>12</i>).

Table 6.5-3c Configuration of the <i>Intmap Document Files</i> Interferometry Measurement Records	
Column	Field Description
7-8	This field has the day of the month for the testing date, two numeric digit characters with leading zeros displayed (1 st Day of Month: 01, 2 nd Day of Month: 02, 3 rd Day of Month: 03, . . . , 31 st Day of Month: 31).
10-16	This field has the master gage block interferometrically-derived nominal deviation, in nanometers.
17-80	This field has the end-of-line remarked statement. Do use all characters.

Table 6.5-4 Listing of a Sample <i>Intmap Document File</i> for Group One of NIST’s Gage Block Interferometric Calibration History	
Column:	10 20 30 40 50 60 70 80
Row:	▼ ▼ ▼ ▼ ▼ ▼ ▼ ▼
0001:	[SIZE= 0.010000 INCH ID=6537 MATERIAL=STEEL]
0002:	\$ 0.00 THN ST REC DOALL
0003:	#ONE DOT (*) MASTERS - Replaced SN: 4154 3/94
0004:	19940301 106.7
0005:	19940301 81.3
0006:	19940301 101.6
0007:	[SIZE= 0.010000 INCH ID=VJV5 MATERIAL=CC]
0008:	\$ 0.00 THN CC REC CROBLOX
0009:	#TWO DOT (**) MASTERS NEW 10/94
0010:	19941001 51.0
0011:	19941001 28.0
0012:	19941001 28.0
0013:	19941001 51.0
0014:	19941001 18.0
0015:	19941001 41.0
0016:	19960301 -9.0
0017:	19960301 26.0
0018:	19960301 4.0
0019:	[SIZE= 0.010050 INCH ID=4527 MATERIAL=STEEL]
0020:	\$ 0.00 THN ST REC DOALL

Table 6.5-4 Listing of a Sample *Intmap Document File* for Group One of NIST’s Gage Block Interferometric Calibration History

Column:	10	20	30	40	50	60	70	80
	▼	▼	▼	▼	▼	▼	▼	▼
Row:	123456789012345678901234567890123456789012345678901234567890123456789012							
0021:	#ONE DOT (*) MASTERS							
0022:	19630101	99.1						
0023:	19670101	88.9						
0024:	19830101	22.9						
0025:	19880316	121.9						
0026:	19880316	129.5						
0027:	19880316	132.1						
0028:	19900401	111.8						
0029:	19900401	94.0						
0030:	19900401	96.5						
0031:	19940701	109.2						
0032:	19940701	101.6						
0033:	19940701	101.6						
0034:	[SIZE= 0.010050 INCH ID=VJV5 MATERIAL=CC]							
0035:	\$ 0.00 THN CC REC CROBLOX							
0036:	#TWO DOT (**) MASTERS NEW 10/94							
0037:	19941001	71.0						
0038:	19941001	10.0						
0039:	19941001	10.0						
0040:	19941001	41.0						
0041:	19941001	74.0						
0042:	19941001	46.0						
0043:	19960301	34.0						
.
.
.
0446:	19960301	-58.0						
0447:	19960301	-54.0						
0448:	[SIZE= 0.093750 INCH ID=043 MATERIAL=STEEL]							
0449:	\$ 0.00 THN ST REC HOMMEL							
0450:	#ONE DOT (*) MASTERS							
0451:	19590101	43.2						
0452:	19630101	17.8						
0453:	19670101	10.2						
0454:	19830101	7.6						
0455:	19880323	20.3						

Table 6.5-4 Listing of a Sample <i>Intmap Document File</i> for Group One of NIST's Gage Block Interferometric Calibration History									
Column:	10	20	30	40	50	60	70	80	
Row:	123456789012345678901234567890123456789012345678901234567890123456789012	123456789012345678901234567890123456789012345678901234567890123456789012	123456789012345678901234567890123456789012345678901234567890123456789012	123456789012345678901234567890123456789012345678901234567890123456789012	123456789012345678901234567890123456789012345678901234567890123456789012	123456789012345678901234567890123456789012345678901234567890123456789012	123456789012345678901234567890123456789012345678901234567890123456789012	123456789012345678901234567890123456789012345678901234567890123456789012	123456789012345678901234567890123456789012345678901234567890123456789012
0456:	19880323	-15.2							
0457:	19880323	5.1							
0458:	19900301	-10.2							
0459:	19900301	7.6							
0460:	19900301	-5.1							
0461:	19900301	15.2							
0462:	19940301	12.7							
0463:	19940301	10.2							
0464:	19940301	22.9							
0465:	[SIZE= 0.093750 INCH ID=VJV5 MATERIAL=CC]								
0466:	\$ 0.00 THN CC REC CROBLOX								
0467:	#TWO DOT (**) MASTERS NEW 10/94								
0468:	19941001	3.0							
0469:	19941001	30.0							
0470:	19941001	25.0							
0471:	19941001	25.0							
0472:	19941001	23.0							
0473:	19941001	56.0							
0474:	19960301	37.0							

The *Intmap* program's *Control Menu* has a plotting function, as Table 6.5-1 shows, to analyze NIST's master gage block interferometric calibration history by performing linear regression analysis. The technical user, who calibrates and measures gage blocks, uses the plotting function to analyze and plot the individual gage blocks' interferometric calibration history. The plotting function is an analysis tool that performs linear regression analysis by using the "least squares" method to fit lines through sets of observations, which are the measurements. By using linear regression analysis to examine individual gage blocks' calibration history, the user can visualize, in charts, the individual gage blocks' history to show patterns or trends clearly, which describes nominal length variations. The analysis tool assumes straight-line relationships between the independent variable, which are the calibrated and measured nominal lengths, and the dependent variable, which are the calibration and measurement dates. For individual gage blocks' history in NIST's master gage block interferometric calibration history, the *Intmap* program's features afford the user to compute the best fit line through interferometric calibration history with significant slopes or to compute the average with no significant slope.

The *Intmap* program determines slopes insignificant with less than five years of available interferometric calibration history or the computed slope is within the three-sigma standard deviation confidence level.

6.6 The *Master* Program

The *Master* program opens, prints, and stores current information about NIST's master gage blocks. As part of the process of starting any NIST's gage block calibration customers' calibrations, the technical user, who calibrates and measures gage blocks, uses the *Master* program to record current information about NIST's master gage blocks, which the user refers as *master information*. This *master information* is the master gage blocks' nominal sizes, identification or serial numbers, material codes, interferometrically-derived nominal deviations, interferometry standard deviations, master gage block mechanical intercomparison controls, master gage block mechanical intercomparison within standard deviations, and master gage block mechanical intercomparison total standard deviations. The user uses the *Master* program to record the *master information* in *Master Document Files*, which are DOS ASCII text files. To calibrate and measure NIST's master gage blocks by interferometry, the user uses the *Spectrum* program to analyze interferometric measurements from the gage block interferometers and to print the interferometric measurement results, the *Intmap* program to analyze the master gage block interferometric calibration history and to print the interferometric calibration history results, and the *Master* program is then used to record the interferometric calibration history results. Before calibrating and measuring any NIST's gage block calibration customers' gage blocks by mechanical intercomparison, the user finds through the brute force method the NIST's master gage block mechanical intercomparison controls using the electro-mechanical gage block comparators, estimates the master gage block mechanical intercomparison within standard deviations and master gage block mechanical intercomparison total standard deviations, and records the results to the *Master Document Files*. After calibrating and measuring NIST's gage block calibration customers' gage blocks by mechanical intercomparison for at least one year, the user uses the *Mecmap* program to compute NIST's master gage block mechanical intercomparison controls, the master gage block mechanical intercomparison within standard deviations, and the master gage block mechanical intercomparison total standard deviations, and records the results to the *Master Document Files*.

The *Master* program has a *Control Menu* with eight functions, as Table 6.6-1 shows. The technical user, who calibrates and measures gage blocks, uses the *Control Menu* functions to do the following:

- Switch between *Master Document Files*
- Edit, print, and store *Master Document Files*
- Backup and restore *Master Document Files*

- View *Master Document Files*

Table 6.6-1 The <i>Master</i> Program's Control Menu Functions	
Name of Function	Function Description
<i>Program Preface .</i>	This function displays the Master program's introductory statement.
<i>Masters</i>	This function switches between <i>Master Document Files</i> in respective <i>Master Document File</i> windows.
<i>View</i>	This function opens the <i>Master Document File</i> editing window with the current <i>Master Document File</i> .
<i>Print</i>	This function prints one copy of the current <i>Master Document File</i> to the printer.
<i>Store</i>	This function stores a copy of the current <i>Master Document File</i> in the current <i>Master Document File</i> window to a working file, <i>Engmstr.gbk</i> for English master gage blocks, <i>Metmstr.gbk</i> for metric master gage blocks, and both files stored in the DOS ASCII text file storage format.
<i>Backup</i>	This function backs up the working file of the current <i>Master Document File</i> in the current <i>Master Document File</i> window to a backup file, <i>Engmstr.gbk</i> for English master gage blocks, <i>Metmstr.gbk</i> for metric master gage blocks, and both files stored in the DOS ASCII text file storage format on labeled floppy diskettes.
<i>Restore</i>	This function restores the backup file of the current <i>Master Document File</i> in the current <i>Master Document File</i> window from a backup file, <i>Engmstr.gbk</i> for English master gage blocks, <i>Metmstr.gbk</i> for metric master gage blocks, and both files stored in the DOS ASCII text file storage format on labeled floppy diskettes.
<i>Exit MASTER</i>	This function stops the Master program and loads and runs the Branch program. When a <i>Master Document File</i> is in the current <i>Master Document File</i> window, a prompt first appears about storing the current <i>Master Document File</i> and an affirmative response causes the function to store the current <i>Master Document File</i> and close the current <i>Master Document File</i> window.

The technical user, who calibrates and measures gage blocks, follows established file naming and storing conventions to manage *Master Document Files*. The established naming

convention for *Master Document Files* is limited to eight characters for filenames with a three-character extension and a period separating the filename from the extension (e.g., *Engmstr.gbk* for English master gage blocks, *Metmstr.gbk* for metric master gage blocks). The working *Master Document Files* are to record current *master information* and the backed up *Master Document Files* to record minimally the current *master information*. When working *Master Documents Files* are corrupted or lost, the user restores the *master information* from the backed up *Master Document Files*, which eliminates re-entering all *master information*. The user stores all working *Master Document Files* in the working file storage device and folder, which is *C:\Gage\Masters*, and the backed up *Master Document Files* on labeled floppy diskettes.

The **Master** program stores *master information* in *Master Document Files*. The configuration of the *Master Document Files*, as Table 6.6-2 shows, with *master information*, each totaling twelve fields and extending 80 characters. This *master information* is the master gage blocks' nominal sizes, identification or serial numbers, material codes, interferometrically-derived nominal deviations, interferometry standard deviations, master gage block mechanical intercomparison controls, master gage block mechanical intercomparison within standard deviations, and master gage block mechanical intercomparison total standard deviations. The technical user, who calibrates and measures gage blocks, stores working *Master Document Files* in the working file storage device and folder, which is *C:\Gage\Masters*. The user backs up the *Master Document Files* on labeled floppy diskettes. The listing of the *Master Document File*, named *Engmstr.gbk*, as Table 6.6-3 shows, has the latest information for NIST's English master gage blocks. The listing of the *Master Document File*, named *Metmstr.gbk*, as Table 6.6-4 shows, has the latest information for NIST's metric master gage blocks.

Table 6.6-2 Configuration of the English and Metric <i>Master Document Files</i>	
Column	Field Description
1-10	This field has the master gage block nominal size (English: <i>in inches</i> , Metric: <i>in millimeters</i>).
12-17	This field has the standard master gage block identification or serial number (zero to six characters accepted, "NONE" for no identification or serial number is recommended).
19-24	This field has the check standard master gage block identification or serial number (zero to six characters accepted, "NONE" for no identification or serial number is recommended).

Table 6.6-2 Configuration of the English and Metric Master Document Files	
Column	Field Description
26-29	This field has the standard master gage block material code, four numeric digit characters with leading zeros displayed (Steel: 0001, Ceramic: 0002, Chrome Carbide: 0003, Tungsten Carbide: 0004, Stainless Steel: 0005, and Other: 0006).
31-34	This field has the check standard master gage block material code, four numeric digit characters with leading zeros displayed (Steel: 0001, Ceramic: 0002, Chrome Carbide: 0003, Tungsten Carbide: 0004, Stainless Steel: 0005, and Other: 0006).
37-41	This field has the standard master gage block interferometrically-derived nominal deviation, in nanometers.
43-47	This field has the check standard master gage block interferometrically-derived nominal deviation, in nanometers.
49-53	This field has the standard master gage block interferometry standard deviation, in nanometers.
55-59	This field has the check standard master gage block interferometry standard deviation, in nanometers.
61-68	This field has the master gage block mechanical intercomparison control, in nanometers.
70-74	This field has the master gage block mechanical intercomparison within standard deviation, in nanometers.
76-80	This field has the master gage block mechanical intercomparison total standard deviation, in nanometers.

Table 6.6-3 Latest Listing of the Engmstr.gbk File															
	Column:	10	20	30	40	50	60	70	80						
		▼	▼	▼	▼	▼	▼	▼	▼						
Row:		1	2	3	4	5	6	7	8	9	10				
0001:		0	.01	0000	6537	VJV5	0001	0003	97	26	25.0	13.0	73.7	6.6	8.5

Table 6.6-3 Latest Listing of the *Engmstr.gbk* File

Column:	10	20	30	40	50	60	70	80				
Row:	1	2	3	4	5	6	7	8	9	10	11	12
0002:	0.010050	4527	VJV5	0001	0003	101	41	12.5	25.0	36.4	6.6	8.5
0003:	0.010100	5113	VJV5	0001	0003	104	-54	5.7	25.0	116.6	6.5	10.8
0004:	0.010200	5116	W7W17	0001	0003	83	49	13.0	13.0	37.7	6.5	10.8
0005:	0.010300	5108	VJV5	0001	0003	105	-85	7.6	25.0	224.8	6.5	10.8
0006:	0.010400	3215	VJV5	0001	0003	40	-10	13.0	13.0	78.4	6.5	10.8
0007:	0.010500	5101	VJV5	0001	0003	-3	54	10.9	13.0	-52.0	6.5	10.8
0008:	0.010600	5108	VJV5	0001	0003	10	-104	13.0	25.0	106.8	6.5	10.8
0009:	0.010700	1007	VJV5	0001	0003	22	-26	7.7	13.0	49.7	6.5	10.8
0010:	0.010800	5105	VJV5	0001	0003	-5	-6	13.0	5.9	31.0	6.5	10.8
0011:	0.010900	5106	VJV5	0001	0003	2	13	5.5	13.0	5.7	6.5	10.8
0012:	0.011000	3105	VJV5	0001	0003	13	45	10.3	11.6	12.4	6.5	10.8
0013:	0.012000	1107	VJV5	0001	0003	-88	-34	6.1	8.4	-59.7	6.5	10.8
0014:	0.013000	6110	VJV5	0001	0003	122	-51	10.0	2.7	145.6	6.5	10.8
0015:	0.014000	5105	VJV5	0001	0003	72	33	8.1	13.0	62.8	6.5	10.8
0016:	0.015000	6216	VJV5	0001	0003	49	-13	10.7	5.3	111.1	6.5	10.8
0017:	0.015625	1225	VJV5	0001	0003	-41	2	8.7	9.5	-32.2	6.6	8.5
0018:	0.016000	5112	VJV5	0001	0003	55	1	13.4	11.1	8.2	6.5	10.8
0019:	0.017000	6103	VJV5	0001	0003	114	49	11.9	13.0	81.2	6.5	10.8
0020:	0.018000	1108	VJV5	0001	0003	45	-18	3.1	7.1	68.7	6.5	10.8
0021:	0.019000	6103	VJV5	0001	0003	61	-54	8.9	10.2	132.7	6.5	10.8
0022:	0.020000	3126	VJV5	0001	0003	51	59	8.9	25.0	-46.4	6.6	8.5
0023:	0.020050	1017	VJV5	0001	0003	113	-67	11.1	13.0	131.6	6.6	8.5
0024:	0.020100	2016	VJV5	0001	0003	111	56	6.6	25.0	27.2	7.6	9.1
0025:	0.020200	2609	VJV5	0001	0003	50	49	9.6	13.0	-33.5	7.6	9.1
0026:	0.020300	2358	VJV5	0001	0003	80	78	9.1	21.2	-42.1	7.6	9.1
0027:	0.020400	2322	VJV5	0001	0003	60	55	7.7	9.0	-36.2	7.6	9.1
0028:	0.020500	2807	VJV5	0001	0003	105	35	7.1	25.0	32.4	7.6	9.1
0029:	0.020600	2124	VJV5	0001	0003	90	4	5.6	8.2	56.1	7.6	9.1
0030:	0.020700	059	VJV5	0001	0003	75	14	8.3	9.2	8.4	7.6	9.1
0031:	0.020800	2559	VJV5	0001	0003	15	39	7.1	25.0	-79.6	7.6	9.1
0032:	0.020900	2638	VJV5	0001	0003	29	103	13.9	5.6	-64.7	7.6	9.1
0033:	0.021000	2428	VJV5	0001	0003	138	28	10.3	20.0	114.2	7.6	9.1
0034:	0.022000	2226	VJV5	0001	0003	-50	-1	9.5	13.0	-84.5	7.6	9.1
0035:	0.023000	2355	VJV5	0001	0003	-45	-32	6.0	12.8	26.0	7.6	9.1
0036:	0.024000	2728	VJV5	0001	0003	98	41	6.9	21.0	22.2	7.6	9.1
0037:	0.025000	2323	VJV5	0001	0003	49	39	10.3	10.2	-14.8	7.6	9.1
0038:	0.026000	2528	VJV5	0001	0003	-20	-1	8.3	5.2	0.6	7.6	9.1
0039:	0.027000	061	VJV5	0001	0003	110	27	8.9	25.0	24.5	7.6	9.1
0040:	0.028000	2252	VJV5	0001	0003	93	44	5.5	21.3	27.4	7.6	9.1

Table 6.6-3 Latest Listing of the *Engmstr.gbk* File

Column:	10	20	30	40	50	60	70	80				
Row:	1	2	3	4	5	6	7	8	9	10	11	12
0041:	0.029000	2133	VJV5	0001 0003	9	87	6.0	8.2	-75.2	7.6	9.1	
0042:	0.030000	063	VJV5	0001 0003	-39	-25	9.5	8.1	-24.0	6.6	8.5	
0043:	0.031250	2306	VJV5	0001 0003	20	53	4.5	25.0	-63.6	6.6	8.5	
0044:	0.040000	2435	VJV5	0001 0003	84	29	7.5	13.0	53.9	6.6	8.5	
0045:	0.046875	1859	VJV5	0001 0003	15	0	7.3	13.0	23.0	6.6	8.5	
0046:	0.050000	D4249	VJV5	0001 0003	21	47	8.0	10.0	-11.0	6.6	8.5	
0047:	0.050050	S	ZWV25	0001 0003	-93	5	9.7	10.1	-78.4	6.6	8.5	
0048:	0.050100	S	PMS-1	0001 0003	-153	-3	8.7	5.3	-116.7	5.6	10.4	
0049:	0.050200	S	PMS-1	0001 0003	-119	3	10.8	5.6	-76.7	5.6	10.4	
0050:	0.050300	S	PMS-1	0001 0003	-61	-6	9.5	4.5	-60.9	5.6	10.4	
0051:	0.050400	S	PMS-1	0001 0003	-74	-3	12.3	4.9	-51.5	5.6	10.4	
0052:	0.050500	S	PMS-1	0001 0003	-155	41	8.0	5.4	-176.6	5.6	10.4	
0053:	0.050600	S	PMS-1	0001 0003	-115	16	12.1	5.9	-119.9	5.6	10.4	
0054:	0.050700	S	PMS-1	0001 0003	-54	29	11.1	5.5	-82.6	5.6	10.4	
0055:	0.050800	S	PMS-1	0001 0003	-95	39	8.4	3.0	-114.6	5.6	10.4	
0056:	0.050900	S	PMS-1	0001 0003	-108	63	6.6	4.6	-171.8	5.6	10.4	
0057:	0.051000	3 15	PMS-1	0001 0003	58	38	8.5	7.3	37.2	5.6	10.4	
0058:	0.052000	4 06	PMS-1	0001 0003	207	4	5.0	7.7	184.7	5.6	10.4	
0059:	0.053000	3 29	PMS-1	0001 0003	10	60	5.4	8.1	-97.6	5.6	10.4	
0060:	0.054000	3 28	PMS-1	0001 0003	-6	12	8.6	6.6	-26.1	5.6	10.4	
0061:	0.055000	3 24	PMS-1	0001 0003	212	-29	6.9	4.0	224.6	5.6	10.4	
0062:	0.056000	4 26	PMS-1	0001 0003	120	20	6.1	11.0	46.6	5.6	10.4	
0063:	0.057000	3 12	PMS-1	0001 0003	-14	0	4.9	7.1	-11.6	5.6	10.4	
0064:	0.058000	3 26	PMS-1	0001 0003	35	-11	6.3	4.8	64.2	5.6	10.4	
0065:	0.059000	3 25	PMS-1	0001 0003	-61	19	10.1	6.4	-79.0	5.6	10.4	
0066:	0.060000	2230	VJV5	0001 0003	97	-2	5.4	7.3	65.9	6.6	8.5	
0067:	0.062500	2160	VJV5	0001 0003	27	41	9.2	11.5	-50.3	6.6	8.5	
0068:	0.070000	065	VJV5	0001 0003	-9	28	7.4	13.0	-44.6	6.6	8.5	
0069:	0.078125	040	VJV5	0001 0003	-115	25	5.6	25.0	-137.2	6.6	8.5	
0070:	0.080000	2218	VJV5	0001 0003	19	24	9.5	9.2	-15.8	6.6	8.5	
0071:	0.090000	066	VJV5	0001 0003	15	-35	9.3	23.4	22.1	6.6	8.5	
0072:	0.093750	043	VJV5	0001 0003	10	28	5.3	25.0	-31.8	6.6	8.5	
0073:	0.100000	5 83	1UN6	0001 0003	5	-27	4.4	13.0	20.5	4.7	5.7	
0074:	0.100005			0001 0001	0	0	0.0	0.0	0.0	0.0	0.0	
0075:	0.100010	S.	S..	0001 0001	0	0	12.7	12.7	0.0	0.0	0.0	
0076:	0.100015			0001 0001	0	0	0.0	0.0	0.0	0.0	0.0	
0077:	0.100020	S.	S..	0001 0001	0	0	12.7	12.7	0.0	0.0	0.0	
0078:	0.100025	3320	1UN6	0001 0003	65	35	4.0	13.0	20.6	4.7	5.7	
0079:	0.100030	S.	S..	0001 0001	0	0	12.7	12.7	0.0	0.0	0.0	

Table 6.6-3 Latest Listing of the *Engmstr.gbk File*

Column:	10	20	30	40	50	60	70	80				
Row:	1	2	3	4	5	6	7	8	9	10	11	12
0080:	0.100035		0001 0001	0	0	0.0	0.0	0.0	0.0	0.0		
0081:	0.100040	S.	S..	0001 0001	0	0	12.7	12.7	0.0	0.0	0.0	
0082:	0.100045		0001 0001	0	0	0.0	0.0	0.0	0.0	0.0		
0083:	0.100050	1986	1UN6	0001 0003	41	39	5.2	13.0	-22.6	4.7	5.7	
0084:	0.100055		0001 0001	0	0	0.0	0.0	0.0	0.0	0.0		
0085:	0.100060	S.	S..	0001 0001	0	0	12.7	12.7	0.0	0.0	0.0	
0086:	0.100065		0001 0001	0	0	0.0	0.0	0.0	0.0	0.0		
0087:	0.100070	S.	S..	0001 0001	0	0	12.7	12.7	0.0	0.0	0.0	
0088:	0.100075	8 06	1UN6	0001 0003	109	39	5.2	13.0	64.3	4.7	5.7	
0089:	0.100080	S.	S..	0001 0001	0	0	12.7	12.7	0.0	0.0	0.0	
0090:	0.100085		0001 0001	0	0	0.0	0.0	0.0	0.0	0.0		
0091:	0.100090	S.	S..	0001 0001	0	0	12.7	12.7	0.0	0.0	0.0	
0092:	0.100095		0001 0001	0	0	0.0	0.0	0.0	0.0	0.0		
0093:	0.100100	3688	1UN6	0001 0003	46	56	4.6	13.0	-27.5	4.7	5.7	
0094:	0.100200	3 45	1UN6	0001 0003	41	11	5.9	13.0	23.9	4.7	5.7	
0095:	0.100300	D4815	1UN6	0001 0003	-52	62	4.6	8.5	-102.3	4.7	5.7	
0096:	0.100400	D4321	1UN6	0001 0003	84	2	3.9	13.0	81.9	4.7	5.7	
0097:	0.100500	4756	1UN6	0001 0003	-5	35	5.6	7.8	-54.4	4.7	5.7	
0098:	0.100600	D4063	1UN6	0001 0003	89	27	4.4	13.0	74.3	4.7	5.7	
0099:	0.100700	D4601	1UN6	0001 0003	74	16	3.8	13.0	56.0	4.7	5.7	
0100:	0.100800	3 42	1UN6	0001 0003	57	4	5.1	11.8	57.4	4.7	5.7	
0101:	0.100900	D4261	1UN6	0001 0003	87	-8	4.7	13.0	99.7	4.7	5.7	
0102:	0.101000	3316	1UN6	0001 0003	0	29	5.8	11.7	-15.3	4.7	5.7	
0103:	0.102000	3 15	1UN6	0001 0003	22	2	5.0	8.8	7.3	4.7	5.7	
0104:	0.103000	3359	1UN6	0001 0003	101	-1	6.6	13.0	82.5	4.7	5.7	
0105:	0.104000	D4512	1UN6	0001 0003	58	42	7.4	12.1	5.3	4.7	5.7	
0106:	0.105000	4178	1UN6	0001 0003	27	24	5.9	11.6	-3.6	4.7	5.7	
0107:	0.106000	3371	1UN6	0001 0003	35	51	6.7	13.0	-4.8	4.7	5.7	
0108:	0.107000	D4504	1UN6	0001 0003	70	23	4.7	13.0	23.0	4.7	5.7	
0109:	0.108000	D4206	1UN6	0001 0003	39	-1	4.3	13.0	45.9	5.0	6.9	
0110:	0.109000	D4662	1UN6	0001 0003	45	11	6.4	9.5	23.1	5.0	6.9	
0111:	0.109375	1029	1UN6	0001 0003	-3	-9	3.8	13.0	12.1	5.0	6.9	
0112:	0.110000	D4552	1UN6	0001 0003	-29	-17	4.4	13.0	-33.8	5.0	6.9	
0113:	0.111000	D1344	1UN6	0001 0003	36	35	3.2	13.0	-8.7	5.0	6.9	
0114:	0.112000	3161	1UN6	0001 0003	20	13	5.7	13.0	14.6	5.0	6.9	
0115:	0.113000	D1446	1UN6	0001 0003	-49	16	3.7	8.7	-101.7	5.0	6.9	
0116:	0.114000	D1859	1UN6	0001 0003	-41	58	4.9	13.0	-91.8	5.0	6.9	
0117:	0.115000	D1243	1UN6	0001 0003	55	12	5.0	13.0	36.7	5.0	6.9	
0118:	0.116000	D1222	1UN6	0001 0003	59	6	3.3	8.1	47.8	5.0	6.9	

Table 6.6-3 Latest Listing of the *Engmstr.gbk* File

	Column: 10	20	30	40	50	60	70	80			
Row:	1	2	3	4	5	6	7	8			
0119:	0.117000	D1402	1UN6	0001 0003	-50	27	3.5	13.0	-94.2	5.0	6.9
0120:	0.118000	D1713	1UN6	0001 0003	33	58	4.9	13.0	-45.6	5.0	6.9
0121:	0.119000	D1154	1UN6	0001 0003	35	15	4.1	5.3	3.9	5.0	6.9
0122:	0.120000	D4517	1UN6	0001 0003	8	1	5.2	10.6	4.3	5.0	6.9
0123:	0.121000	2617	1UN6	0001 0003	87	7	4.8	13.0	34.3	5.0	6.9
0124:	0.122000	9937	1UN6	0001 0003	92	42	3.2	12.8	33.6	5.0	6.9
0125:	0.123000	D1924	1UN6	0001 0003	22	22	4.6	6.7	-30.3	5.0	6.9
0126:	0.124000	D1551	1UN6	0001 0003	-51	-13	4.7	11.7	-64.0	5.0	6.9
0127:	0.125000	D3145	1UN6	0001 0003	-7	-36	5.7	13.0	15.8	5.0	6.9
0128:	0.126000	2762	1UN6	0001 0003	59	18	3.3	13.0	49.2	5.0	6.9
0129:	0.127000	1 29	1UN6	0001 0003	57	16	5.3	8.8	9.5	4.7	5.6
0130:	0.128000	2452	1UN6	0001 0003	21	23	6.9	13.0	-11.9	4.7	5.6
0131:	0.129000	9911	1UN6	0001 0003	93	21	6.7	13.0	57.0	4.7	5.6
0132:	0.130000	3475	1UN6	0001 0003	-5	9	7.4	13.0	-31.1	4.7	5.6
0133:	0.131000	D1929	1UN6	0001 0003	-42	13	4.5	13.0	-95.7	4.7	5.6
0134:	0.132000	D1712	1UN6	0001 0003	16	41	5.7	13.0	-52.6	4.7	5.6
0135:	0.133000	D1309	1UN6	0001 0003	46	18	6.7	13.0	20.6	4.7	5.6
0136:	0.134000	9938	1UN6	0001 0003	72	36	6.1	13.0	-2.4	4.7	5.6
0137:	0.135000	D1160	1UN6	0001 0003	13	-14	4.3	13.0	18.2	4.7	5.6
0138:	0.136000	D1005	1UN6	0001 0003	78	46	5.3	13.0	19.0	4.7	5.6
0139:	0.137000	D1851	1UN6	0001 0003	57	31	3.9	13.0	17.5	4.7	5.6
0140:	0.138000	2 23	1UN6	0001 0003	63	-2	5.8	13.0	37.4	4.7	5.6
0141:	0.139000	3260	1UN6	0001 0003	-5	2	6.4	13.0	21.2	4.7	5.6
0142:	0.140000	3431	1UN6	0001 0003	75	36	8.8	13.0	30.5	4.7	5.6
0143:	0.141000	D1132	1UN6	0001 0003	45	-4	4.9	9.9	39.9	4.7	5.6
0144:	0.142000	D1353	1UN6	0001 0003	-5	6	4.7	13.0	-35.1	4.7	5.6
0145:	0.143000	D1649	1UN6	0001 0003	-46	12	7.7	13.0	-69.1	4.7	5.6
0146:	0.144000	D1358	1UN6	0001 0003	-30	49	4.8	12.5	-94.9	4.7	5.6
0147:	0.145000	D1140	1UN6	0001 0003	13	33	6.8	13.0	-43.3	4.7	5.6
0148:	0.146000	D1754	1UN6	0001 0003	-21	11	4.0	12.6	-67.4	4.7	5.6
0149:	0.147000	D1230	1UN6	0001 0003	28	47	2.7	13.0	-24.8	4.7	5.1
0150:	0.148000	D1244	1UN6	0001 0003	23	43	4.4	13.0	-36.7	4.7	5.1
0151:	0.149000	D1707	1UN6	0001 0003	25	19	5.0	13.0	-23.3	4.7	5.1
0152:	0.150000	D5219	1UN6	0001 0003	-29	6	3.6	13.0	-33.4	4.7	5.1
0153:	0.160000	3340	1UN6	0001 0003	154	-11	8.3	10.3	137.3	4.7	5.1
0154:	0.170000	8650	1UN6	0001 0003	45	12	4.9	13.0	16.5	4.7	5.1
0155:	0.180000	8632	1UN6	0001 0003	27	-19	5.3	13.0	27.6	4.7	5.1
0156:	0.190000	8444	1UN6	0001 0003	58	-12	10.6	13.0	27.8	4.7	5.1
0157:	0.200000	4766	1UN6	0001 0003	-230	3	6.6	13.0	-205.5	4.7	5.1

Table 6.6-3 Latest Listing of the <i>Engmstr.gbk</i> File												
Column:	10	20	30	40	50	60	70	80				
Row:	1	2	3	4	5	6	7	8	9	10	11	12
0158:	0.250000	6592	1UN6	0001	0003	73	27	6.0	13.0	30.3	4.7	5.1
0159:	0.300000	5835	1UN6	0001	0003	70	40	7.8	13.0	-0.2	4.7	5.1
0160:	0.350000	3389	1UN6	0001	0003	65	-13	8.4	13.0	57.2	4.7	5.1
0161:	0.400000	5398	1UN6	0001	0003	-33	73	5.0	13.0	-133.1	4.7	5.1
0162:	0.450000	6318	1UN6	0001	0003	25	39	8.2	13.0	-29.2	4.7	5.1
0163:	0.500000	6185	1UN6	0001	0003	24	57	9.1	13.0	-49.8	4.7	5.1
0164:	0.550000	4225	1UN6	0001	0003	59	58	6.4	13.0	-3.9	5.3	6.4
0165:	0.600000	6496	1UN6	0001	0003	35	58	8.8	13.0	-27.4	5.3	6.4
0166:	0.650000	3639	1UN6	0001	0003	42	17	9.6	13.0	-46.6	5.3	6.4
0167:	0.700000	6225	1UN6	0001	0003	125	42	8.8	13.0	107.3	5.3	6.4
0168:	0.750000	5019	1UN6	0001	0003	54	42	6.8	13.0	-15.5	5.3	6.4
0169:	0.800000	3840	1UN6	0001	0003	30	45	9.0	13.0	-25.4	5.3	6.4
0170:	0.850000	4793	1UN6	0001	0003	-39	-6	10.5	13.0	-58.1	5.3	6.4
0171:	0.900000	2942	1UN6	0001	0003	12	-4	5.7	11.3	12.0	5.3	6.4
0172:	0.950000	3647	1UN6	0001	0003	34	67	6.5	13.0	-54.8	5.3	6.4
0173:	1.000000	3360	1UN6	0001	0003	-27	14	8.3	13.0	-23.3	5.3	6.4
0174:	2.000000	2110	1UN6	0001	0003	-80	69	6.9	8.1	-160.4	9.7	13.3
0175:	3.000000	1452	1UN6	0001	0003	-40	99	8.9	8.8	-153.4	9.3	17.2
0176:	4.000000	4361	1UN6	0001	0003	-350	-5	7.5	11.2	-340.9	10.4	20.5
0177:	5.000000	M136A	H178	0001	0001	-202	135	38.8	38.8	-353.7	5.7	10.9
0178:	6.000000	M115A	H312	0001	0001	842	-716	27.7	27.7	1626.6	4.8	26.2
0179:	7.000000	W202A	H105	0001	0001	383	-1343	41.6	41.6	1755.2	6.8	24.0
0180:	8.000000	M103A	H143	0001	0001	1406	-819	34.3	34.3	2225.0	6.9	31.5
0181:	10.000000	M109A	H148	0001	0001	1635	-1119	44.4	44.4	2746.6	7.5	22.6
0182:	12.000000	M135A	H249	0001	0001	1846	-88	36.7	36.7	1932.8	9.8	38.0
0183:	16.000000	M109A	H155	0001	0001	1756	-570	46.7	46.7	2266.3	10.9	43.6
0184:	20.000000	A157	H146	0001	0001	-851	395	46.6	46.6	-1409.4	12.3	55.5

Table 6.6-4 Latest Listing of the <i>Metmstr.gbk</i> File												
Column:	10	20	30	40	50	60	70	80				
Row:	1	2	3	4	5	6	7	8	9	10	11	12
0001:	0.100000			0001	0001	0	0	12.7	12.7	0.0	0.0	0.0
0002:	0.200000			0001	0001	0	0	12.7	12.7	0.0	0.0	0.0
0003:	0.250000			0001	0001	0	0	12.7	12.7	0.0	0.0	0.0

Table 6.6-4 Latest Listing of the *Metmstr.gbk* File

Column:	10	20	30	40	50	60	70	80				
Row:	1	2	3	4	5	6	7	8	9	10	11	12
0004:	0.300000	NONE	ZWV25	0001 0003	32	24	13.0	15.3	14.3	6.3	7.9	
0005:	0.350000			0001 0001	0	0	12.7	12.7	0.0	0.0	0.0	
0006:	0.400000	NONE	ZWV25	0001 0003	103	95	17.0	14.6	12.6	6.3	7.9	
0007:	0.405000	NONE	ZWV25	0001 0003	55	21	6.3	11.3	22.8	6.3	7.9	
0008:	0.410000	NONE	ZWV25	0001 0003	39	-105	21.3	11.5	114.2	6.3	7.9	
0009:	0.420000	NONE	ZWV25	0001 0003	-46	23	12.1	12.5	-56.8	6.3	7.9	
0010:	0.430000	NONE	ZWV25	0001 0003	195	140	22.6	15.8	25.3	6.3	7.9	
0011:	0.440000	NONE	ZWV25	0001 0003	12	-94	27.8	12.3	71.6	6.3	7.9	
0012:	0.450000	NONE	ZWV25	0001 0003	4	-65	8.2	9.7	58.2	6.3	7.9	
0013:	0.460000	NONE	ZWV25	0001 0003	57	-23	8.3	9.5	37.3	6.3	7.9	
0014:	0.470000	NONE	ZWV25	0001 0003	116	-88	13.6	8.3	186.7	6.3	7.9	
0015:	0.480000	NONE	ZWV25	0001 0003	73	32	16.0	10.5	31.6	6.3	7.9	
0016:	0.490000	NONE	ZWV25	0001 0003	77	-49	14.7	12.7	84.3	6.3	7.9	
0017:	0.500000	229	2HN30	0001 0003	41	-11	7.7	8.1	53.9	5.4	15.4	
0018:	0.550000			0001 0001	0	0	12.7	12.7	0.0	0.0	0.0	
0019:	0.600000	NONE	ZWV25	0001 0003	73	13	17.7	13.4	28.9	6.3	7.9	
0020:	0.650000			0001 0001	0	0	12.7	12.7	0.0	0.0	0.0	
0021:	0.700000	NONE	ZWV25	0001 0003	44	-118	14.5	8.9	119.2	6.3	7.9	
0022:	0.750000			0001 0001	0	0	12.7	12.7	0.0	0.0	0.0	
0023:	0.800000	NONE	ZWV25	0001 0003	-27	-43	16.6	8.6	2.0	6.3	7.9	
0024:	0.850000			0001 0001	0	0	12.7	12.7	0.0	0.0	0.0	
0025:	0.900000	NONE	ZWV25	0001 0003	51	-71	25.3	5.8	129.7	6.3	7.9	
0026:	0.950000			0001 0001	0	0	12.7	12.7	0.0	0.0	0.0	
0027:	1.000000	F15	2HN30	0001 0003	-133	51	7.7	6.2	-150.6	4.7	4.9	
0028:	1.000500	0123	2HN30	0001 0003	108	45	17.0	7.0	62.5	4.7	4.9	
0029:	1.001000	Z	2HN30	0001 0003	-9	30	10.4	5.9	-8.8	4.7	4.9	
0030:	1.002000	99	2HN30	0001 0003	-61	22	12.0	7.2	-75.6	4.7	4.9	
0031:	1.003000	231	2HN30	0001 0003	6	18	6.1	7.8	11.8	4.7	4.9	
0032:	1.004000	Z	2HN30	0001 0003	44	12	8.6	8.3	59.3	4.7	4.9	
0033:	1.005000	F 15	2HN30	0001 0003	-94	4	8.6	10.7	-114.3	4.7	4.9	
0034:	1.006000	99	2HN30	0001 0003	243	-13	12.9	11.2	257.6	4.7	4.9	
0035:	1.007000	233	2HN30	0001 0003	52	25	6.9	6.9	41.7	4.7	4.9	
0036:	1.008000	Z	2HN30	0001 0003	43	39	7.2	4.2	-12.1	4.7	4.9	
0037:	1.009000	Z	2HN30	0001 0003	-3	5	4.9	4.7	-21.2	4.7	4.9	
0038:	1.010000	F 15	2HN30	0001 0003	74	28	6.6	6.9	58.5	4.7	4.9	
0039:	1.020000	F 15	2HN30	0001 0003	-196	-14	8.2	7.8	-132.0	4.7	4.9	
0040:	1.030000	Z	2HN30	0001 0003	-9	7	6.5	11.2	0.6	4.7	4.9	
0041:	1.040000	F 15	2HN30	0001 0003	-37	12	7.8	7.4	-48.3	4.7	4.9	
0042:	1.050000	F 15	2HN30	0001 0003	-148	-21	9.6	8.8	-137.5	4.7	4.9	

Table 6.6-4 Latest Listing of the *Metmstr.gbk* File

Column:	10	20	30	40	50	60	70	80				
Row:	1	2	3	4	5	6	7	8	9	10	11	12
0043:	1.060000	F 15	2HN30	0001 0003	-100	7	6.7	4.6	-107.5	4.7	4.9	
0044:	1.070000	F 15	2HN30	0001 0003	-94	42	7.2	9.3	-102.4	4.7	4.9	
0045:	1.080000	99	2HN30	0001 0003	-9	56	7.5	10.9	-63.6	4.7	4.9	
0046:	1.090000	F 15	2HN30	0001 0003	76	10	9.4	5.7	65.0	4.7	4.9	
0047:	1.100000	F 15	2HN30	0001 0003	30	-20	9.8	9.7	30.1	4.5	5.0	
0048:	1.110000	F 154	2HN30	0001 0003	-68	-1	8.1	6.5	-88.6	4.5	5.0	
0049:	1.120000	99	2HN30	0001 0003	56	39	10.9	7.1	-9.0	4.5	5.0	
0050:	1.130000	F 15	2HN30	0001 0003	-53	19	8.3	9.0	-60.9	4.5	5.0	
0051:	1.140000	F 15	2HN30	0001 0003	-46	5	7.6	6.0	-62.1	4.5	5.0	
0052:	1.150000	Z	2HN30	0001 0003	95	18	9.7	7.7	60.9	4.5	5.0	
0053:	1.160000	F 15	2HN30	0001 0003	-79	16	11.8	6.0	-102.9	4.5	5.0	
0054:	1.170000	F 15	2HN30	0001 0003	15	27	6.2	7.7	1.2	4.5	5.0	
0055:	1.180000	F 15	2HN30	0001 0003	-114	10	7.5	7.3	-110.2	4.5	5.0	
0056:	1.190000	F 15	2HN30	0001 0003	49	40	9.9	3.7	16.8	4.5	5.0	
0057:	1.200000	F 15	2HN30	0001 0003	51	53	7.5	5.3	-1.7	4.5	5.0	
0058:	1.210000	F 15	2HN30	0001 0003	-183	1	11.4	6.8	-192.7	4.5	5.0	
0059:	1.220000	F 15	2HN30	0001 0003	61	11	6.6	3.2	-28.0	4.5	5.0	
0060:	1.230000	F 15	2HN30	0001 0003	-2	58	10.6	8.2	-28.0	4.5	5.0	
0061:	1.240000	Z	2HN30	0001 0003	31	6	7.7	4.6	64.1	4.5	5.0	
0062:	1.250000	F 15	2HN30	0001 0003	-143	18	8.6	6.8	-150.8	4.5	5.0	
0063:	1.260000	F 15	2HN30	0001 0003	-22	49	6.6	9.4	-47.9	4.5	5.0	
0064:	1.270000	F 15	2HN30	0001 0003	99	11	6.7	5.6	104.6	4.5	5.0	
0065:	1.280000	F 15	2HN30	0001 0003	-29	13	8.1	8.9	-16.6	4.5	5.0	
0066:	1.290000	F 15	2HN30	0001 0003	-45	19	10.1	5.1	-71.5	4.5	5.0	
0067:	1.300000	Z	2HN30	0001 0003	82	21	9.1	7.5	75.9	4.4	5.9	
0068:	1.310000	F 15	2HN30	0001 0003	0	-15	7.4	7.0	45.8	4.4	5.9	
0069:	1.320000	F 15	2HN30	0001 0003	71	29	9.0	7.4	62.7	4.4	5.9	
0070:	1.330000	F 15	2HN30	0001 0003	50	7	7.9	12.4	32.4	4.4	5.9	
0071:	1.340000	Z	2HN30	0001 0003	35	13	8.3	5.1	55.4	4.4	5.9	
0072:	1.350000	237	2HN30	0001 0003	60	19	11.2	8.9	52.4	4.4	5.9	
0073:	1.360000	238	2HN30	0001 0003	20	7	9.4	8.4	27.2	4.4	5.9	
0074:	1.370000	Z	2HN30	0001 0003	18	22	10.3	6.8	-26.6	4.4	5.9	
0075:	1.380000	F 15	2HN30	0001 0003	-91	0	4.7	10.5	-62.1	4.4	5.9	
0076:	1.390000	F 15	2HN30	0001 0003	-90	9	10.2	8.9	-103.0	4.4	5.9	
0077:	1.400000	F 15	2HN30	0001 0003	94	-5	6.8	4.2	78.7	4.4	5.9	
0078:	1.410000	F 15	2HN30	0001 0003	-91	34	8.0	10.7	-130.6	4.4	5.9	
0079:	1.420000	Z	2HN30	0001 0003	51	18	5.6	6.6	45.3	4.4	5.9	
0080:	1.430000	F 15	2HN30	0001 0003	41	23	8.0	8.4	18.4	4.4	5.9	
0081:	1.440000	F 15	2HN30	0001 0003	22	-2	7.1	6.9	23.6	4.4	5.9	

Table 6.6-4 Latest Listing of the *Metmstr.gbk* File

Column:	10	20	30	40	50	60	70	80				
Row:	1	2	3	4	5	6	7	8	9	10	11	12
0082:	1.450000	F 15	2HN30	0001 0003	-110	41	10.6	9.7	-134.1	4.4	5.9	
0083:	1.460000	F 15	2HN30	0001 0003	-35	13	7.8	10.0	-33.7	4.4	5.9	
0084:	1.470000	F 15	2HN30	0001 0003	-40	17	6.2	6.5	-78.4	4.4	5.9	
0085:	1.480000	F 15	2HN30	0001 0003	-52	23	11.2	8.3	-36.9	4.4	5.9	
0086:	1.490000	F 15	2HN30	0001 0003	-50	0	9.5	5.0	-67.8	4.4	5.9	
0087:	1.500000	F 15	2HN30	0001 0003	-107	39	10.2	7.6	-133.7	4.4	6.4	
0088:	1.600000	0112	ZWV25	0001 0003	40	44	10.3	8.5	8.1	4.4	6.4	
0089:	1.700000	0121	ZWV25	0001 0003	62	1	9.2	12.9	77.9	4.4	6.4	
0090:	1.800000	9114	ZWV25	0001 0003	66	10	8.5	8.8	83.0	4.4	6.4	
0091:	1.900000	240	ZWV25	0001 0003	-29	8	8.8	6.7	-39.2	4.4	6.4	
0092:	2.000000	99	2HN30	0001 0003	52	-7	5.1	6.1	36.6	4.4	6.4	
0093:	2.000500	1-61	ZWV25	0001 0003	-28	52	11.7	13.3	-46.7	4.4	6.4	
0094:	2.001000	8114	ZWV25	0001 0003	9	6	5.4	12.1	7.3	4.4	6.4	
0095:	2.002000	0114	ZWV25	0001 0003	10	-10	10.8	13.0	26.7	4.4	6.4	
0096:	2.003000	0135	ZWV25	0001 0003	44	-10	12.6	13.0	29.0	4.4	6.4	
0097:	2.004000	0102	ZWV25	0001 0003	63	30	10.2	13.0	46.8	4.4	6.4	
0098:	2.005000	0136	ZWV25	0001 0003	11	35	9.9	13.0	-4.9	4.4	6.4	
0099:	2.006000	0134	ZWV25	0001 0003	24	43	5.4	5.2	-12.5	4.4	6.4	
0100:	2.007000	0144	ZWV25	0001 0003	32	21	6.8	14.9	20.7	4.4	6.4	
0101:	2.008000	0140	ZWV25	0001 0003	24	11	7.6	9.4	15.1	4.4	6.4	
0102:	2.009000	8148	ZWV25	0001 0003	-53	-19	10.9	6.5	-59.5	4.4	6.4	
0103:	2.010000	0101	ZWV25	0001 0003	-32	-39	11.0	13.0	-21.5	4.4	6.4	
0104:	2.020000	9131	ZWV25	0001 0003	8	-16	5.5	13.0	38.8	4.4	6.4	
0105:	2.030000	9114	ZWV25	0001 0003	61	-41	11.4	13.0	111.8	4.4	6.4	
0106:	2.040000	0138	ZWV25	0001 0003	43	12	13.0	13.0	20.1	4.4	6.4	
0107:	2.050000	9134	ZWV25	0001 0003	176	8	9.8	13.0	172.1	4.4	6.4	
0108:	2.060000	0112	ZWV25	0001 0003	65	-40	7.6	13.0	69.9	4.4	6.4	
0109:	2.070000	0123	ZWV25	0001 0003	28	-9	8.3	8.1	51.9	4.4	6.4	
0110:	2.080000	9135	ZWV25	0001 0003	-134	20	7.7	13.0	-122.9	4.4	6.4	
0111:	2.090000	0121	ZWV25	0001 0003	-20	-36	7.9	13.0	36.2	4.4	6.4	
0112:	2.100000	0145	ZWV25	0001 0003	49	14	5.9	7.3	39.8	4.1	7.9	
0113:	2.110000	1-47	ZWV25	0001 0003	48	-38	6.8	13.0	38.3	4.1	7.9	
0114:	2.120000	1-41	ZWV25	0001 0003	41	-9	9.9	13.0	43.1	4.1	7.9	
0115:	2.130000	1-36	ZWV25	0001 0003	9	43	4.8	13.0	-33.1	4.1	7.9	
0116:	2.140000	1-08	ZWV25	0001 0003	64	-6	13.0	13.0	29.4	4.1	7.9	
0117:	2.150000	1-40	ZWV25	0001 0003	35	40	6.6	11.0	6.3	4.1	7.9	
0118:	2.160000	1-90	ZWV25	0001 0003	30	-57	8.9	13.0	71.8	4.1	7.9	
0119:	2.170000	1-70	ZWV25	0001 0003	-42	-15	5.2	12.1	-40.6	4.1	7.9	
0120:	2.180000	1-58	ZWV25	0001 0003	81	51	3.3	13.3	49.1	4.1	7.9	

Table 6.6-4 Latest Listing of the *Metmstr.gbk* File

Column:	10	20	30	40	50	60	70	80				
Row:	1	2	3	4	5	6	7	8	9	10	11	12
0121:	2.190000	1-67	ZWV25	0001	0003	-7	-43	8.8	13.0	30.6	4.1	7.9
0122:	2.200000	9109	ZWV25	0001	0003	64	12	8.8	8.3	60.5	4.1	7.9
0123:	2.210000	1-13	ZWV25	0001	0003	4	-47	11.4	13.0	19.6	4.1	7.9
0124:	2.220000	1-47	ZWV25	0001	0003	28	-11	7.6	9.0	27.1	4.1	7.9
0125:	2.230000	1-18	ZWV25	0001	0003	73	15	4.5	9.7	69.9	4.1	7.9
0126:	2.240000	1-30	ZWV25	0001	0003	2	-10	10.5	13.0	-3.9	4.1	7.9
0127:	2.250000	1-33	ZWV25	0001	0003	20	19	6.4	9.0	-35.8	4.1	7.9
0128:	2.260000	0134	ZWV25	0001	0003	8	-53	7.8	13.0	36.4	4.1	7.9
0129:	2.270000	1-53	ZWV25	0001	0003	-40	-15	6.1	9.4	-24.8	4.1	7.9
0130:	2.280000	1-91	ZWV25	0001	0003	7	32	9.6	10.7	-28.0	4.1	7.9
0131:	2.290000	1-34	ZWV25	0001	0003	-18	-36	13.0	9.0	0.8	4.1	7.9
0132:	2.300000	0140	ZWV25	0001	0003	62	2	9.7	13.0	74.7	4.6	6.8
0133:	2.310000	1-64	ZWV25	0001	0003	59	-26	12.9	13.0	74.9	4.6	6.8
0134:	2.320000	1-70	ZWV25	0001	0003	21	12	8.7	13.0	-13.0	4.6	6.8
0135:	2.330000	1-42	ZWV25	0001	0003	21	17	10.7	13.0	31.6	4.6	6.8
0136:	2.340000	1-02	ZWV25	0001	0003	-91	-14	6.8	13.0	-91.4	4.6	6.8
0137:	2.350000	1-37	ZWV25	0001	0003	29	-7	11.2	6.6	31.0	4.6	6.8
0138:	2.360000	1-54	ZWV25	0001	0003	-47	40	10.5	13.0	-64.6	4.6	6.8
0139:	2.370000	1-14	ZWV25	0001	0003	-18	-30	6.4	12.1	8.4	4.6	6.8
0140:	2.380000	0109	ZWV25	0001	0003	68	10	6.7	11.8	78.3	4.6	6.8
0141:	2.390000	1-51	ZWV25	0001	0003	-36	35	13.0	13.0	-43.4	4.6	6.8
0142:	2.400000	0108	ZWV25	0001	0003	22	8	7.5	13.0	30.6	4.6	6.8
0143:	2.410000	1-49	ZWV25	0001	0003	61	14	10.3	12.7	20.7	4.6	6.8
0144:	2.420000	1-23	ZWV25	0001	0003	82	-24	11.9	8.6	84.8	4.6	6.8
0145:	2.430000	1-35	ZWV25	0001	0003	-37	18	14.0	13.0	-41.0	4.6	6.8
0146:	2.440000	1-02	ZWV25	0001	0003	84	85	9.2	13.0	-3.1	4.6	6.8
0147:	2.450000	1-76	ZWV25	0001	0003	33	-14	8.1	10.7	15.2	4.6	6.8
0148:	2.460000	1-88	ZWV25	0001	0003	-3	31	13.0	13.0	-8.1	4.6	6.8
0149:	2.470000	1-69	ZWV25	0001	0003	-25	-18	9.6	13.0	-2.7	4.6	6.8
0150:	2.480000	1-45	ZWV25	0001	0003	-49	26	12.6	9.3	-62.3	4.6	6.8
0151:	2.490000	1-29	ZWV25	0001	0003	-17	18	13.0	13.0	-11.4	4.6	6.8
0152:	2.500000	F 15	2HN30	0001	0003	-31	16	6.3	10.0	-62.1	4.7	6.9
0153:	2.600000	0116	ZWV25	0001	0003	54	-15	10.3	13.1	75.7	4.7	6.9
0154:	2.700000	0105	ZWV25	0001	0003	24	23	13.0	12.5	-0.2	4.7	6.9
0155:	2.800000	0110	ZWV25	0001	0003	0	-27	10.6	13.0	28.5	4.7	6.9
0156:	2.900000	0114	ZWV25	0001	0003	70	10	13.0	12.3	48.6	4.7	6.9
0157:	3.000000	F 15	2HN30	0001	0003	-24	2	8.9	7.6	-45.6	4.7	6.9
0158:	3.500000	F 15	2HN30	0001	0003	-43	57	9.5	13.0	-95.1	4.7	6.9
0159:	4.000000	Z	2HN30	0001	0003	31	18	5.2	7.8	36.2	4.7	6.9

Table 6.6-4 Latest Listing of the *Metmstr.gbk* File

Column:	10	20	30	40	50	60	70	80				
Row:	1	2	3	4	5	6	7	8	9	10	11	12
0160:	4.500000	F 15	2HN30	0001 0003	79	7	9.2	9.5	72.7	4.7	6.9	
0161:	5.000000	Z	2HN30	0001 0003	-40	-32	9.6	12.1	-14.0	4.7	6.9	
0162:	5.500000	F 15	2HN30	0001 0003	-51	44	13.0	13.0	-90.6	4.7	6.9	
0163:	6.000000	F 15	2HN30	0001 0003	-84	35	9.2	13.0	-125.4	4.7	6.9	
0164:	6.500000	F 15	2HN30	0001 0003	-16	46	10.3	8.2	-45.2	4.7	6.9	
0165:	7.000000	F 15	2HN30	0001 0003	-47	25	4.6	11.7	-95.9	4.7	6.9	
0166:	7.500000	F 15	2HN30	0001 0003	95	48	5.5	13.0	42.0	4.7	6.9	
0167:	8.000000	F 15	2HN30	0001 0003	38	67	5.0	12.6	-47.0	4.7	6.9	
0168:	8.500000	F 15	2HN30	0001 0003	66	24	6.8	13.0	-5.5	4.7	6.9	
0169:	9.000000	F 15	2HN30	0001 0003	-49	40	10.7	13.0	-119.0	4.7	6.9	
0170:	9.500000	F 15	2HN30	0001 0003	26	51	11.4	13.0	-19.4	4.7	6.9	
0171:	10.000000	F 15	2HN30	0001 0003	62	41	9.2	13.6	17.8	4.7	6.9	
0172:	10.500000	F 15	2HN30	0001 0003	-132	45	9.8	12.8	-183.8	4.7	5.0	
0173:	11.000000	F 15	2HN30	0001 0003	-10	73	7.6	13.0	-94.5	4.7	5.0	
0174:	11.500000	F 15	2HN30	0001 0003	74	48	8.8	13.0	32.9	4.7	5.0	
0175:	12.000000	F 15	2HN30	0001 0003	35	70	9.2	6.9	-42.6	4.7	5.0	
0176:	12.500000	F 15	2HN30	0001 0003	-54	63	9.4	13.0	-100.3	4.7	5.0	
0177:	13.000000	0120	2HN30	0001 0003	12	0	6.6	6.8	-48.9	4.7	5.0	
0178:	13.500000	F 15	2HN30	0001 0003	-5	53	10.6	8.7	-74.0	4.7	5.0	
0179:	14.000000	6-22	2HN30	0001 0003	-18	64	8.7	13.0	-79.6	4.7	5.0	
0180:	14.500000	F 15	2HN30	0001 0003	25	80	3.7	5.6	-74.6	4.7	5.0	
0181:	15.000000	F 15	2HN30	0001 0003	102	34	10.0	6.2	48.0	4.7	5.0	
0182:	15.500000	3-48	2HN30	0001 0003	-53	12	6.9	13.0	-92.5	4.7	5.0	
0183:	16.000000	F 15	2HN30	0001 0003	-31	46	8.7	13.0	-114.6	4.7	5.0	
0184:	16.500000	F 15	2HN30	0001 0003	107	50	6.1	10.2	25.1	4.7	5.0	
0185:	17.000000	H7	2HN30	0001 0003	90	71	7.2	13.5	-23.5	4.7	5.0	
0186:	17.500000	F 15	2HN30	0001 0003	22	60	8.8	11.4	-47.3	4.7	5.0	
0187:	18.000000	6-37	2HN30	0001 0003	-27	54	11.5	9.2	-95.4	4.7	5.0	
0188:	18.500000	1104	2HN30	0001 0003	100	54	10.5	13.0	29.2	4.7	5.0	
0189:	19.000000	6-41	2HN30	0001 0003	-3	41	7.2	10.8	-47.7	4.7	5.0	
0190:	19.500000	F 15	2HN30	0001 0003	28	88	10.4	13.1	-85.7	4.7	5.0	
0191:	20.000000	391	2HN30	0001 0003	50	15	9.5	12.6	11.8	4.7	5.0	
0192:	20.500000	1134	2HN30	0001 0003	96	62	12.2	13.0	52.9	4.5	5.4	
0193:	21.000000	F 15	2HN30	0001 0003	75	90	12.9	8.0	-17.0	4.5	5.4	
0194:	21.500000	1101	2HN30	0001 0003	10	59	11.0	11.7	-44.9	4.5	5.4	
0195:	22.000000	112	2HN30	0001 0003	148	64	12.6	13.0	82.5	4.5	5.4	
0196:	22.500000	0131	2HN30	0001 0003	-48	49	13.0	12.6	-108.5	4.5	5.4	
0197:	23.000000	243	2HN30	0001 0003	51	83	8.7	13.0	-6.9	4.5	5.4	
0198:	23.500000	9118	2HN30	0001 0003	-140	74	12.1	13.0	-195.1	4.5	5.4	

Table 6.6-4 Latest Listing of the *Metmstr.gbk* File

Column:	10	20	30	40	50	60	70	80				
Row:	1	2	3	4	5	6	7	8	9	10	11	12
0199:	24.000000	7-43	2HN30	0001 0003	-148	72	10.1	13.0	-218.9	4.5	5.4	
0200:	24.500000	760	2HN30	0001 0003	16	79	12.9	9.2	-55.5	4.5	5.4	
0201:	25.000000	F 15	2HN30	0001 0003	18	30	11.3	10.9	-17.6	4.5	5.4	
0202:	30.000000	9119	4DN8	0001 0003	92	64	6.7	11.2	58.6	7.6	11.2	
0203:	40.000000	0115	4DN8	0001 0003	-65	71	5.9	9.9	-122.2	7.5	13.8	
0204:	50.000000	1248	2HN30	0001 0003	-254	36	8.6	13.5	-281.2	7.3	8.5	
0205:	60.000000	9-15	4DN8	0001 0003	-180	64	12.2	9.3	-244.1	7.0	12.0	
0206:	70.000000	0210	4DN8	0001 0003	-175	135	11.1	12.8	-314.5	10.1	13.2	
0207:	75.000000	0136	2HN30	0001 0003	-50	155	10.0	12.5	-203.6	7.3	12.5	
0208:	80.000000	9-45	66N12	0001 0003	86	103	10.2	12.5	-10.3	8.9	9.6	
0209:	90.000000	1020	66N12	0001 0003	-47	160	13.4	17.1	-224.2	8.3	12.6	
0210:	100.000000	0111	2HN30	0001 0003	-89	142	11.9	17.8	-197.3	9.3	21.7	
0211:	125.000000	PMS-2	3-13	0001 0001	1050	-111	26.5	26.5	1154.5	4.8	55.4	
0212:	150.000000	PMS-2	1-20	0001 0001	386	-400	46.3	46.3	822.4	5.9	33.9	
0213:	175.000000	PMS-2	1-09	0001 0001	-115	-130	56.5	56.5	-101.1	4.0	21.2	
0214:	200.000000	PMS-2	P122	0001 0001	25	461	27.7	27.7	-391.2	6.2	49.3	
0215:	250.000000	PMS-2	R111	0001 0001	753	60	33.7	33.7	654.2	8.2	48.8	
0216:	300.000000	0124	R109	0001 0001	42	-51	77.2	77.2	65.3	6.3	41.4	
0217:	400.000000	P113	2-02	0001 0001	-630	819	77.0	77.0	-1493.2	7.9	44.5	
0218:	500.000000	N106	3-11	0001 0001	-51	787	36.2	36.2	-829.6	13.0	67.7	

6.7 The *Mecmap* Program

The *Mecmap* program opens, analyzes, and prints the mechanical intercomparison control history for all NIST's gage block mechanical intercomparison calibrations and measurements, which the *Gage* program records during its use in calibrations and measurements. The second part of NIST's gage block measurement assurance program the technical user, who calibrates and measures gage blocks, accomplishes together through running the *Gage* program in *Gage* mode to calibrate and measure NIST's gage block calibration customers' gage blocks by mechanical intercomparison and using the *Mecmap* program to analyze NIST's gage block mechanical intercomparison calibration history. Running the *Gage* program in *Gage* mode to calibrate and measure gage blocks writes results to the screen display and printer, the *Setup Document Files*, and the *Gagemap Document Files* that the *Mecmap* program uses to analyze the mechanical intercomparison control history for all NIST's gage block mechanical intercomparison calibrations and measurements. Running the *Mecmap* program's *Mapsort*

function assembles the *Mecmap Document Files*, by generating anew the mechanical intercomparison control history for all NIST's gage block mechanical intercomparison calibrations and measurements from the *Gage* program's *Gagemap Document Files* selected, reordering all records by the gage blocks' nominal sizes, identification or serial numbers, and calibration and measurement dates. Running the *Mecmap* program provides process control parameters for the mechanical intercomparison process and estimates measurement process variability of NIST's gage block mechanical intercomparison calibration history, which records the measured differences between the NIST's two master gage blocks used in every calibration and measurement and the derived standard deviations of every calibration and measurement.

The use of the *Mecmap* program is the second of three parts of NIST's gage block measurement assurance program. The first part is the continuous calibration and measurement of NIST's master gage blocks by interferometry under process control. The technical user, who calibrates and measures gage blocks, together through using the *Spectrum*, *Edit*, and *Intmap* programs, analyzes and records NIST's master gage block interferometric measurement results from the gage block interferometers and NIST's master gage block interferometric calibration history. After accumulating NIST's master gage block interferometric measurement results, the user plots control charts to individually check the variability of NIST's master gage blocks' interferometric calibration history. When the user use NIST's master gage blocks to calibrate and measure NIST's gage block calibration customers' gage blocks by mechanical intercomparison, NIST Reports' of Calibration report, for every calibration and measurement, the interferometric measurement uncertainty combined in quadrature with the mechanical intercomparison uncertainty. The second part of NIST's gage block measurement assurance program the user accomplishes together through running the *Gage* program in *Gage* mode to calibrate and measure NIST's gage block calibration customers' gage blocks by mechanical intercomparison and using the *Mecmap* program to analyze NIST's gage block mechanical intercomparison calibration history. Providing process control parameters for the mechanical intercomparison process and estimating measurement process variability is NIST's gage block mechanical intercomparison calibration history, which records the measured differences between the NIST's two master gage blocks used in every calibration and measurement and the derived standard deviations of every calibration and measurement. As the third part of NIST's gage block measurement assurance program, the user uses the *History* program to authenticate past and present calibration and measurement results.

The *Mecmap* program simplifies efforts by the technical user, who calibrates and measures gage blocks, to manage and statistically analyze NIST's master gage block mechanical intercomparison calibration history. Today, with the *Mecmap* program, to quantitatively characterize NIST's master gage block mechanical intercomparison calibration process, the user uses NIST's master gage block mechanical intercomparison calibration history for determining or predicting measurement process variability. To improve complete measurement confidence, the *Mecmap* program helps the user to routinely monitor NIST's master gage block mechanical intercomparison calibration history. Providing process control parameters for the mechanical

intercomparison process and estimating measurement process variability is NIST's gage block mechanical intercomparison calibration history, which records the measured differences between the NIST's each two master gage blocks used in every mechanical intercomparison calibration and measurement and the derived standard deviations of every mechanical intercomparison calibration and measurement.

For short term variability, the user uses the *Mecmap* program to analyze NIST's master gage block mechanical intercomparison calibration history from which determine or predict the within standard deviations against which the *Gage* program checks the derived standard deviations of every mechanical intercomparison calibration and measurement. When running the *Gage* program in *Gage* mode to calibrate and measure NIST's gage block calibration customers' gage blocks by mechanical intercomparison, the derived standard deviations of every mechanical intercomparison calibration and measurement are checked against the within standard deviations the *Mecmap* program determines or predicts from previous mechanical intercomparison calibrations and measurements and stored for determining or predicting new within standard deviations. In the *Gage* program, the within standard deviations the *Mecmap* program determines or predicts are called the "accepted" standard deviations and the derived standard deviations of every mechanical intercomparison calibration and measurement are called the "observed" standard deviations. Because error sources for similarly-sized gage blocks are alike, the *Mecmap* program, to enhance statistical precision, pools the derived standard deviations of mechanical intercomparison calibrations and measurements for similarly-sized gage blocks from NIST's master gage block mechanical intercomparison calibration history.

For measurement process control, the user uses the *Mecmap* program to analyze NIST's master gage block mechanical intercomparison calibration history from which determine or predict the "best" measurement process controls against which the *Gage* program checks the derived differences between each two of NIST's master gage blocks of every mechanical intercomparison calibration and measurement. When running the *Gage* program in *Gage* mode to calibrate and measure NIST's gage block calibration customers' gage blocks by mechanical intercomparison, the derived differences between each two of NIST's master gage blocks of every mechanical intercomparison calibration and measurement are checked against the "best" measurement process controls the *Mecmap* program determines or predicts from previous mechanical intercomparison calibrations and measurements and stored for determining or predicting new measurement process controls. In the *Gage* program, the "best" measurement process controls the *Mecmap* program determines or predicts are called the "accepted" mechanical and measurement process controls and the derived differences between each two of NIST's master gage blocks of every mechanical intercomparison calibration and measurement are called the "observed" mechanical and measurement process controls. For NIST's master gage blocks having lesser amounts of available mechanical intercomparison calibration history or exhibiting dimensional stability or negligible length changes, the user uses the *Mecmap* program to average the mechanical intercomparison calibration history for finding "mean" difference between each two of NIST's master gage blocks of every mechanical intercomparison calibration

and measurement. For NIST's master gage blocks exhibiting general patterns of length changes, the user uses the *Mecmap* program to do linear regression analysis by using the "least squares" method to fit lines through sets of measurements for establishing "predicted" difference between each two of NIST's master gage blocks of every mechanical intercomparison calibration and measurement.

For long term variability, the user uses the *Mecmap* program to analyze NIST's master gage block mechanical intercomparison calibration history from which determine or predict the total standard deviations against which the *Gage* program checks the derived standard deviations of every mechanical intercomparison calibration and measurement. The measurement process variability can be estimated and reported for every mechanical intercomparison calibration and measurement completed by combining in quadrature the standard deviations that the *Intmap* program determines or predicts from the interferometric calibration history and the total standard deviations that the *Mecmap* program determines from the mechanical intercomparison calibration history all combined in quadrature using a coverage factor of $k=2$ (95 percent confidence level). These uncertainties are calculated according to "Guidelines for Evaluating and Expressing the Uncertainty of NIST Measurement Results" by Barry N. Taylor and Chris E. Kuyatt (*National Institute of Standards and Technology (U.S.) Technical Note 1297, 1994*) [36].

The *Mecmap* program has a *Control Menu* with seventeen functions, as Table 6.7-1 shows. The technical user, who calibrates and measures gage blocks, uses the *Control Menu* functions to do the following:

- Customize the *Mecmap* program's current preferences
- Switch between *Mecmap Document Files*
- View and print NIST's gage block mechanical intercomparison calibration history
- View, plot, and print individual gage blocks' history in NIST's gage block mechanical intercomparison calibration history
- Load and run the *Edit* program to automatically open *Mecmap Document Files*
- Backup and restore *Mecmap Document Files*
- Assemble *Mecmap Document Files* by generating anew the mechanical intercomparison control history for all NIST's gage block mechanical intercomparison calibrations and measurements from the *Gage* program's *Gagemap Document Files* selected, reordering all records by the gage blocks' nominal sizes, identification or serial numbers, and calibration and measurement dates

Table 6.7-1 The <i>Mecmap</i> Program's Control Menu Functions	
Name of Function	Function Description
<i>Program Preface</i> .	This function displays the <i>Mecmap</i> program's introductory statement.
<i>Preferences</i>	This function opens the <i>Preferences</i> window with the <i>Mecmap</i> program's current preferences. In this window, the computer user customizes the file storage devices and folders that the <i>Mecmap</i> program uses to open, backup, and restore <i>Mecmap Document Files</i> . Among other preferences in this window, the computer user customizes the method and date that the <i>Mecmap</i> program uses to predict future nominal length variations and perform linear regression analysis.
<i>Catalog</i>	This function catalogs the working <i>Mecmap Document Files</i> in the working file storage device and folder, which is <i>C:\Gage\Mecmaps</i> by default.
<i>Select Group</i>	This function prompts the computer user to select among the groups of working <i>Mecmap Document Files</i> with the mechanical intercomparison control history for NIST's gage block mechanical intercomparison calibrations and measurements stored in the working file storage device and folder, which is <i>C:\Gage\Mecmaps</i> by default.
<i>Select Files</i>	This function prompts the computer user to select among the working <i>Mecmap Document Files</i> with the mechanical intercomparison control history for NIST's gage block mechanical intercomparison calibrations and measurements stored in the working file storage device and folder, which is <i>C:\Gage\Mecmaps</i> by default.
<i>Open</i>	This function opens copies of <i>Mecmap Document Files</i> into the <i>Mecmap Document File</i> window. <i>Mecmap Document Files</i> are working <i>Mecmap Document Files</i> in the working file storage device and folder, which is <i>C:\Gage\Mecmaps</i> by default.
<i>Run</i>	This function assembles the <i>Mecmap Report Document</i> by generating anew a report about the mechanical intercomparison control history for NIST's gage block mechanical intercomparison calibrations and measurements from the current <i>Mecmap Document Files</i> in the <i>Mecmap Report Document</i> viewing window, recording from all records the gage blocks' nominal sizes, identification or serial numbers, current and predicted statistical mechanical intercomparison controls and standard deviations, and good tests to date.

Table 6.7-1 The <i>Mecmap</i> Program's Control Menu Functions	
Name of Function	Function Description
<i>View Report</i>	This function opens the <i>Mecmap Report Document</i> viewing window with the current <i>Mecmap Report Document</i> .
<i>Print Report</i>	This function prints one copy of the current <i>Mecmap Report Document</i> in the <i>Mecmap Report Document</i> viewing window to the printer.
<i>Store Report</i>	This function stores the current <i>Mecmap Report Document</i> in the <i>Mecmap Report Document</i> viewing window to a <i>Mecmap Report Document File</i> stored in the DOS ASCII text file storage format in the file storage device and folder that the <i>Mecmap</i> program uses, which is <i>C:\Gage\Mecmaps</i> by default.
<i>View Masters</i>	This function opens the <i>Master Document File</i> editing window with the current <i>Master Document File</i> .
<i>View</i>	This function opens the <i>Mecmap Document File</i> viewing window with the current <i>Mecmap Document Files</i> for examining and printing an NIST's gage block mechanical intercomparison calibration history.
<i>Plot</i>	This function opens the <i>Mecmap Document File</i> plotting window with the current <i>Mecmap Document Files</i> for examining, plotting, and printing individual gage blocks' history in an NIST's gage block mechanical intercomparison calibration history
<i>Backup</i>	This function backs up the working files of the current <i>Mecmap Document Files</i> in the <i>Mecmap Document File</i> window or all working <i>Mecmap Document Files</i> , among selected years, from the file storage device and folder that the <i>Mecmap</i> program uses, which is <i>C:\Gage\Mecmap s</i> by default, to backup files each stored in the DOS ASCII text file storage format on labeled floppy diskettes.
<i>Restore</i>	This function restores the working files of the current <i>Mecmap Document Files</i> in the <i>Mecmap Document File</i> window or all working <i>Mecmap Document Files</i> , among selected years, from backup files each stored in the DOS ASCII text file storage format on labeled floppy diskettes to the file storage device and folder that the <i>Mecmap</i> program uses, which is <i>C:\Gage\Mecmaps</i> by default.

Name of Function	Function Description
<i>Mapsort</i>	This function assembles the <i>Mecmap Document Files</i> by generating anew the mechanical intercomparison control history for all NIST's gage block mechanical intercomparison calibrations and measurements from the <i>Gage</i> program's <i>Gagemap Document Files</i> selected, reordering all records by the gage blocks' nominal sizes, identification or serial numbers, and calibration and measurement dates.
<i>Exit MECMAP</i> . . .	This function stops the <i>Mecmap</i> program and loads and runs the <i>Branch</i> program. When <i>Mecmap Document Files</i> are in the <i>Mecmap Document File</i> window, the function closes the current <i>Mecmap Document File</i> and <i>Mecmap Report Document File</i> windows.

The technical user, who calibrates and measures gage blocks, follows established file naming and storing conventions to manage *Mecmap Document Files*. The established naming convention for *Mecmap Document Files* is limited to eight characters for filenames with a three-character extension and a period separating the filename from the extension. The working *Mecmap Document Files* are to record current *mecmap information* and the backed up *Mecmap Document Files* to record minimally the current *mecmap information*. When working *Mecmap Documents Files* are corrupted or lost, the user restores the *mecmap information* from the backed up *Mecmap Document Files*, which eliminates re-entering all *mecmap information*. The user stores all working *Mecmap Document Files* in the working file storage device and folder, which is *C:\Gage\Mecmaps*, and the backed up *Mecmap Document Files* on labeled floppy diskettes.

The *Mecmap* program uses *mecmap information* in *Mecmap Document Files*. The *Mecmap Document Files*, as Table 6.7-2 shows, organize into groups NIST's gage block mechanical intercomparison calibration history gage blocks with common physical length characteristics, which improves the significance of the statistical analyses. The configuration of *Mecmap Document Files*, as Table 6.7-3 shows, with *mecmap information*, each totaling fourteen fields and extending 80 characters. This *mecmap information* is the remark status, NIST's master gage blocks' nominal sizes, identification or serial numbers, master type, material codes, accepted master gage block mechanical intercomparison controls, accepted master gage block mechanical intercomparison within standard deviations, testing method codes, electro-mechanical gage block comparators' identification codes, observed temperatures, observers' initials, testing dates, statistical process control codes, observed master gage block mechanical intercomparison controls, and observed master gage block mechanical intercomparison within standard deviations. The technical user, who calibrates and measures gage blocks, stores working *Mecmap Document Files* in the working file storage device and folder, which is

C:\Gage\Mecmaps. The user stores backed up *Mecmap Document Files* on labeled floppy diskettes. The listing of a sample working *Mecmap Document File*, as Table 6.7-4 shows, has information that the *Gage* program wrote when running in *Gage* mode to calibrate and measure gage blocks at NIST’s first gage block calibration workstation and the *Mecmap* program assembles.

Table 6.7-2 Organization Groups of NIST’s Gage Block Mechanical Intercomparison Calibration History in <i>Mecmap Document Files</i> and <i>Mecmap Report Document Files</i>			
Group Name	Master Gage Block Nominal Sizes in Group	Name of <i>Mecmap</i> <i>Document File</i>	Name of <i>Mecmap Report</i> <i>Document File</i>
<i>GROUP 01 English Thins</i>	0.010 to 0.09375 Inches	<i>MMAPGRP.001</i>	<i>MMAPRPT.001</i>
<i>GROUP 02 English Gage Blocks</i>	0.100 to 0.107 Inches	<i>MMAPGRP.002</i>	<i>MMAPRPT.002</i>
<i>GROUP 03 English Gage Blocks</i>	0.108 to 0.126 Inches	<i>MMAPGRP.003</i>	<i>MMAPRPT.003</i>
<i>GROUP 04 English Gage Blocks</i>	0.127 to 0.146 Inches	<i>MMAPGRP.004</i>	<i>MMAPRPT.004</i>
<i>GROUP 05 English Gage Blocks</i>	0.147 to 0.500 Inches	<i>MMAPGRP.005</i>	<i>MMAPRPT.005</i>
<i>GROUP 06 English Gage Blocks</i>	0.550 to 4.000 Inches	<i>MMAPGRP.006</i>	<i>MMAPRPT.006</i>
<i>GROUP 07 English Long Blocks</i>	5.0 to 20.0 Inches	<i>MMAPGRP.007</i>	<i>MMAPRPT.007</i>

**Table 6.7-2 Organization Groups of NIST's
Gage Block Mechanical Intercomparison
Calibration History in *Mecmap Document Files*
and *Mecmap Report Document Files***

Group Name	Master Gage Block Nominal Sizes in Group	Name of <i>Mecmap</i> Document File	Name of <i>Mecmap Report</i> Document File
<i>GROUP 08</i> <i>English 010 Series</i> <i>Thins</i>	0.01005 to 0.019 Inches	<i>MMAPGRP.008</i>	<i>MMAPRPT.008</i>
<i>GROUP 09</i> <i>English 020 Series</i> <i>Thins</i>	0.02005 to 0.029 Inches	<i>MMAPGRP.009</i>	<i>MMAPRPT.009</i>
<i>GROUP 10</i> <i>English 050 Series</i> <i>Thins</i>	0.05005 to 0.059 Inches	<i>MMAPGRP.010</i>	<i>MMAPRPT.010</i>
<i>GROUP 13</i> <i>Metric Thins</i>	0.10 to 0.95 Millimeters	<i>MMAPGRP.013</i>	<i>MMAPRPT.013</i>
<i>GROUP 14</i> <i>Metric Gage Blocks</i>	1.00 to 1.09 Millimeters	<i>MMAPGRP.014</i>	<i>MMAPRPT.014</i>
<i>GROUP 15</i> <i>Metric Gage Blocks</i>	1.10 to 1.29 Millimeters	<i>MMAPGRP.015</i>	<i>MMAPRPT.015</i>
<i>GROUP 16</i> <i>Metric Gage Blocks</i>	1.30 to 1.49 Millimeters	<i>MMAPGRP.016</i>	<i>MMAPRPT.016</i>
<i>GROUP 17</i> <i>Metric Gage Blocks</i>	1.50 to 2.09 Millimeters	<i>MMAPGRP.017</i>	<i>MMAPRPT.017</i>
<i>GROUP 18</i> <i>Metric Gage Blocks</i>	2.10 to 2.29 Millimeters	<i>MMAPGRP.018</i>	<i>MMAPRPT.018</i>
<i>GROUP 19</i> <i>Metric Gage Blocks</i>	2.30 to 2.49 Millimeters	<i>MMAPGRP.019</i>	<i>MMAPRPT.019</i>

**Table 6.7-2 Organization Groups of NIST’s
Gage Block Mechanical Intercomparison
Calibration History in *Mecmap Document Files*
and *Mecmap Report Document Files***

Group Name	Master Gage Block Nominal Sizes in Group	Name of <i>Mecmap Document File</i>	Name of <i>Mecmap Report Document File</i>
<i>GROUP 20 Metric Gage Blocks</i>	2.50 to 10.0 Millimeters	<i>MMAPGRP.020</i>	<i>MMAPRPT.020</i>
<i>GROUP 21 Metric Gage Blocks</i>	10.5 to 20.0 Millimeters	<i>MMAPGRP.021</i>	<i>MMAPRPT.021</i>
<i>GROUP 22 Metric Gage Blocks</i>	20.5 to 50 Millimeters	<i>MMAPGRP.022</i>	<i>MMAPRPT.022</i>
<i>GROUP 23 Metric Gage Blocks</i>	60 to 100 Millimeters	<i>MMAPGRP.023</i>	<i>MMAPRPT.023</i>
<i>GROUP 24 Metric Gage Blocks</i>	125 to 500 Millimeters	<i>MMAPGRP.024</i>	<i>MMAPRPT.024</i>

Table 6.7-3 Configuration of *Mecmap Document Files*

Column	Field Description
<i>1</i>	This field has the testing status (Yes: <i>Blank</i> , No: <i>Asterisk</i> , Remark: <i>Exclamation Point</i>).
<i>2-11</i>	This field has the gage block nominal size (English: <i>in inches</i> , Metric: <i>in millimeters</i>).
<i>13-18</i>	This field has the standard gage block identification or serial number (zero to six characters accepted, “NONE” for no identification or serial number is recommended).
<i>20-25</i>	This field has the check standard gage block identification or serial number (zero to six characters accepted, “NONE” for no identification or serial number is recommended).

Table 6.7-3 Configuration of <i>Mecmap Document Files</i>	
Column	Field Description
27	This field has the master gage block type (English: 1, Metric: 2).
28-35	This field has the accepted master gage block mechanical intercomparison control, in nanometers.
37-41	This field has the accepted master gage block mechanical intercomparison within standard deviation, in nanometers.
43-44	This field has the testing method code (Exempt: 0, Interferometry: 1, 3-2 Design: 2, 3-4 Design: 3, 3-6 Design: 4, 4-4 Design: 5, 4-6 Design: 6, 5-4 Design: 7, 6-4 Design: 8, 7-4 Design: 9, 8-4 Design: 10, 9-4 Design: 11, 10-4 Design: 12, 11-4 Design: 13, ABCA Design: 14, 4-1 Design: 15).
45-46	This field has the electro-mechanical gage block comparators' identification code (Workstation One: F1, Workstation Two: F2, Workstation Three: F3, Workstation Four: F4, Workstation Five: F5, Workstation Six: F6, Workstation Seven: F7, Workstation Eight: F8, and Workstation Nine: F9).
48-53	This field has the observed temperature, in degrees Celsius.
55-57	This field has the observer's initials, one to three alphanumeric characters accepted, all initials recommended. The observer is the technical user, who calibrates and measures gage blocks, which includes NIST's gage block calibration customers' gage blocks.
58-61	This field has the year for the testing date, four numeric digit characters with leading zeros displayed, century mandatory.
62-63	This field has the month for the testing date, two numeric digit characters with leading zeros displayed (January: 01, February: 02, March: 03, April: 04, May: 05, June: 06, July: 07, August: 08, September: 09, October: 10, November: 11, December: 12).
64-65	This field has the day of the month for the testing date, two numeric digit characters with leading zeros displayed (1 st Day of Month: 01, 2 nd Day of Month: 02, 3 rd Day of Month: 03, . . . , 31 st Day of Month: 31).
66	This field has the statistical process control codes (Test Passed: 0, Test Failed on the F-test: 1, Test Failed on the T-test: 2, Test Failed on both the F-test and the T-test: 3).

Table 6.7-3 Configuration of <i>Mecmap Document Files</i>	
Column	Field Description
67-74	This field has the observed master gage block mechanical intercomparison control, in nanometers.
76-80	This field has the observed master gage block mechanical intercomparison within standard deviation, in nanometers.

Table 6.7-4 Listing of a Sample <i>Mecmap Document File</i> for Group One of NIST's Gage Block Mechanical Intercomparison Calibration Workstation											
	Column:	10	20	30	40	50	60	70	80		
		▼	▼	▼	▼	▼	▼	▼	▼		
Row:	123456789012345678901234567890123456789012345678901234567890123456789012										
0001:	0.010050	4527	VJV5	1	33.0	6.2	04F1	20.020	EMT199801050	20.3	4.1
0002:	0.040000	2435	VJV5	1	64.7	6.2	04F1	20.160	EMT199801050	56.5	1.6
0003:	0.050000	D4249	VJV5	1	-9.4	6.2	04F1	20.180	EMT199801051	-5.8	15.3
0004:	0.078125	040	VJV5	1	-136.2	6.2	04F1	20.190	EMT199801051	-134.9	23.8
0005:	0.020000	3126	VJV5	1	-38.9	6.2	04F1	20.160	EMT199801060	-57.5	8.9
0006:	0.050000	D4249	VJV5	1	-9.4	6.2	04F1	20.160	EMT199801060	-19.4	7.9
0007:	0.078125	040	VJV5	1	-136.2	6.2	04F1	20.170	EMT199801061	-121.9	33.3
0008:	0.078125	040	VJV5	1	-136.2	6.2	04F1	20.180	EMT199801060	-138.4	3.7
0009:	0.090000	066	VJV5	1	22.8	6.2	04F1	20.200	EMT199801060	18.1	3.5
0010:	0.050000	D4249	VJV5	1	-9.4	6.2	04F1	19.680	EMT199801083	-210.7	12.3
0011:	0.050000	D4249	VJV5	1	-9.4	6.2	04F1	19.680	EMT199801083	-220.7	11.5
0012:	0.050000	D4249	VJV5	1	-9.4	6.2	04F1	19.840	EMT199801100	-7.5	6.3
0013:	0.050000	D4249	VJV5	1	-9.4	6.2	04F1	19.840	EMT199801100	-11.5	5.2
0014:	0.050000	D4249	VJV5	1	-9.4	6.2	04F1	19.670	EMT199801113	-81.8	208.5
0015:	0.050000	D4249	VJV5	1	-9.4	6.2	04F1	19.670	EMT199801121	-33.2	95.6
0016:	0.050000	D4249	VJV5	1	-9.4	6.2	04F1	19.840	EMT199801170	-8.0	8.8
0017:	0.050000	D4249	VJV5	1	-9.4	6.2	04F1	19.850	MTS199805210	-16.1	10.0
0018:	0.031250	2306	VJV5	1	-63.6	6.6	04F1	19.770	SRF199806010	-53.5	4.6
0019:	0.046875	1859	VJV5	1	23.0	6.6	04F1	19.780	SRF199806010	18.6	3.0
0020:	0.050000	D4249	VJV5	1	-11.0	6.6	04F1	19.800	SRF199806010	-11.8	7.3
0021:	0.062500	2160	VJV5	1	-50.3	6.6	04F1	19.810	SRF199806010	-45.3	3.0
0022:	0.078125	040	VJV5	1	-137.2	6.6	04F1	19.810	SRF199806010	-143.2	6.1
0023:	0.093750	043	VJV5	1	-31.8	6.6	04F1	19.830	SRF199806010	-34.8	2.2
0024:	0.010000	6537	VJV5	1	73.7	6.6	04F1	19.870	SRF199806070	67.8	6.6

**Table 6.7-4 Listing of a Sample *Mecmap Document File*
for Group One of NIST's Gage Block
Mechanical Intercomparison Calibration Workstation**

	Column: 10	20	30	40	50	60	70	80			
	▼	▼	▼	▼	▼	▼	▼	▼			
Row:	123456789012345678901234567890123456789012345678901234567890123456789012										
0025:	0.020000	3126	VJV5	1	-46.4	6.6	04F1	19.880	SRF199806070	-54.4	4.6
0026:	0.020050	1017	VJV5	1	131.6	6.6	04F1	19.880	SRF199806070	135.6	3.0
0027:	0.030000	063	VJV5	1	-24.0	6.6	04F1	19.780	SRF199806140	-15.8	3.8
0028:	0.040000	2435	VJV5	1	53.9	6.6	04F1	19.780	SRF199806140	56.4	2.3
0029:	0.050000	D4249	VJV5	1	-11.0	6.6	04F1	19.800	SRF199806140	-10.0	4.7
0030:	0.060000	2230	VJV5	1	65.9	6.6	04F1	19.800	SRF199806140	65.2	1.6
0031:	0.070000	065	VJV5	1	-44.6	6.6	04F1	19.800	SRF199806140	-39.9	3.0
0032:	0.080000	2218	VJV5	1	-15.8	6.6	04F1	19.800	SRF199806140	-17.2	10.5
0033:	0.090000	066	VJV5	1	22.1	6.6	04F1	19.800	SRF199806141	20.6	11.7
0034:	0.090000	066	VJV5	1	22.1	6.6	04F1	19.800	SRF199806140	19.0	6.8
0035:	0.010000	6537	VJV5	1	73.7	6.6	04F1	19.660	SRF199806160	60.5	7.1
0036:	0.010000	6537	VJV5	1	73.7	6.6	04F1	19.850	SRF199806160	71.5	5.2
0037:	0.020000	3126	VJV5	1	-46.4	6.6	04F1	19.780	SRF199806160	-56.2	2.8
0038:	0.020000	3126	VJV5	1	-46.4	6.6	04F1	19.890	SRF199806160	-54.1	3.4
0039:	0.030000	063	VJV5	1	-24.0	6.6	04F1	19.900	SRF199806160	-25.0	5.8
0040:	0.030000	063	VJV5	1	-24.0	6.6	04F1	19.900	SRF199806161	-21.9	11.4
0041:	0.030000	063	VJV5	1	-24.0	6.6	04F1	19.900	SRF199806160	-20.3	4.6
0042:	0.040000	2435	VJV5	1	53.9	6.6	04F1	19.900	SRF199806160	54.0	2.3
0043:	0.040000	2435	VJV5	1	53.9	6.6	04F1	19.900	SRF199806160	58.5	4.3
0044:	0.050000	D4249	VJV5	1	-11.0	6.6	04F1	19.900	SRF199806160	-12.0	3.3
0045:	0.050000	D4249	VJV5	1	-11.0	6.6	04F1	19.940	SRF199806160	-4.8	4.8
0046:	0.010000	6537	VJV5	1	73.7	6.6	04F1	19.660	SRF199806191	72.1	16.1
0047:	0.010000	6537	VJV5	1	73.7	6.6	04F1	19.660	SRF199806190	82.5	8.3
0048:	0.010050	4527	VJV5	1	36.4	6.6	04F1	19.670	SRF199806190	41.1	5.5
0049:	0.015625	1225	VJV5	1	-32.2	6.6	04F1	19.760	SRF199806191	-29.2	13.8
0050:	0.015625	1225	VJV5	1	-32.2	6.6	04F1	19.760	SRF199806191	-28.4	37.8
0051:	0.015625	1225	VJV5	1	-32.2	6.6	04F1	19.780	SRF199806190	-27.4	10.7
0052:	0.020000	3126	VJV5	1	-46.4	6.6	04F1	19.780	SRF199806190	-59.4	3.6
0053:	0.020050	1017	VJV5	1	131.6	6.6	04F1	19.790	SRF199806190	131.2	3.9
0054:	0.030000	063	VJV5	1	-24.0	6.6	04F1	19.760	SRF199806200	-25.5	8.1
0055:	0.031250	2306	VJV5	1	-63.6	6.6	04F1	19.780	SRF199806200	-65.5	7.3
0056:	0.040000	2435	VJV5	1	53.9	6.6	04F1	19.780	SRF199806200	56.3	3.3
0057:	0.046875	1859	VJV5	1	23.0	6.6	04F1	19.780	SRF199806200	19.3	3.5
0058:	0.050000	D4249	VJV5	1	-11.0	6.6	04F1	19.790	SRF199806202	18.8	4.9
0059:	0.050000	D4249	VJV5	1	-11.0	6.6	04F1	19.790	SRF199806202	20.4	5.3
0060:	0.050050	S	ZWV25	1	-78.4	6.6	04F1	19.790	SRF199806200	-89.4	5.7

Table 6.7-4 Listing of a Sample *Mecmap Document File* for Group One of NIST’s Gage Block Mechanical Intercomparison Calibration Workstation

	Column:	10	20	30	40	50	60	70	80		
		▼	▼	▼	▼	▼	▼	▼	▼		
Row:		123456789012345678901234567890123456789012345678901234567890123456789012									
0061:	0.050000	D4249	VJV5	1	-11.0	6.6	04F1	19.710	SRF199806240	-12.7	5.3
0062:	0.060000	2230	VJV5	1	65.9	6.6	04F1	19.770	SRF199806241	80.3	54.2
0063:	0.060000	2230	VJV5	1	65.9	6.6	04F1	19.770	SRF199806240	65.2	3.8
0064:	0.062500	2160	VJV5	1	-50.3	6.6	04F1	19.770	SRF199806240	-50.3	6.7
0065:	0.070000	065	VJV5	1	-44.6	6.6	04F1	19.770	SRF199806240	-41.2	1.6
0066:	0.078125	040	VJV5	1	-137.2	6.6	04F1	19.800	SRF199806240	-143.4	2.3
0067:	0.080000	2218	VJV5	1	-15.8	6.6	04F1	19.800	SRF199806240	-22.7	3.2
0068:	0.090000	066	VJV5	1	22.1	6.6	04F1	19.800	SRF199806240	20.2	2.6
0069:	0.093750	043	VJV5	1	-31.8	6.6	04F1	19.840	SRF199806240	-34.8	2.5
0070:	0.010000	6537	VJV5	1	73.7	6.6	04F1	19.760	SRF199806270	72.8	6.9
0071:	0.020000	3126	VJV5	1	-46.4	6.6	04F1	19.770	SRF199806270	-54.3	4.9
0072:	0.020050	1017	VJV5	1	131.6	6.6	04F1	19.770	SRF199806271	142.0	14.4
0073:	0.020050	1017	VJV5	1	131.6	6.6	04F1	19.770	SRF199806270	136.8	5.0
0074:	0.030000	063	VJV5	1	-24.0	6.6	04F1	19.900	SRF199806270	-30.1	6.6
0075:	0.040000	2435	VJV5	1	53.9	6.6	04F1	19.900	SRF199806270	56.5	4.3
0076:	0.050000	D4249	VJV5	1	-11.0	6.6	04F1	19.900	SRF199806270	-6.9	7.5
0077:	0.060000	2230	VJV5	1	65.9	6.6	04F1	19.920	SRF199806270	69.1	8.7
0078:	0.070000	065	VJV5	1	-44.6	6.6	04F1	19.930	SRF199806271	-41.3	11.4
0079:	0.070000	065	VJV5	1	-44.6	6.6	04F1	19.930	SRF199806270	-45.4	3.2
0080:	0.080000	2218	VJV5	1	-15.8	6.6	04F1	19.950	SRF199806270	-14.9	8.4
0081:	0.090000	066	VJV5	1	22.1	6.6	04F1	19.950	SRF199806270	20.8	4.3
0082:	0.010000	6537	VJV5	1	73.7	6.6	04F1	19.780	SRF199806280	77.1	2.8
0083:	0.020000	3126	VJV5	1	-46.4	6.6	04F1	19.780	SRF199806280	-56.4	9.7
0084:	0.020050	1017	VJV5	1	131.6	6.6	04F1	19.790	SRF199806280	134.6	9.5
0085:	0.030000	063	VJV5	1	-24.0	6.6	04F1	19.740	SRF199806280	-26.5	5.0
0086:	0.040000	2435	VJV5	1	53.9	6.6	04F1	19.770	SRF199806280	51.4	4.5
0087:	0.050000	D4249	VJV5	1	-11.0	6.6	04F1	19.790	SRF199806280	-17.5	6.1
0088:	0.060000	2230	VJV5	1	65.9	6.6	04F1	19.800	SRF199806280	65.2	4.2
0089:	0.070000	065	VJV5	1	-44.6	6.6	04F1	19.820	SRF199806280	-42.5	5.9
0090:	0.080000	2218	VJV5	1	-15.8	6.6	04F1	19.830	SRF199806280	-18.8	6.1
0091:	0.090000	066	VJV5	1	22.1	6.6	04F1	19.840	SRF199806280	18.6	9.1
0092:	0.050000	D4249	VJV5	1	-11.0	6.6	04F1	19.730	SRF199807010	-8.8	7.8
0093:	0.062500	2160	VJV5	1	-50.3	6.6	04F1	19.730	SRF199807010	-52.0	7.8
0094:	0.078125	040	VJV5	1	-137.2	6.6	04F1	19.730	SRF199807010	-141.2	4.6
0095:	0.093750	043	VJV5	1	-31.8	6.6	04F1	19.770	SRF199807010	-33.1	2.9
0096:	0.015625	1225	VJV5	1	-32.2	6.6	04F1	19.810	SRF199807071	-11.6	31.0

**Table 6.7-4 Listing of a Sample *Mecmap Document File*
for Group One of NIST's Gage Block
Mechanical Intercomparison Calibration Workstation**

Column:	10	20	30	40	50	60	70	80			
Row:	1	2	3	4	5	6	7	8			
0097:	0.015625	1225	VJV5	1	-32.2	6.6	04F1	19.810	SRF199807070	-32.1	6.8
0098:	0.031250	2306	VJV5	1	-63.6	6.6	04F1	19.840	SRF199807070	-67.2	3.3
0099:	0.046875	1859	VJV5	1	23.0	6.6	04F1	19.850	SRF199807070	14.8	3.4
0100:	0.050000	D4249	VJV5	1	-11.0	6.6	04F1	19.870	SRF199807071	-20.4	16.9
0101:	0.050000	D4249	VJV5	1	-11.0	6.6	04F1	19.870	SRF199807070	-22.7	8.2
0102:	0.062500	2160	VJV5	1	-50.3	6.6	04F1	19.890	SRF199807070	-58.6	3.8
0103:	0.078125	040	VJV5	1	-137.2	6.6	04F1	19.900	SRF199807071	-138.5	11.2
0104:	0.078125	040	VJV5	1	-137.2	6.6	04F1	19.900	SRF199807070	-143.4	5.1
0105:	0.093750	043	VJV5	1	-31.8	6.6	04F1	19.910	SRF199807071	-33.1	14.0
0106:	0.093750	043	VJV5	1	-31.8	6.6	04F1	19.910	SRF199807070	-36.3	1.9
0107:	0.050000	D4249	VJV5	1	-11.0	6.6	04F1	19.740	MTS199807081	-6.8	12.6
0108:	0.050000	D4249	VJV5	1	-11.0	6.6	04F1	19.740	MTS199807080	-19.3	6.9
0109:	0.062500	2160	VJV5	1	-50.3	6.6	04F1	19.740	MTS199807080	-50.9	7.8
0110:	0.078125	040	VJV5	1	-137.2	6.6	04F1	19.750	MTS199807080	-138.8	4.5
0011:	0.093750	043	VJV5	1	-31.8	6.6	04F1	19.770	MTS199807080	-35.4	4.1

6.8 The *Probe* Program

The *Probe* program opens, prints, and stores the measurements and probe calibration results of NIST's electro-mechanical gage block comparators' calibrations. The technical user, who calibrates and measures gage blocks, calibrates NIST's electro-mechanical gage block comparators, using the *Probe* program to measure NIST's two or three eleven-piece sets of gage blocks, which the NIST technical staff refers as *step master gage blocks*, analyze the measurements, and print, plot, and record the measurements and probe calibration results the *Gage* program uses to help the user better calibrate and measure NIST's gage block calibration customers' gage blocks. The three eleven-piece sets of gage blocks, which the NIST technical staff refers as *step master gage blocks*, each consists of a selection of rectangular gage blocks having nominal gage block sizes from 0.1 through 0.1001 inches, in increments of 0.0001 inches, one each of steel, chrome carbide, and tungsten carbide gage blocks. When the user uses the *Gage* program to calibrate and measure NIST's gage block calibration customers' gage blocks, the *Gage* program uses the probe calibration results the *Probe* program records to automatically compensate measurements for effects of NIST's electro-mechanical gage block

comparators' scale magnification and variable measuring forces and measuring probe tip geometry. The **Probe** program records the measurements and probe calibration results of NIST's electro-mechanical gage block comparators' calibrations to **Probe Document Files**, which are DOS ASCII text files.

The **Probe** and **Gage** programs alike derive length differences between gage blocks when the technical user, who calibrates and measures gage blocks, inserts gage blocks, one at a time, between the two diamond-tipped measuring probe tips of NIST's electro-mechanical gage block comparators and the **Gage** program takes differences between pairs of measurements. The electro-mechanical gage block comparators each use one linear variable differential transformer (LVDT) to measure the relative displacement of two measuring probe tips [1]. The **Probe** and **Gage** programs use the digital voltmeters to read the LVDT analog signals that, when triggered by the user pressing the auxiliary trigger mechanisms, send the measured voltages to the microcomputers. The **Probe** program, by design, relates the LVDT analog signals to measuring probe tip displacement and relates the elastic deformation properties of the three gage blocks' materials to the measuring probe tip penetration of gage blocks' gaging faces, which together the **Gage** program then uses. The probe calibration results the **Probe** program records, which the user calls *probe calibration information*, enables NIST to measure, with better accuracy, NIST's gage block calibration customers' steel, chrome carbide, and tungsten carbide gage blocks.

The **Probe** program's two probe calibration procedures requires the technical user, who calibrates and measures gage blocks, to measure NIST's two or three eleven-piece sets of gage blocks, which the NIST technical staff refers as *step master gage blocks*, starting with one gage block randomly selected and designated the *repeat block*, going in successive measurement sequences of progressing order from nominal gage block sizes 0.1 through 0.1001 inches and together measuring blocks matching in nominal sizes one at a time, alternatively measuring repeatedly the *repeat block* between sequences. The **Probe** program records the measurements, which are the LVDT analog signals the digital voltmeters read, as voltages, when triggered by the user pressing the auxiliary trigger mechanism, and uses linear regression analysis to solve the linear equation of length differences that is equal to the slope times voltage plus the y-intercept.

The **Probe** program has a *Control Menu* with fifteen functions, as Table 6.8-1 shows. The technical user, who calibrates and measures gage blocks, uses the *Control Menu* functions to do the following:

- Create, open, print, store, and archive *Probe Document Files*, which stores the measurements and probe calibration results of NIST's electro-mechanical gage block comparators' calibrations
- Switch between NIST's electro-mechanical gage block comparators the **Probe** program calibrates and the **Gage** program uses when calibrating and measuring NIST's gage block calibration customers' gage blocks

- Switch between the probe calibration method the **Gage** program uses when calibrating and measuring NIST's gage block calibration customers' gage blocks
- Switch between the probe calibration baseline the **Gage** program uses when calibrating and measuring NIST's gage block calibration customers' gage blocks
- Switch between *Probe Document Files* stored and the **Gage** program uses when calibrating and measuring NIST's gage block calibration customers' gage blocks
- View opened *Probe Document Files*
- Record automatically, when running the **Probe** program's probe calibration procedure, the electro-mechanical gage block comparators' readings every time by pressing the auxiliary trigger mechanism
- View, plot, and print the measurements and probe calibration results of NIST's electro-mechanical gage block comparators' probe calibration history
- View and print the measurements and probe calibration results of NIST's electro-mechanical gage block comparators' calibrations
- View the *Step Master Document File*

Table 6.8-1 The *Probe* Program's Control Menu Functions

Name of Function	Function Description
<i>Program Preface</i> .	This function displays the Probe program's introductory statement.
<i>View Masters</i>	This function opens the <i>Step Master Document File</i> viewing window with the <i>Step Master Document File</i> .
<i>Instrument</i>	This function prompts the computer user to select the electro-mechanical gage block comparator the Gage program uses when calibrating and measuring NIST's gage block calibration customers' gage blocks.
<i>Method</i>	This function prompts the computer user to select the probe calibration method the Gage program uses when calibrating and measuring NIST's gage block calibration customers' gage blocks.
<i>Baseline</i>	This function prompts the computer user to select the probe calibration baseline the Gage program uses when calibrating and measuring NIST's gage block calibration customers' gage blocks.
<i>New</i>	This function opens a copy of a new <i>Probe Document File</i> into the <i>Probe Document File</i> window.

Table 6.8-1 The <i>Probe</i> Program's Control Menu Functions	
Name of Function	Function Description
<i>Open</i>	This function opens a copy of a <i>Probe Document File</i> into the <i>Probe Document File</i> window. <i>Probe Document Files</i> include working <i>Probe Document Files</i> in the working and archived file storage device and folders, which are C:\Gage\Probes\F1 for Workstation One, C:\Gage\Probes\F2 for Workstation Two, C:\Gage\Probes\F3 for Workstation Three, C:\Gage\Probes\F4 for Workstation Four, C:\Gage\Probes\F5 for Workstation Five, C:\Gage\Probes\F6 for Workstation Six, C:\Gage\Probes\F7 for Workstation Seven, C:\Gage\Probes\F8 for Workstation Eight, and C:\Gage\Probes\F9 for Workstation Nine, and archived <i>Probe Document Files</i> on labeled floppy diskettes. This function copies, deletes, moves, and renames <i>Probe Document Files</i> in file storage devices and folders.
<i>Run</i>	This function runs the probe calibration procedure, which directs the computer user to measure NIST's one-to-three eleven-piece sets of gage blocks, which the NIST technical staff refers as <i>step master gage blocks</i> , starting with one gage block randomly selected and designated the <i>repeat block</i> , going in successive measurement sequences of progressing order from nominal gage block sizes 0.1 through 0.1001 inches and together measuring blocks matching in nominal sizes one at a time, alternatively measuring repeatedly the <i>repeat block</i> between sequences. The function prompts the computer user when all measurements complete to record the measurements, which are the LVDT analog signals, in voltage, the digital voltmeters read when triggered by the user pressing the auxiliary trigger mechanisms, and uses linear regression analysis to solve the linear equation of length differences is equal to the slope times voltage plus the y-intercept.
<i>View Plot</i>	This function opens the <i>Probe Document File</i> plotting window with the <i>Probe Document File</i> for examining, plotting, and printing the measurements and probe calibration results in a <i>Probe Document File</i> .
<i>View Report</i>	This function opens the <i>Probe Report Document</i> viewing window with the <i>Probe Report Document</i> for examining and printing the measurements and probe calibration results in a <i>Probe Document File</i> .
<i>Select</i>	This function prompts the computer user to select the probe calibration among the <i>Probe Document Files</i> stored the Gage program uses for calibrations of NIST's electro-mechanical gage block comparators.

Table 6.8-1 The <i>Probe</i> Program's Control Menu Functions	
Name of Function	Function Description
<i>View History</i>	This function opens the <i>Probe History Document</i> viewing window with the <i>Probe History Document</i> for examining and printing the electro-mechanical gage block comparators' probe calibration history.
<i>Store</i>	This function stores a copy of the current <i>Probe Document File</i> in the current <i>Probe Document File</i> window to a working file and stored in the DOS ASCII text file storage format. When a file already exists, a prompt first appears about overwriting the current <i>Probe Document File</i> to this file or storing the current <i>Probe Document File</i> to a new file.
<i>Archive</i>	This function archives a copy of the current <i>Probe Document File</i> in the current <i>Probe Document File</i> window to an archived file and stored in the DOS ASCII text file storage format. When a file already exists, a prompt first appears about overwriting the current <i>Probe Document File</i> to this file or storing the current <i>Probe Document File</i> to a new file.
<i>Exit PROBE</i>	This function stops the <i>Probe</i> program and loads and runs the <i>Branch</i> program. When a <i>Probe Document File</i> is in the current <i>Probe Document File</i> window, a prompt first appears about storing the current <i>Probe Document File</i> and an affirmative response causes the function to store the current <i>Probe Document File</i> and close the current <i>Probe Document File</i> window.

The ***NIST Gage Block Calibration Software System***'s calibration and measurement software programs offer the technical user, who calibrates and measures gage blocks, two probe calibration procedures to calibrate NIST's electro-mechanical gage block comparators, as Table 6.8-2 shows. As the two probe calibration procedures prescribe, the user randomly selects and designates as the *repeat block* one gage block nominally sized from 0.1 to 0.1001 inches, which typically the NIST technical staff selects among NIST's two or three sets of step master gage blocks. The *Two-Set Method* uses the steel and chrome carbide step master gage blocks and the *Three-Set Method* uses the steel, chrome carbide, and tungsten carbide step master gage blocks. Following one of the two probe calibration procedures, the user measures all step master gage blocks, one gage block at a time, in the following way:

- Grouping all step master gage blocks by nominal size from 0.1 through 0.1001 inches
- Grouping each group of step master gage blocks farther by order of material, steel, chrome carbide, and optionally tungsten carbide

Alternatively, the user measures the *repeat block* between successive nominal size sequences. The **Probe** program’s two calibration procedures both call for using any *repeat block* among NIST’s two or three sets of step master gage blocks between probe calibrations and using the same *repeat block* during a probe calibration.

Table 6.8-2 Probe Calibration Method Designs	
Method	Design Description
<i>TWO-SET</i>	Y_0 = Randomly Selected Repeat Step Master Gage Block Y_1 = 0.100000 Inch, 1DOT (Steel) Step Master Gage Block Y_2 = 0.100000 Inch, 2DOT (Chrome Carbide) Step Master Gage Block Y_3 = Randomly Selected Repeat Step Master Gage Block Y_4 = 0.100010 Inch, 1DOT (Steel) Step Master Gage Block Y_5 = 0.100010 Inch, 2DOT (Chrome Carbide) Step Master Gage Block Y_6 = Randomly Selected Repeat Step Master Gage Block Y_7 = 0.100020 Inch, 1DOT (Steel) Step Master Gage Block Y_8 = 0.100020 Inch, 2DOT (Chrome Carbide) Step Master Gage Block Y_9 = Randomly Selected Repeat Step Master Gage Block Y_{10} = 0.100030 Inch, 1DOT (Steel) Step Master Gage Block Y_{11} = 0.100030 Inch, 2DOT (Chrome Carbide) Step Master Gage Block Y_{12} = Randomly Selected Repeat Step Master Gage Block Y_{13} = 0.100040 Inch, 1DOT (Steel) Step Master Gage Block Y_{14} = 0.100040 Inch, 2DOT (Chrome Carbide) Step Master Gage Block Y_{15} = Randomly Selected Repeat Step Master Gage Block Y_{16} = 0.100050 Inch, 1DOT (Steel) Step Master Gage Block Y_{17} = 0.100050 Inch, 2DOT (Chrome Carbide) Step Master Gage Block Y_{18} = Randomly Selected Repeat Step Master Gage Block

Table 6.8-2 Probe Calibration Method Designs

Method	Design Description
	<p> Y_{19} = 0.100060 Inch, 1DOT (Steel) Step Master Gage Block Y_{20} = 0.100060 Inch, 2DOT (Chrome Carbide) Step Master Gage Block Y_{21} = Randomly Selected Repeat Step Master Gage Block Y_{22} = 0.100070 Inch, 1DOT (Steel) Step Master Gage Block Y_{23} = 0.100070 Inch, 2DOT (Chrome Carbide) Step Master Gage Block Y_{24} = Randomly Selected Repeat Step Master Gage Block Y_{25} = 0.100080 Inch, 1DOT (Steel) Step Master Gage Block Y_{26} = 0.100080 Inch, 2DOT (Chrome Carbide) Step Master Gage Block Y_{27} = Randomly Selected Repeat Step Master Gage Block Y_{28} = 0.100090 Inch, 1DOT (Steel) Step Master Gage Block Y_{29} = 0.100090 Inch, 2DOT (Chrome Carbide) Step Master Gage Block Y_{30} = Randomly Selected Repeat Step Master Gage Block Y_{31} = 0.100100 Inch, 1DOT (Steel) Step Master Gage Block Y_{32} = 0.100100 Inch, 2DOT (Chrome Carbide) Step Master Gage Block Y_{33} = Randomly Selected Repeat Step Master Gage Block </p>
<i>THREE-SET</i>	<p> Y_0 = Randomly Selected Repeat Step Master Gage Block Y_1 = 0.100000 Inch, 1DOT (Steel) Step Master Gage Block Y_2 = 0.100000 Inch, 2DOT (Chrome Carbide) Step Master Gage Block Y_3 = 0.100000 Inch, 3DOT (Tungsten Carbide) Step Master Gage Block Y_4 = Randomly Selected Repeat Step Master Gage Block Y_5 = 0.100010 Inch, 1DOT (Steel) Step Master Gage Block Y_6 = 0.100010 Inch, 2DOT (Chrome Carbide) Step Master Gage Block Y_7 = 0.100010 Inch, 3DOT (Tungsten Carbide) Step Master Gage Block Y_8 = Randomly Selected Repeat Step Master Gage Block </p>

Table 6.8-2 Probe Calibration Method Designs

Method	Design Description
	<p>Y₉ = 0.100020 Inch, 1DOT (Steel) Step Master Gage Block</p> <p>Y₁₀ = 0.100020 Inch, 2DOT (Chrome Carbide) Step Master Gage Block</p> <p>Y₁₁ = 0.100020 Inch, 3DOT (Tungsten Carbide) Step Master Gage Block</p> <p>Y₁₂ = Randomly Selected Repeat Step Master Gage Block</p> <p>Y₁₃ = 0.100030 Inch, 1DOT (Steel) Step Master Gage Block</p> <p>Y₁₄ = 0.100030 Inch, 2DOT (Chrome Carbide) Step Master Gage Block</p> <p>Y₁₅ = 0.100030 Inch, 3DOT (Tungsten Carbide) Step Master Gage Block</p> <p>Y₁₆ = Randomly Selected Repeat Step Master Gage Block</p> <p>Y₁₇ = 0.100040 Inch, 1DOT (Steel) Step Master Gage Block</p> <p>Y₁₈ = 0.100040 Inch, 2DOT (Chrome Carbide) Step Master Gage Block</p> <p>Y₁₉ = 0.100040 Inch, 3DOT (Tungsten Carbide) Step Master Gage Block</p> <p>Y₂₀ = Randomly Selected Repeat Step Master Gage Block</p> <p>Y₂₁ = 0.100050 Inch, 1DOT (Steel) Step Master Gage Block</p> <p>Y₂₂ = 0.100050 Inch, 2DOT (Chrome Carbide) Step Master Gage Block</p> <p>Y₂₃ = 0.100050 Inch, 3DOT (Tungsten Carbide) Step Master Gage Block</p> <p>Y₂₄ = Randomly Selected Repeat Step Master Gage Block</p> <p>Y₂₅ = 0.100060 Inch, 1DOT (Steel) Step Master Gage Block</p> <p>Y₂₆ = 0.100060 Inch, 2DOT (Chrome Carbide) Step Master Gage Block</p> <p>Y₂₇ = 0.100060 Inch, 3DOT (Tungsten Carbide) Step Master Gage Block</p> <p>Y₂₈ = Randomly Selected Repeat Step Master Gage Block</p> <p>Y₂₉ = 0.100070 Inch, 1DOT (Steel) Step Master Gage Block</p> <p>Y₃₀ = 0.100070 Inch, 2DOT (Chrome Carbide) Step Master Gage Block</p> <p>Y₃₁ = 0.100070 Inch, 3DOT (Tungsten Carbide) Step Master Gage Block</p> <p>Y₃₂ = Randomly Selected Repeat Step Master Gage Block</p> <p>Y₃₃ = 0.100080 Inch, 1DOT (Steel) Step Master Gage Block</p> <p>Y₃₄ = 0.100080 Inch, 2DOT (Chrome Carbide) Step Master Gage Block</p> <p>Y₃₅ = 0.100080 Inch, 3DOT (Tungsten Carbide) Step Master Gage Block</p> <p>Y₃₆ = Randomly Selected Repeat Step Master Gage Block</p>

Table 6.8-2 Probe Calibration Method Designs	
Method	Design Description
	Y_{37} = 0.100090 Inch, 1DOT (Steel) Step Master Gage Block Y_{38} = 0.100090 Inch, 2DOT (Chrome Carbide) Step Master Gage Block Y_{39} = 0.100090 Inch, 3DOT (Tungsten Carbide) Step Master Gage Block Y_{40} = Randomly Selected Repeat Step Master Gage Block Y_{41} = 0.100100 Inch, 1DOT (Steel) Step Master Gage Block Y_{42} = 0.100100 Inch, 2DOT (Chrome Carbide) Step Master Gage Block Y_{43} = 0.100100 Inch, 3DOT (Tungsten Carbide) Step Master Gage Block Y_{44} = Randomly Selected Repeat Step Master Gage Block

The technical user, who calibrates and measures gage blocks, follows established file naming and storing conventions to manage the *Step Master Document File*. The established naming convention for the *Step Master Document File* is limited to eight characters for the filename with a three-character extension and a period separating the filename from the extension (e.g., *Stepmstr.gbk* for NIST's step master gage blocks). The working *Step Master Document File* is to record current *step master information* and the backed up *Step Master Document File* to record minimally the current *step master information*. When the working *Step Master Document File* is corrupted or lost, the user restores the *step master information* from the backed up *Step Master Document File*, which eliminates re-entering all *step master information*. The user stores the working *Step Master Document File* in the working file storage device and folder, which is *C:\Gage\Masters*, and the backed up *Step Master Document File* on labeled floppy diskettes.

The technical user, who calibrates and measures gage blocks, uses the *Edit* program to store *step master information* in the *Step Master Document File*. The configuration of the *Step Master Document File*, as Table 6.8-3 shows, with *step master information*, each totaling ten fields and extending 64 characters. This *step master information* is the step master gage blocks' nominal sizes, identification or serial numbers, material codes, and interferometrically-derived nominal deviations, which the user orders respectively by material type as follows: steel, chrome carbide, and tungsten carbide. The user stores the working *Step Master Document File* in the working file storage device and folder, which is *C:\Gage\Masters*. The user backs up the *Step Master Document File* on labeled floppy diskettes. The listing of the *Step Master Document File*, named *Stepmstr.gbk*, as Table 6.8-4 shows, has the latest information for NIST's three sets of step master gage blocks.

Table 6.8-3 Configuration of the <i>Step Master Document File</i>	
Column	Field Description
<i>1-10</i>	This field has the step master gage block nominal size (English: <i>in inches</i>).
<i>12-17</i>	This field has the first set's step gage block identification or serial number (zero to six characters accepted, "NONE" for no identification or serial number is recommended).
<i>19-24</i>	This field has the second set's step gage block identification or serial number (zero to six characters accepted, "NONE" for no identification or serial number is recommended).
<i>26-31</i>	This field has the third set's step gage block identification or serial number (zero to six characters accepted, "NONE" for no identification or serial number is recommended).
<i>33-36</i>	This field has the first set's step gage block material code, four numeric digit characters with leading zeros displayed (Steel: <i>0001</i> , Ceramic: <i>0002</i> , Chrome Carbide: <i>0003</i> , Tungsten Carbide: <i>0004</i> , Stainless Steel: <i>0005</i> , and Other: <i>0006</i>).
<i>38-41</i>	This field has the second set's step gage block material code, four numeric digit characters with leading zeros displayed (Steel: <i>0001</i> , Ceramic: <i>0002</i> , Chrome Carbide: <i>0003</i> , Tungsten Carbide: <i>0004</i> , Stainless Steel: <i>0005</i> , and Other: <i>0006</i>).
<i>43-46</i>	This field has the third set's step gage block material code, four numeric digit characters with leading zeros displayed (Steel: <i>0001</i> , Ceramic: <i>0002</i> , Chrome Carbide: <i>0003</i> , Tungsten Carbide: <i>0004</i> , Stainless Steel: <i>0005</i> , and).
<i>48-52</i>	This field has the first set's step gage block interferometrically-derived nominal deviation, in nanometers.
<i>54-58</i>	This field has the second set's standard step gage block interferometrically-derived nominal deviation, in nanometers.
<i>40-64</i>	This field has the third set's standard step gage block interferometrically-derived nominal deviation, in nanometers.

Table 6.8-4 Latest Listing of the <i>Stepmstr.gbk</i> File											
Column:	10	20	30	40	50	60	70	80			
Row:	1	2	3	4	5	6	7	8	9	10	11
0001:	0.100000	950028	w7w17	1780	0001	0003	0004	60	25	6	
0002:	0.100010	960064	w7w17	1780	0001	0003	0004	129	-4	74	
0003:	0.100020	960070	w7w17	1780	0001	0003	0004	103	-9	-31	
0004:	0.100030	960076	w7w17	1780	0001	0003	0004	71	32	-73	
0005:	0.100040	960084	w7w17	1780	0001	0003	0004	34	5	69	
0006:	0.100050	900808	w7w17	1780	0001	0003	0004	49	-6	24	
0007:	0.100060	960093	w7w17	1780	0001	0003	0004	50	26	-83	
0008:	0.100070	960100	w7w17	1780	0001	0003	0004	71	-24	-68	
0009:	0.100080	960107	w7w17	1780	0001	0003	0004	15	-25	90	
0010:	0.100090	960090	w7w17	1780	0001	0003	0004	19	-31	39	
0011:	0.100100	940694	w7w17	1780	0001	0003	0004	17	35	-7	

The *Probe* and *Gage* programs get *probe setup information* for NIST's electro-mechanical gage block comparator workstations from the DOS ASCII text file, named *Probe.ini*. The *Probe.ini* file resides in the *Gage* folder, which is the current and customary program folder for the *NIST Gage Block Calibration Software System* under normal operations. As Table 6.8-5 shows, the *Probe.ini* file contains ten sections. The first section, which the statement “[*PROBE CALIBRATION*]” identifies, has the number of electro-mechanical gage block comparators in the *NIST Gage Block Calibration Software System* and the technical user, who calibrates and measures gage blocks, latest selection among NIST's electro-mechanical gage block comparator workstation. When running the *Probe* and *Gage* programs and selecting among the NIST's electro-mechanical gage block comparator workstations, every time the user makes workstation selections the *Probe* and *Gage* programs records the workstations selected to the *Probe.ini* file's first section. Following the first section are nine sections, such that, the statement “[*WORKSTATION 1 PROBE SETUP*]” identifies the first section, “[*WORKSTATION 2 PROBE SETUP*]” identifies the second section, “[*WORKSTATION 3 PROBE SETUP*]” identifies the third section, “[*WORKSTATION 4 PROBE SETUP*]” identifies the fourth section, “[*WORKSTATION 5 PROBE SETUP*]” identifies the fifth section, “[*WORKSTATION 6 PROBE SETUP*]” identifies the sixth section, “[*WORKSTATION 7 PROBE SETUP*]” identifies the seventh section, “[*WORKSTATION 8 PROBE SETUP*]” identifies the eighth section, and “[*WORKSTATION 9 PROBE SETUP*]” identifies the ninth section. These sections store the workstations' respective hardware devices' select codes, digital voltmeters' voltage scales, electro-mechanical gage comparators' descriptions, lower and upper probe forces, and probe calibration cycles.

The technical user, who calibrates and measures gage blocks, uses the *Edit* program to change the *probe setup information* in the *Probe.ini* file. This *probe setup information* is the workstations' respective hardware devices' select codes, digital voltmeters' voltage scales, electro-mechanical gage comparators' descriptions, lower and upper probe forces, and probe calibration cycles. The user stores the working *Probe.ini* file in the *Gage* folder. The user backs up the *Probe.ini* file on labeled floppy diskettes. The listing of the *Probe.ini* file, as Table 6.8-5 shows, has the latest information for NIST's electro-mechanical gage block comparator workstations.

Table 6.8-5 Latest Listing of the <i>Probe.ini</i> File									
Column:	10	20	30	40	50	60	70	80	
Row:	1	2	3	4	5	6	7	8	
0001:	[	P	R	O	B	E		C	A
0002:	W	o	r	k	s	t	a	t	i
0003:	W	o	r	k	s	t	a	t	i
0004:									
0005:	[	W	O	R	K	S	T	A	T
0006:	W	o	r	k	s	t	a	t	i
0007:	W	o	r	k	s	t	a	t	i
0008:	D	e	s	c	r	i	p	t	i
0009:	P	r	o	b	e	F	o	r	c
0010:	P	r	o	b	e	F	o	r	c
0011:	P	r	o	b	e	C	a	l	i
0012:	P	r	o	b	e	C	a	l	i
0013:									
0014:	[	W	O	R	K	S	T	A	T
0015:	W	o	r	k	s	t	a	t	i
0016:	W	o	r	k	s	t	a	t	i
0017:	D	e	s	c	r	i	p	t	i
0018:	P	r	o	b	e	F	o	r	c
0019:	P	r	o	b	e	F	o	r	c
0020:	P	r	o	b	e	C	a	l	i
0021:	P	r	o	b	e	C	a	l	i
0022:									
0023:	[	W	O	R	K	S	T	A	T
0024:	W	o	r	k	s	t	a	t	i
0025:	W	o	r	k	s	t	a	t	i
0026:	D	e	s	c	r	i	p	t	i
0027:	P	r	o	b	e	F	o	r	c
0028:	P	r	o	b	e	F	o	r	c

Table 6.8-5 Latest Listing of the <i>Probe.ini</i> File	
Column:	10 20 30 40 50 60 70 80
Row:	▼ ▼ ▼ ▼ ▼ ▼ ▼ ▼
0068:	[WORKSTATION 8 PROBE SETUP]
0069:	WorkstationSelectCode=0
0070:	WorkstationVoltsScale=0 DCVolts
0071:	Description=Station 8 X-Inch Federal Comparator ... NIST Property No. XXXXXX
0072:	ProbeForce[Lower]=0 Pounds
0073:	ProbeForce[Upper]=0 Pounds
0074:	ProbeCalibrationCycle=0 Days
0075:	ProbeCalibrationCycle=0 Tests
0076:	
0077:	[WORKSTATION 9 PROBE SETUP]
0078:	WorkstationSelectCode=0
0079:	WorkstationVoltsScale=0 DCVolts
0080:	Description=Station 9 X-Inch Federal Comparator ... NIST Property No. XXXXXX
0081:	ProbeForce[Lower]=0 Pounds
0082:	ProbeForce[Upper]=0 Pounds
0083:	ProbeCalibrationCycle=0 Days
	ProbeCalibrationCycle=0 Tests

Every time the technical user, who calibrates and measures gage blocks, selects the *Probe Document Files* and probe calibration methods and baselines that the *Gage* program uses to calibrate and measure NIST’s gage block calibration customers’ gage blocks, the *Probe* program records the selections’ *probe calibration record information* in the *Probe Document Log File*, which is a DOS ASCII text file, named *Probe.log*. The *Probe Document Log File* resides in the *Gage* folder, which is the current and customary program folder for the *NIST Gage Block Calibration Software System* under normal operations. The configuration of the *Probe Document Log File*, as Table 6.8-6 shows, with *probe calibration record information*, each totaling ten fields and extending 78 characters. This *probe calibration information*, which the *Probe* program appends to the *Probe Document Log File* every time the user selects the *Probe Document Files* and probe calibration methods and baselines, have workstation numbers that identify NIST’s electro-mechanical gage block comparators, the *Probe Document Files*’ file names storing the *probe calibration information* and calibration and measurement results, dates user selects the *Probe Document Files* and probe calibration methods and baselines, the probe calibration methods and baselines, the scale magnifications and standard deviations for the probe calibrations, and the probe calibration residuals for NIST’s first, second, and optionally third step master gage block sets. The listing of a sample *Probe Document Log File*, as Table 6.8-7 shows,

has information that the *Probe* program writes every time the user selects the *Probe Document Files* and probe calibration methods and baselines at NIST's gage block calibration workstations.

Column	Field Description
1-2	This field has the number that identifies NIST's electro-mechanical gage block comparator the computer user selects for the <i>Probe</i> program to calibrate and the <i>Gage</i> program to use when calibrating and measuring NIST's gage block calibration customers' gage blocks (e.g., "F1" for Workstation One, "F2" for Workstation Two, "F3" for Workstation Three, "F4" for Workstation Four, "F5" for Workstation Five, "F6" for Workstation Six, "F7" for Workstation Seven, "F8" for Workstation Eight, and "F9" for Workstation Nine).
4-15	This field has the file name of the <i>Probe Document File</i> storing probe calibration that the computer user selects.
17-27	This field has the date the computer user selects the <i>Probe Document File</i> and probe calibration method and baseline.
29-32	This field has the probe calibration method the computer user selects (e.g., "2SET" for <i>Two-Set Method</i> , "3SET" for <i>Three-Set Method</i>).
34-37	This field has the probe calibration baseline the computer user selects (e.g., "1DOT" to use as a baseline NIST's first step master gage block set, "2DOT" to use as a baseline NIST's second step master gage block set, "3DOT" to use as a baseline NIST's third step master gage block set).
39-47	This field has the probe calibration scale magnification.
49-54	This field has the probe calibration standard deviation, in nanometers.
56-62	This field has the probe calibration residual for NIST's first step master gage block set.
64-70	This field has the probe calibration residual for NIST's second step master gage block set.
72-78	This field has the probe calibration residual for NIST's third step master gage block set.

Table 6.8-7 Latest Listing of a <i>Sample Probe.log File</i>									
Column:	10	20	30	40	50	60	70	80	
Row:	1	2	3	4	5	6	7	8	9
0001:	F1:19960807.001	07-Aug-1996	3SET	2DOT	511.51	18.690	36.35	0.00	29.00
0002:	F1:19960808.001	08-Aug-1996	3SET	2DOT	513.31	20.732	38.10	0.00	28.23
0003:	F1:19960809.001	09-Aug-1996	3SET	2DOT	510.00	19.018	36.55	0.00	25.63
0004:	F1:19960809.002	09-Aug-1996	2SET	2DOT	511.33	22.082	36.08	0.00	
0005:	F1:19960809.003	09-Aug-1996	2SET	2DOT	511.31	21.988	33.82	0.00	
0006:	F1:19960812.001	10-Aug-1996	2SET	2DOT	511.46	21.953	34.81	0.00	
0007:	F1:19960916.001	16-Sep-1996	2SET	2DOT	513.29	21.842	34.61	0.00	
0008:	F1:19961029.001	29-Oct-1996	2SET	2DOT	511.35	21.869	35.04	0.00	
0009:	F1:19961122.001	22-Nov-1996	3SET	2DOT	510.70	19.032	36.01	0.00	24.92
0010:	F1:19961122.002	22-Nov-1996	3SET	2DOT	511.95	23.219	37.23	0.00	12.55
0011:	F1:19961122.003	22-Nov-1996	3SET	2DOT	511.58	22.696	38.21	0.00	20.97
0012:	F1:19961123.001	23-Nov-1996	3SET	2DOT	511.18	19.944	36.18	0.00	21.43
0013:	F1:19961219.001	19-Dec-1996	2SET	2DOT	509.28	25.519	35.05	0.00	
0014:	F1:19970205.001	05-Feb-1997	3SET	2DOT	509.87	12.900	15.29	0.00	1.15
0015:	F1:19970206.001	06-Feb-1997	3SET	2DOT	512.23	14.382	14.15	0.00	-1.56
0016:	F1:19970420.001	20-Apr-1997	2SET	2DOT	512.05	14.820	16.97	0.00	
0017:	F1:19970420.001	21-Apr-1997	2SET	1DOT	512.05	14.820	0.00	-16.97	
0018:	F1:19970420.001	15-May-1997	2SET	1DOT	512.05	14.820	0.00	-16.97	
0019:	F1:19970528.001	28-May-1997	2SET	2DOT	511.27	13.244	11.60	0.00	
0020:	F1:19970611.001	11-Jun-1997	2SET	2DOT	512.22	13.500	13.29	0.00	
0021:	F1:19970611.001	22-Jun-1997	2SET	2DOT	512.22	13.500	13.29	0.00	
0022:	F1:19970711.001	11-Jul-1997	2SET	2DOT	510.58	13.731	14.15	0.00	
0023:	F1:19970711.002	11-Jul-1997	2SET	2DOT	511.09	13.056	9.73	0.00	
0024:	F1:19970711.001	11-Jul-1997	2SET	2DOT	510.58	13.731	14.15	0.00	
0025:	F1:19970730.001	29-Jul-1997	2SET	2DOT	511.97	14.817	13.86	0.00	
0026:	F1:19970903.002	03-Sep-1997	2SET	2DOT	510.69	13.462	11.29	0.00	
0027:	F1:19971222.001	14-Dec-1997	2SET	2DOT	510.56	13.110	10.84	0.00	
0028:	F1:19980105.001	05-Jan-1998	2SET	2DOT	510.11	13.723	12.98	0.00	
0029:	F1:19980202.001	02-Feb-1998	2SET	2DOT	509.51	14.302	12.78	0.00	
0030:	F1:19980514.001	14-May-1998	2SET	2DOT	512.70	13.243	6.93	0.00	
0031:	F1:19980519.001	19-May-1998	2SET	2DOT	510.84	13.916	13.03	0.00	
0032:	F1:19980607.001	07-Jun-1998	2SET	2DOT	511.58	13.675	11.58	0.00	
0033:	F1:19980707.002	07-Jul-1998	2SET	2DOT	511.40	13.224	9.68	0.00	

Every time the technical user, who calibrates and measures gage blocks, selects the *Probe Document Files* and probe calibration methods and baselines that the **Gage** program uses to calibrate and measure NIST’s gage block calibration customers’ gage blocks, the **Probe** program

records the selections' *probe calibration record information* in *Probe Configuration Document Files*, which are DOS ASCII text files. The **Probe** program stores respectively the workstations' *probe calibration record information* in *Probe Configuration Document Files* in the following way:

- Workstation One's Probe Calibration Record Information in the *Probef1.ini* file
- Workstation Two's Probe Calibration Record Information in the *Probef2.ini* file
- Workstation Three's Probe Calibration Record Information in the *Probef3.ini* file
- Workstation Four's Probe Calibration Record Information in the *Probef4.ini* file
- Workstation Five's Probe Calibration Record Information in the *Probef5.ini* file
- Workstation Six's Probe Calibration Record Information in the *Probef6.ini* file
- Workstation Seven's Probe Calibration Record Information in the *Probef7.ini* file
- Workstation Eight's Probe Calibration Record Information in the *Probef8.ini* file
- Workstation Nine's Probe Calibration Record Information in the *Probef9.ini* file

The *Probe Configuration Document Files* each have the file name of the *Probe Document File* complete with the working file storage device and folder, which stores the probe calibration, the probe calibration method and baseline, the measurement drift and standard deviation for the *repeat block*, the scale magnification, slope, y-intercept, and standard deviation for the probe calibration, the probe calibration's normalized residuals and standard deviations for NIST's first, second, and optionally third step master gage block sets, and the temperature, date, time of the probe calibration, the observer's initials, and the number of tests the **Gage** program uses the *probe calibration information* since the user selected the *Probe Document File* and probe calibration method and baseline. The listing of a sample *Probe Configuration Document File*, as Table 6.8-8 shows, has information that the **Probe** program writes every time the user stores and selects the *Probe Document Files* and probe calibration methods and baselines at NIST's gage block calibration workstations.

Table 6.8-8 Latest Listing of a <i>Probe Configuration Document File</i>								
Column:	10	20	30	40	50	60	70	80
Row:	1234567890	1234567890	1234567890	1234567890	1234567890	1234567890	1234567890	1234567890
0001:	[WORKSTATION 1 PROBE CALIBRATION]							
0002:	FileName=C:\GAGE\PROBES\F1\19980707.002							
0003:	ProbeCalibrationMethod=1:2-SET (1-2 DOT)							
0004:	ProbeCalibrationBaselineSet=2:2-DOT							

Table 6.8-8 Latest Listing of a <i>Probe Configuration Document File</i>								
Column:	10	20	30	40	50	60	70	80
Row:	123456789012345678901234567890123456789012345678901234567890123456789012							
0005:	RepeatBlockDrift=.00388752913753 VoltsPerMeasurement							
0006:	RepeatBlockDriftStandardDeviation=4.84016015321 Nanometers							
0007:	ScaleMagnification=511.403308692 NanometersPerVolt							
0008:	ScaleMagnificationSlope=.00195540385251 VoltsPerNanometer							
0009:	ScaleMagnificationYIntercept=-.0770042419682 Volts							
0010:	ScaleMagnificationStandardDeviation=13.2235873491 Nanometers							
0011:	NormalizedResidual[Steel.....]=9.68141850561 Nanometers							
0012:	NormalizedResidual[Chrome Carbide....]=0 Nanometers							
0013:	NormalizedResidual[Tungsten Carbide..]=0 Nanometers							
0014:	ResidualStandardDeviation[Steel.....]=11.4821434693 Nanometers							
0015:	ResidualStandardDeviation[Chrome Carbide....]=13.7298105879 Nanometers							
0016:	ResidualStandardDeviation[Tungsten Carbide..]=0 Nanometers							
0017:	Temperature=19.73 DegreesCelsius							
0018:	Date= 7 Jul 1998							
0019:	Time=08:02:06							
0020:	Observer=SRF							
0021:	Tests=147							

The technical user, who calibrates and measures gage blocks, follows established file naming and storing conventions to manage *Probe Document Files*. The established naming convention for *Probe Document Files* is limited to eight characters for filenames with a three-character extension and a period separating the filename from the extension. The working and archived *Probe Document Files* are to record *probe calibration information* and calibration and measurement results. When working *Probe Documents Files* are corrupted or lost, the user restores the *probe calibration information* from the archived *Probe Document Files*, which eliminates re-entering all *probe calibration information*. The user stores respectively all workstations' working *Probe Document Files* in the working file storage device and folders in the following way:

- Workstation One's *Probe Document Files* in the C:\Gage\Probes\F1 folder
- Workstation Two's *Probe Document Files* in the C:\Gage\Probes\F2 folder
- Workstation Three's *Probe Document Files* in the C:\Gage\Probes\F3 folder
- Workstation Four's *Probe Document Files* in the C:\Gage\Probes\F4 folder
- Workstation Five's *Probe Document Files* in the C:\Gage\Probes\F5 folder

- Workstation Six's *Probe Document Files* in the *C:\Gage\Probes\F6* folder
- Workstation Seven's *Probe Document Files* in the *C:\Gage\Probes\F7* folder
- Workstation Eight's *Probe Document Files* in the *C:\Gage\Probes\F8* folder
- Workstation Nine's *Probe Document Files* in the *C:\Gage\Probes\F9* folder

The technical user, who calibrates and measures gage blocks, stores archived *Probe Document Files* on labeled floppy diskettes. For continuity reasons, the user typically names *Probe Document Files* using literally the actual dates they calibrate NIST's electro-mechanical gage block comparators. The user typically assigns specific, numerically increasing three-digit extensions for *Probe Document Files* to order the calibrating of NIST's electro-mechanical gage block comparators. The user, for example, will name the first *Probe Document File* stored on January 02, 1998 using "19980102.001," the second *Probe Document File* stored on January 02, 1998 using "19980102.002," the third *Probe Document File* stored on January 02, 1998 using "19980102.003," and so forth.

The ***Probe*** program stores *probe calibration information* and calibration and measurement results in *Probe Document Files*. *Probe Document Files* contain three sections, the first section stores the *probe calibration information*, the second section is a copy of the *step master information* from *Step Master Document File*, and the third section stores the calibration and measurement results. In the first section, the *probe calibration information* is the file name of the *Probe Document File* complete with the working file storage device and folder, which stores the probe calibration, the probe calibration method and baseline, the measurement drift and standard deviation for the *repeat block*, the scale magnification, slope, y-intercept, and standard deviation for the probe calibration, the probe calibration's normalized residuals and standard deviations for NIST's first, second, and optionally third step master gage block sets, and the temperature, date, time of the probe calibration, and the observer's initials. The observer is the technical user, who calibrates and measures gage blocks, which includes NIST's gage block calibration customers' gage blocks. In the second section, the *step master information* is the step master gage blocks' nominal sizes, identification or serial numbers, material codes, and interferometrically-derived nominal deviations, which the user respectively orders by material type as follows: steel, chrome carbide, and tungsten carbide. In the third section, the calibration and measurement results are the step heights and the voltage measurements. The listing of a sample *Probe Document File*, as Table 6.8-9 shows, has *probe calibration information* and calibration and measurement results that the ***Probe*** program writes every time NIST's technical staff stores *Probe Document Files* at NIST's gage block calibration workstations.

Table 6.8-9 Latest Listing of a Sample Probe Document File

Column:	10	20	30	40	50	60	70	80
Row:	1	2	3	4	5	6	7	8
0001:	[PROBE CALIBRATION]							
0002:	FileName=C:\GAGE\PROBES\F1\19980707.002							
0003:	ProbeCalibrationMethod=1:2-SET (1-2 DOT)							
0004:	ProbeCalibrationBaselineSet=2:2-DOT							
0005:	RepeatBlockDrift=.00388752913753 VoltsPerMeasurement							
0006:	RepeatBlockStandardDeviation=4.84016015321 Nanometers							
0007:	ScaleMagnification=511.403308692 NanometersPerVolt							
0008:	ScaleMagnificationSlope=.00195540385251 VoltsPerNanometer							
0009:	ScaleMagnificationYIntercept=-.0770042419682 Volts							
0010:	ScaleMagnificationStandardDeviation=13.2235873491 Nanometers							
0011:	NormalizedResidual[Steel.....]=9.68141850561 Nanometers							
0012:	NormalizedResidual[Chrome Carbide....]=0 Nanometers							
0013:	NormalizedResidual[Tungsten Carbide..]=0 Nanometers							
0014:	ResidualStandardDeviation[Steel.....]=11.4821434693 Nanometers							
0015:	ResidualStandardDeviation[Chrome Carbide....]=13.7298105879 Nanometers							
0016:	ResidualStandardDeviation[Tungsten Carbide..]=0 Nanometers							
0017:	Temperature=19.73 DegreesCelsius							
0018:	Date= 7 Jul 1998							
0019:	Time=08:02:06							
0020:	Observer=SRF							
0021:								
0022:	[STEP GAGE BLOCK MASTERS]							
0023:	English	Gage Block		Gage Block		Gage Block		Gage Block
0024:	Gage Block	Serial Number		Material Specifier		Nominal Deviation		
0025:	Nominal	1DOT	2DOT	3DOT	1DOT	2DOT	3DOT	1DOT 2DOT 3DOT
0026:	=====	=====	=====	=====	=====	=====	=====	=====
0027:	0.100000	950028	W7W17	1780	0001	0003	0004	60 25 6
0028:	0.100010	960064	W7W17	1780	0001	0003	0004	129 -4 74
0029:	0.100020	960070	W7W17	1780	0001	0003	0004	103 -9 -31
0030:	0.100030	960076	W7W17	1780	0001	0003	0004	71 32 -73
0031:	0.100040	960084	W7W17	1780	0001	0003	0004	34 5 69
0032:	0.100050	900808	W7W17	1780	0001	0003	0004	49 -6 24
0033:	0.100060	960093	W7W17	1780	0001	0003	0004	50 26 -83
0034:	0.100070	960100	W7W17	1780	0001	0003	0004	71 -24 -68
0035:	0.100080	960107	W7W17	1780	0001	0003	0004	15 -25 90
0036:	0.100090	960090	W7W17	1780	0001	0003	0004	19 -31 39
0037:	0.100100	940694	W7W17	1780	0001	0003	0004	17 35 -7
0038:								
0039:	[OBSERVATIONS]							

Table 6.8-9 Latest Listing of a Sample Probe Document File

	Column: 10	20	30	40	50	60	70	80
Row:	1	2	3	4	5	6	7	8
0040:	Point StepHeight (Nanometers)				Point Voltage (Volts)			
0041:	=====				=====			
0042:	X[00]	0			Y[00]	-2.5185		
0043:	X[01]	60			Y[01]	-2.463		
0044:	X[02]	25			Y[02]	-2.5105		
0045:	X[03]	0			Y[03]	-2.512		
0046:	X[04]	129			Y[04]	-1.78425		
0047:	X[05]	-4			Y[05]	-2.10575		
0048:	X[06]	0			Y[06]	-2.48875		
0049:	X[07]	103			Y[07]	-1.39125		
0050:	X[08]	-9			Y[08]	-1.55925		
0051:	X[09]	0			Y[09]	-2.49		
0052:	X[10]	71			Y[10]	-.93925		
0053:	X[11]	32			Y[11]	-.963		
0054:	X[12]	0			Y[12]	-2.47725		
0055:	X[13]	34			Y[13]	-.447		
0056:	X[14]	5			Y[14]	-.4625		
0057:	X[15]	0			Y[15]	-2.46575		
0058:	X[16]	49			Y[16]	.068		
0059:	X[17]	-6			Y[17]	-.022		
0060:	X[18]	0			Y[18]	-2.457		
0061:	X[19]	50			Y[19]	.54275		
0062:	X[20]	26			Y[20]	.54475		
0063:	X[21]	0			Y[21]	-2.42375		
0064:	X[22]	71			Y[22]	1.12425		
0065:	X[23]	-24			Y[23]	.963		
0066:	X[24]	0			Y[24]	-2.4185		
0067:	X[25]	15			Y[25]	1.50425		
0068:	X[26]	-25			Y[26]	1.49575		
0069:	X[27]	0			Y[27]	-2.4		
0070:	X[28]	19			Y[28]	2.02575		
0071:	X[29]	-31			Y[29]	1.94625		
0072:	X[30]	0			Y[30]	-2.40675		
0073:	X[31]	17			Y[31]	2.5315		
0074:	X[32]	35			Y[32]	2.58025		
0075:	X[33]	0			Y[33]	-2.40575		

6.9 The *Report* Program

The *Report* program opens, creates, prints, and stores NIST's gage block calibration customers' NIST Reports' of Calibration. To calibrate and measure NIST's gage block calibration customers' gage blocks, the technical user, who calibrates and measures gage blocks, first uses the *Setup* program to record the *setup information* in *Setup Document Files*, which are DOS ASCII text files. To calibrate and measure gage blocks by mechanical intercomparison, the user uses the *Gage* program in *Gage* mode to analyze measurements from the electro-mechanical gage block comparators, print the results, and record the results to the *Setup Document Files*. As part of the process to ensure quality assurance, the *Gage* program estimates short-term and long-term measurement process variability by measuring and recording the differences in length of the two master gage blocks used for every NIST's gage block calibration customers' gage blocks calibrated and measured by mechanical intercomparison and comparing past and present calibration and measurement results. As another part of the process to ensure quality assurance, the user uses the *History* program to authenticate past and present calibration and measurement results, which occasionally requisite retests. Once authenticated, the user then merges and records the present calibration and measurement results to the *History Document Files* and creates NIST Reports' of Calibration. To create NIST Reports' of Calibration, the user runs the *Report* program, which uses the *folder information* from the *Folder Document Files* and the stored gage block calibration and measurement results from the *Setup* and *Gage* programs.

The *Report* program has a *Control Menu* with ten functions, as Table 6.9-1 shows. The technical user, who calibrates and measures gage blocks, uses the *Control Menu* functions to do the following:

- Create, open, print, store, archive, and edit *Report Document Files*
- Open working *Folder Document Files* and *Setup Document Files*
- Assembles the *Report Document File* by generating anew an official NIST Report of Calibration, which uses the *folder information* from the *Folder Document File* and the *setup information* from the *Setup Document File*
- Load and run the *Edit* program to automatically open stored *Report Document Files*
- View and print NIST Reports' of Calibration

Table 6.9-1 The *Report* Program's Control Menu Functions

Name of Function	Function Description
<i>Program Preface</i> .	This function displays the <i>Report</i> program's introductory statement.

Table 6.9-1 The *Report* Program's Control Menu Functions

Name of Function	Function Description
<i>Open Folder</i>	This function opens a copy of a <i>Folder Document File</i> . The <i>Folder Document Files</i> are working <i>Folder Document Files</i> in the working file storage device and folder, which is <i>C:\Gage\Work</i> . This function copies, deletes, moves, and renames <i>Folder Document Files</i> in file storage devices and folders.
<i>Open Setup</i>	This function opens a copy of a <i>Setup Document File</i> . The <i>Setup Document Files</i> are working <i>Setup Document Files</i> in the working file storage device and folder, which is <i>C:\Gage\Work</i> . This function copies, deletes, moves, and renames <i>Setup Document Files</i> in file storage devices and folders.
<i>Run</i>	This function assembles the <i>Report Document File</i> by generating anew an official NIST Report of Calibration, which uses the <i>folder information</i> from the <i>Folder Document File</i> and the <i>setup information</i> from the <i>Setup Document File</i> . The <i>setup information</i> is gage block calibration and measurement results the Setup and Gage programs store.
<i>View</i>	This function opens the <i>Report Document File</i> viewing window with the <i>Report Document File</i> for examining and printing the official NIST Report of Calibration.
<i>Edit</i>	This function stops the Report program and loads and runs the Edit program. When the <i>Report Document File</i> needs storing, a prompt first appears about storing the <i>Report Document File</i> and an affirmative response causes the function to store the <i>Report Document File</i> , stop the Report program, and load and run the Edit program, which automatically opens the stored <i>Report Document File</i> .
<i>Print</i>	This function prints one copy of the <i>Report Document File</i> to the printer.
<i>Store</i>	This function stores a copy of the <i>Report Document File</i> in the <i>Report Document File</i> window to a working file, such as <i>Filename.rpt</i> , and stored in the DOS ASCII text file storage format. When a file already exists, a prompt first appears about overwriting the <i>Report Document File</i> to this file or storing the <i>Report Document File</i> to a new file.

Table 6.9-1 The <i>Report</i> Program’s Control Menu Functions	
Name of Function	Function Description
<i>Archive</i>	This function archives a copy of the <i>Report Document File</i> in the <i>Report Document File</i> window to an archived file, such as <i>Filename.rph</i> , and stored in the DOS ASCII text file storage format. When a file already exists, a prompt first appears about overwriting the <i>Report Document File</i> to this file or storing the <i>Report Document File</i> to a new file.
<i>Exit REPORT</i>	This function stops the <i>Report</i> program and loads and runs the <i>Branch</i> program. When a <i>Report Document File</i> is in the current <i>Report Document File</i> window, a prompt first appears about storing the <i>Report Document File</i> and an affirmative response causes the function to store the <i>Report Document File</i> and closes all document files opened, which include the <i>Folder Document File</i> , the <i>Setup Document File</i> , and the <i>Report Document File</i> .

The technical user, who calibrates and measures gage blocks, follows established file naming and storing conventions to manage *Report Document Files*. The established naming convention for *Report Document Files* is limited to eight characters for filenames with a three-character extension and a period separating the filename from the extension. The working and archived *Report Document Files* are to record official NIST Report of Calibration documentation plus the *folder information* and *setup information*, which has the calibration and measurement results. The user stores all working *Report Document Files* in the working file storage device and folder, which is *C:\Gage\Work*, and the archived *Report Document Files* in the *Historys* storage device and folder, which is *C:\Gage\Historys*, and on labeled floppy diskettes. For continuity reasons, the user typically assigns common filenames to *Folder Document Files*, *Report Document Files*, and *Setup Document Files* for every NIST’s gage block calibration customers’ calibration. The three-character extension for working *Report Document Files* is “*rpt*” and for archived *Report Document Files* is “*rph*.”

The ***Report*** program stores *report information* in *Report Document Files*. This *report information* is the official NIST Report of Calibration documentation and plus the *folder information*, which has correspondence information, and *setup information*, which has the calibration and measurement results. The folder information is the NIST test folder number, the description of gage blocks calibrated and measured, the primary identification or serial number of the gage block set, and the NIST’s gage block calibration customer’s name and address, which includes their division or post office box number, street address, city, state, and U.S. Postal Service ZIP Code+4 within the United States and its territories. The *setup information* is the gage blocks’ testing status, nominal sizes, identification or serial numbers, master type, material

codes, thermal coefficients of expansion, observed nominal deviations and uncertainties, testing dates, observers' initials, and testing method codes. The technical user, who calibrates and measures gage blocks, stores working *Report Document Files* in the working file storage device and folder, which is *C:\Gage\Work*. The user stores archived *Report Document Files* and *History Document Files* in the *Historys* storage device and folder, which is *C:\Gage\Historys*, and on labeled floppy diskettes.

As Table 6.9-2 through Table 6.9-7 shows, the **Report** program gets documentation for NIST Reports' of Calibration from the following files: *Heading.txt*, *Ending.txt*, *Repteng.txt*, *Reptmet.txt*, *Rept1all.txt*, and *Rept2all.txt*, which are DOS ASCII text files. For the correspondence page of NIST Reports' of Calibration, which the technical user, who calibrates and measures gage blocks, refers as the *report page*, the **Report** program gets the letterhead text from *Heading.txt* and the signatory text from *Ending.txt*. For the body of the correspondence page, the **Report** program gets the report text for the interferometric calibration and measurement of English gage blocks from *Repteng.txt*, the report text for the interferometric calibration and measurement of metric gage blocks from *Reptmet.txt*, the report text for the mechanical intercomparison calibration and measurement of English and metric gage blocks from *Rept1all.txt*, which is for calibrations for individual gage blocks, and *Rept2all.txt*, which is for calibrations of gage block sets. For the interferometric calibration and measurement of English and metric gage blocks, the **Report** program decides which paragraphs to use from *Repteng.txt* or *Reptmet.txt* by prompting the user to enter the following information:

- Flatness measured when calibrating and measuring gage blocks
- Parallelism measured when calibrating and measuring gage blocks
- Reference flats of various diameters, which the NIST technical staff refers as *optical flats* and *platens*, used belonging to NIST or NIST's gage block calibration customers for calibrating and measuring gage blocks
- Gage block type calibrated and measured, which include rectangular, square (Hoke), or and circularly cross-sectional shaped

Table 6.9-2 Latest Listing of the <i>Heading.txt</i> File								
Column:	10	20	30	40	50	60	70	80
Row:	1	2	3	4	5	6	7	8
0001:	UNITED STATES DEPARTMENT OF COMMERCE							
0002:	NATIONAL INSTITUTE OF STANDARDS AND TECHNOLOGY							
0003:	GAITHERSBURG, MARYLAND 20899							
0004:								

Table 6.9-2 Latest Listing of the <i>Heading.txt</i> File								
Column:	10	20	30	40	50	60	70	80
	▼	▼	▼	▼	▼	▼	▼	▼
Row:	12345678901234567890123456789012345678901234567890123456789012							
0005:	R E P O R T O F C A L I B R A T I O N							

Table 6.9-3 Latest Listing of the <i>Ending.txt</i> File								
Column:	10	20	30	40	50	60	70	80
	▼	▼	▼	▼	▼	▼	▼	▼
Row:	12345678901234567890123456789012345678901234567890123456789012							
0001:	Measurements made by _____ (301) 975-3468.							
0002:								
0003:	For the Director,							
0004:	National Institute of Standards and Technology							
0005:								
0006:								
0007:								
0008:	Dr. Howard H. Harary, Group Leader							
0009:	Engineering Metrology Group							
0010:	Precision Engineering Division							
0011:	Manufacturing Engineering Laboratory							

Table 6.9-4 Latest Listing of the <i>Repteng.txt</i> File								
Column:	10	20	30	40	50	60	70	80
	▼	▼	▼	▼	▼	▼	▼	▼
Row:	12345678901234567890123456789012345678901234567890123456789012							
0001:	11 This gage block has been wrung to a steel platen and measured							
0002:	by static interferometry using a stabilized helium-neon as the							
0003:	intrinsic length standard. Details of the process are covered in							
0004:	NBS Monograph 152, "A Gage Block Measurement Process Using Single							
0005:	Wavelength Interferometry," which is considered to be a part of							
0006:	this report.							
0007:	12 These gages blocks have been wrung to a steel platen and measured							
0008:	by static interferometry using a stabilized helium-neon as the							
0009:	intrinsic length standard. Details of the process are covered in							
0010:	NBS Monograph 152, "A Gage Block Measurement Process Using Single							

Table 6.9-4 Latest Listing of the *Repteng.txt* File

Column:	10	20	30	40	50	60	70	80
Row:	1	2	3	4	5	6	7	8
0011:	Wavelength	Interferometry,"	which is	considered	to be a	part of		
0012:	this	report.						
0013:	21	This	gage	block	was	compared	with	the
0014:	Standards.	The	comparison	process	employs	electromechanical		
0015:	comparators,	NIST	standard	and	check	standard	gage	blocks,
0016:	and	test	gage	blocks.				
0017:	22	These	gage	blocks	were	compared	with	the
0018:	Standards.	The	comparison	process	employs	electromechanical		
0019:	comparators,	NIST	standard	and	check	standard	gage	blocks,
0020:	and	test	gage	blocks.				
0021:	31	The	length	of	a	square	gage	block
0022:	perpendicular	distance	from	a	point	on	the	top
0023:	gage	block	midway	between	the	hole	and	the
0024:	surface	of	the	platen.	The	reference	edge	is
0025:	on	the	side	of	the	block	with	the
0026:	the	right	of	the	size	marking	when	it
0027:	surface.							
0028:	32	The	length	of	a	wrung	gage	block
0029:	from	a	point	on	the	middle	of	the
0030:	to	the	surface	of	the	platen.		
0031:	33	The	length	of	the	gage	block	is
0032:	perpendicular	distance	from	a	point	on	one	contact
0033:	midway	between	the	hole	and	the	reference	edge.
0034:	The	reference	edge	is	defined	as	the	edge
0035:	on	the	side	of	the	block	with	the
0036:	size	marking,	or	the	edge	to	the	right
0037:	of	the	size	marking	when	it	is	marked
0038:	on	the	contact	surface.				
0039:	34	The	length	of	the	gage	block	is
0040:	perpendicular	distance	from	a	point	on	one	contact
0041:	surface	to	a	point	on	the	middle	of
0042:	the	other	contact	surface.				
0043:	41	If	a	minus	sign	is	given	with
0044:	the	reported	length	deviation,	it	indicates	that	the
0045:	block	is	shorter	than	the	nominal	length.	If
0046:	no	sign	or	a	plus	sign	is	given,
0047:	the	block	is	longer	than	the	nominal	length.
0048:	51	The	customer's	platen	was	used	during	these
0049:	measurements	and	no	correction	for	phase	shift	of
0050:	light	was	included	in	the	reported	deviations.	
0051:	61	The	flatness	of	the	blocks	were	not
0052:	measured.							
0053:	62	Blocks	less	than	0.100000	inch	in	length
0054:	were	not	measured	for	flatness	since	most	thin
0055:	blocks	are	warped.					

Table 6.9-4 Latest Listing of the *Repteng.txt* File

Column:	10	20	30	40	50	60	70	80
Row:	1	2	3	4	5	6	7	8
0050:	63 Neither flatness nor parallelism of the blocks were measured.							
0051:	71 The deviations in flatness of the contact surfaces are measured							
0052:	along lines midway between each pair of opposite sides (see lines							
0053:	a and b in figure 2).							
0054:	72 The deviation in flatness of the contact surfaces are measured							
0055:	along lines midway between the sides both across the width and							
0056:	along the length of the surfaces (see lines a and b in figure 1),							
0057:	but the measurement along the length does not include 0.02 inch							
0058:	of the surface nearest each end.							
0059:	73 Only those flatness deviations are reported which exceed							
0060:	3 microinches in either of the two directions.							
0061:	74 Only those flatness deviations are reported which exceed							
0062:	3 microinches in either of the two directions for blocks up to							
0063:	and including 2 inches in length, and 4 microinches for blocks							
0064:	longer than 2 inches.							
0065:	75 Only those flatness deviations across the width are reported							
0066:	which exceed 2 microinches or along the length of contact							
0067:	surfaces which exceed 3 microinches.							
0068:	76 Only those flatness deviations across the width are reported							
0069:	which exceed 2 microinches for blocks up to and including							
0070:	2 inches in length, and 3 microinches for blocks longer than							
0071:	2 inches; flatness deviations along the length of the contact							
0072:	surfaces which exceed 3 microinches for blocks up to and							
0073:	including 2 inches in length, 4 microinches for all blocks longer							
0074:	than 2 inches.							
0075:	81 The deviations in parallelism of the contact surfaces are							
0076:	measured in both directions parallel to the edges across the							
0077:	middle of the block. The deviation in parallelism along a line							
0078:	perpendicular to the reference edge is the total variation in							
0079:	length across the middle of the block and when reported is shown							
0080:	as plus when the length increases with respect to the length at							
0081:	the reference edge (see figure 2). The deviation in parallelism							
0082:	in the other direction is shown without sign and when reported is							
0083:	designated by the letter "b".							
0084:	82 The deviations in parallelism of the contact surfaces are							
0085:	measured both across the width and along the length of the							
0086:	blocks. The deviation in parallelism across the width is the							
0087:	total variation in length across the middle of the block and,							
0088:	when reported, is shown as plus if the length increases with							

Table 6.9-4 Latest Listing of the *Repteng.txt* File

Column:	10	20	30	40	50	60	70	80
Row:	1	2	3	4	5	6	7	8
0089:	respect to the length at the reference edge (see figure 1). The							
0090:	deviation in parallelism along the length is the total variation							
0091:	in length measured midway between the sides but excluding							
0092:	0.02 inch at each end of the contact surfaces. This deviation,							
0093:	when reported, is designated by the letter "b"; neither positive							
0094:	nor negative signs are used.							
0095:	83	Only those parallelism deviations are reported which exceed						
0096:	3 microinches.							
0097:	84	Only those parallelism deviations are reported which exceed						
0098:	3 microinches for blocks up to and including 2 inches in length,							
0099:	and 4 microinches for blocks longer than 2 inches.							
0100:	85	Only those parallelism deviations are reported which exceed						
0101:	2 microinches.							
0102:	86	Only those parallelism deviations are reported which exceed						
0103:	2 microinches for blocks up to and including 2 inches in length,							
0104:	and 3 microinches for blocks longer than 2 inches.							
0105:	91	The uncertainty value placed on the length determination was						
0106:	calculated according to NIST Technical Note 1297, "Guidelines for							
0107:	Evaluating and Expressing the Uncertainty of NIST Measurement							
0108:	Results," which is considered to be a part of this report. The							
0109:	expanded uncertainty, U, is reported on the following page using							
0110:	a coverage factor of k = 2.							
0111:								
0112:	The average deviation in length from the nominal size at							
0113:	20 degrees Celsius is reported on the following page.							
0114:	92	The uncertainty values placed on the length determinations were						
0115:	calculated according to NIST Technical Note 1297, "Guidelines for							
0116:	Evaluating and Expressing the Uncertainty of NIST Measurement							
0117:	Results," which is considered to be a part of this report. The							
0118:	expanded uncertainties, U, are reported on the following pages							
0119:	using a coverage factor of k = 2.							
0120:								
0121:	The average deviations in length from the nominal size at							
0122:	20 degrees Celsius are reported on the following pages.							

Table 6.9-5 Latest Listing of the *Reptmet.txt* File

Column:	10	20	30	40	50	60	70	80
Row:	12345678901234567890123456789012345678901234567890123456789012345678901234567890123456789012							
0001:	11	This	gag	blo	ck	ha	s	be
0002:		en	be	wru	ng	to	a	st
0003:		ee	l	pl	ate	n	an	d
0004:		me	as	ur	e	d		
0005:		by	st	at	ic	in	te	r
0006:		fe	ro	me	tr	e	tr	y
0007:		us	in	g	us	in	g	
0008:		12	Th	es	e	g	a	g
0009:		es	bl	oc	k	s	h	a
0010:		ve	be	w	r	u	n	g
0011:		to	a	st	e	e		
0012:		l	pl	ate	n	an	d	
0013:		me	as	ur	e	d		
0014:		by	st	at	ic	in	te	r
0015:		fe	ro	me	tr	e	tr	y
0016:		us	in	g	us	in	g	
0017:		21	This	gag	blo	ck	wa	s
0018:		co	m	pa	r	e	d	
0019:		22	Th	es	e	g	a	g
0020:		es	bl	oc	k	s	we	r
0021:		re	co	m	pa	r	e	d
0022:		with	the	st	an	d	ar	d
0023:		of	the	un	it	e	d	
0024:		23	The	l	e	n	g	t
0025:		h	o	f	a	s	q	u
0026:		are	the	l	e	n	g	t
0027:		of	a	s	q	u	a	r
0028:		re	g	u	ag	e	bl	o
0029:		ck	w	r	u	n	g	t
0030:		to	a	pl	ate	n	is	
0031:		the	l	e	n	g	t	
0032:		per	p	e	n	d	i	c
0033:		u	l	a	r	e		
0034:		31	The	l	e	n	g	t
0035:		h	o	f	a	s	q	u
0036:		are	the	l	e	n	g	t
0037:		of	a	s	q	u	a	r
0038:		re	g	u	ag	e	bl	o
0039:		ck	w	r	u	n	g	t
		to	a	pl	ate	n	is	
		the	l	e	n	g	t	
		per	p	e	n	d	i	c
		u	l	a	r	e		
		32	The	l	e	n	g	t
		h	o	f	a	s	q	u
		are	the	l	e	n	g	t
		of	a	s	q	u	a	r
		re	g	u	ag	e	bl	o
		ck	w	r	u	n	g	t
		to	a	pl	ate	n	is	
		the	l	e	n	g	t	
		per	p	e	n	d	i	c
		u	l	a	r	e		
		33	The	l	e	n	g	t
		h	o	f	a	s	q	u
		are	the	l	e	n	g	t
		of	a	s	q	u	a	r
		re	g	u	ag	e	bl	o
		ck	w	r	u	n	g	t
		to	a	pl	ate	n	is	
		the	l	e	n	g	t	
		per	p	e	n	d	i	c
		u	l	a	r	e		
		34	The	l	e	n	g	t
		h	o	f	a	s	q	u
		are	the	l	e	n	g	t
		of	a	s	q	u	a	r
		re	g	u	ag	e	bl	o
		ck	w	r	u	n	g	t
		to	a	pl	ate	n	is	
		the	l	e	n	g	t	
		per	p	e	n	d	i	c
		u	l	a	r	e		

Table 6.9-5 Latest Listing of the *Reptmet.txt* File

	Column: 10	20	30	40	50	60	70	80
Row:	12345678901234567890123456789012345678901234567890123456789012345678901234567890123456789012							
0040:	41	If	a	minus	sign	is	given	with
0041:		the	reported	length	deviation,	it		
0042:		indicates	that	the	block	is	shorter	than
0043:		the	nominal	length.				
0044:	51	The	customer's	platen	was	used	during	these
0045:		measurements	and	no	correction	for	phase	shift
0046:		of	light	was	included	in	the	reported
0047:		deviations.						
0048:	61	The	flatness	of	the	blocks	were	not
0049:		measured.						
0050:	62	Blocks	less	than	2.50000	millimeter	in	length
0051:		were	not	measured				
0052:	63	Neither	flatness	nor	parallelism	of	the	blocks
0053:		were	measured.					
0054:	71	The	deviations	in	flatness	of	the	contact
0055:		surfaces	are	measured				
0056:	72	The	deviation	in	flatness	of	the	contact
0057:		surfaces	are	measured				
0058:		along	lines	midway	between	each	pair	of
0059:		opposite	sides	(see	lines	a	and	b
0060:		in	figure	2).				
0061:	73	Only	those	flatness	deviations	are	reported	which
0062:		exceed						
0063:	74	Only	those	flatness	deviations	are	reported	which
0064:		exceed						
0065:	75	Only	those	flatness	deviations	across	the	width
0066:		are	reported	which	exceed	50	nanometers	or
0067:		along	the	length	of	contact	surfaces	which
0068:		exceed	80	nanometers.				
0069:	76	Only	whose	flatness	deviations	across	the	width
0070:		are	reported	which	exceed	50	nanometers	for
0071:		blocks	up	to	and	including	50	millimeters
0072:		in	length,	and	80	nanometers	for	blocks
0073:		longer	than	50	millimeters;	flatness	deviations	along
0074:		the	length	of	the	contact	surfaces	which
0075:		exceed	80	nanometers	for	blocks	up	to
0076:		and	including	50	millimeters	in	length,	100
0077:		nanometers	for	all	blocks	longer	than	50
0078:		millimeters.						
0079:	81	The	deviations	in	parallelism	of	the	contact
0080:		surfaces	are	measured	in	both	directions	parallel
0081:		to	the	edges	across	the	middle	of
0082:		the	block.	The	deviation	in	parallelism	along
0083:		a	line	perpendicular	to	the	reference	edge
0084:		is	the	total	variation	in		

Table 6.9-5 Latest Listing of the *Reptmet.txt* File

Column:	10	20	30	40	50	60	70	80
Row:	1	2	3	4	5	6	7	8
0079:	length across the middle of the block and when reported is shown							
0080:	as plus when the length increases with respect to the length at							
0081:	the reference edge (see figure 2). The deviation in parallelism							
0082:	in the other direction is shown without sign and when reported is							
0083:	designated by the letter "b".							
0084:	82 The deviations in parallelism of the contact surfaces are							
0085:	measured both across the width and along the length of the							
0086:	blocks. The deviation in parallelism across the width is the							
0087:	total variation in length across the middle of the block and,							
0088:	when reported, is shown as plus if the length increases with							
0089:	respect to the length at the reference edge (see figure 1). The							
0090:	deviation in parallelism along the length is the total variation							
0091:	in length measured midway between the sides but excluding							
0092:	0.5 millimeter at each end of the contact surfaces. This							
0093:	deviation, when reported, is designated by the letter "b";							
0094:	neither positive nor negative signs are used.							
0095:	83 Only those parallelism deviations are reported which exceed							
0096:	80 nanometers.							
0097:	84 Only those parallelism deviations are reported which exceed							
0098:	80 nanometers for blocks up to and including 50 millimeters in							
0099:	length, and 100 nanometers for blocks longer than 50 millimeters.							
0100:	85 Only those parallelism deviations are reported which exceed							
0101:	50 nanometers.							
0102:	86 Only those parallelism deviations are reported which exceed							
0103:	50 nanometers for blocks up to and including 50 millimeters in							
0104:	length, and 80 nanometers for blocks longer than 50 millimeters.							
0105:	91 The uncertainty value placed on the length determination was							
0106:	calculated according to NIST Technical Note 1297, "Guidelines for							
0107:	Evaluating and Expressing the Uncertainty of NIST Measurement							
0108:	Results," which is considered to be a part of this report. The							
0109:	expanded uncertainty, U, is reported on the following page using							
0110:	a coverage factor of k = 2.							
0111:								
0112:	The average deviation in length from the nominal size at							
0113:	20 degrees Celsius is reported on the following page.							
0114:	92 The uncertainty values placed on the length determinations were							
0115:	calculated according to NIST Technical Note 1297, "Guidelines for							
0116:	Evaluating and Expressing the Uncertainty of NIST Measurement							
0117:	Results," which is considered to be a part of this report. The							

Table 6.9-5 Latest Listing of the *Reptmet.txt* File

	Column: 10	20	30	40	50	60	70	80
	▼	▼	▼	▼	▼	▼	▼	▼
Row:	123456789012345678901234567890123456789012345678901234567890123456789012							
0118:	expanded uncertainties, U, are reported on the following pages							
0119:	using a coverage factor of k = 2.							
0120:								
0121:	The average deviations in length from the nominal size at							
0122:	20 degrees Celsius are reported on the following pages.							

Table 6.9-6 Latest Listing of the *Rept1all.txt* File

	Column: 10	20	30	40	50	60	70	80
	▼	▼	▼	▼	▼	▼	▼	▼
Row:	123456789012345678901234567890123456789012345678901234567890123456789012							
0001:	This gage block was compared with the standards of the United							
0002:	States. The comparison process employs electromechanical							
0003:	comparators, NIST standard and check standard gage blocks, and							
0004:	test gage blocks in a least squares intercomparison schedule							
0005:	designed to eliminate the effects of linear thermal drift.							
0006:								
0007:	This process together with its statistical analysis constitutes a							
0008:	continuous measurement assurance program at NIST. Details of the							
0009:	process are covered in NIST Monograph 180, "The Gage Block							
0010:	Handbook," which is considered to be a part of this report and							
0011:	available upon request.							
0012:								
0013:	The uncertainty values placed on the length determinations were							
0014:	calculated according to NIST Technical Note 1297, "Guidelines for							
0015:	Evaluating and Expressing the Uncertainty of NIST Measurement							
0016:	Results," which is considered to be a part of this report. The							
0017:	expanded uncertainty, U, is reported on the following page using							
0018:	a coverage factor of k = 2.							
0019:								
0020:	The deviation in length from the nominal size at 20 degrees							
0021:	Celsius is reported on the following page.							

Table 6.9-7 Latest Listing of the <i>Rept2all.txt</i> File	
Column:	10 20 30 40 50 60 70 80
Row:	123456789012345678901234567890123456789012345678901234567890123456789012
0001:	These gage blocks were compared with the standards of the United
0002:	States. The comparison process employs electromechanical
0003:	comparators, NIST standard and check standard gage blocks, and
0004:	test gage blocks in a least squares intercomparison schedule
0005:	designed to eliminate the effects of linear thermal drift.
0006:	
0007:	This process together with its statistical analysis constitutes a
0008:	continuous measurement assurance program at NIST. Details of the
0009:	process are covered in NIST Monograph 180, "The Gage Block
0010:	Handbook," which is considered to be a part of this report and
0011:	available upon request.
0012:	
0013:	The uncertainty values placed on the length determinations were
0014:	calculated according to NIST Technical Note 1297, "Guidelines for
0015:	Evaluating and Expressing the Uncertainty of NIST Measurement
0016:	Results," which is considered to be a part of this report. The
0017:	expanded uncertainties, U, are reported on the following pages
0018:	using a coverage factor of k = 2.
0019:	
0020:	The deviations in length from the nominal size at 20 degrees
0021:	Celsius are reported on the following pages.

6.10 The *Setup* Program

The *Setup* program opens, prints, and stores NIST’s gage block calibration customers’ gage blocks’ sizes, identification or serial numbers, and calibration and measurement information. As part of the process of starting NIST’s gage block calibration customers’ calibrations, the technical user, who calibrates and measures gage blocks, completes customer summary sheets, as Figure 6.10-1 shows, for every gage block calibration. Called *setup information* by the user, customer summary sheets each contain the NIST test folder number, the NIST gage block customer’s name and address, description of gage blocks calibrated, primary identification or serial number of a gage block set, the purchase order number, internal or group control number, and the individual gage blocks’ sizes and identification or serial numbers. The user uses the *Setup* program to record the *setup information* in *Setup Document Files*, which are DOS ASCII text files. To calibrate and measure gage blocks by interferometry, the user uses the

Spectrum program to analyze interferometric measurements from the gage block interferometers and to print the results and the *Setup* program is then used to record the results. To calibrate and measure gage blocks by mechanical intercomparison, the user uses the *Gage* program to analyze measurements from the electro-mechanical gage block comparators, print the results, and record the results to the *Setup Document Files*. As part of the process to ensure quality assurance, the user uses the *History* program to compare past and present calibration and measurement results, which they then merge and record to the *History Document Files*. To create NIST Reports' of Calibration, the user runs the *Report* program, which uses the *folder information* from the *Folder Document Files* and the stored gage block calibration and measurement results from the *Setup* and *Gage* programs.

The *Setup* program has a *Control Menu* with nine functions, as Table 6.10-1 shows. The technical user, who calibrates and measures gage blocks, uses the *Control Menu* functions to do the following:

- Create, open, print, store, and archive *Setup Document Files*
- Switch between opened *Setup Document Files*
- View opened *Setup Document Files*

The technical user, who calibrates and measures gage blocks, follows established file naming and storing conventions to manage *Setup Document Files*. The established naming convention for *Setup Document Files* is limited to eight characters for filenames with a three-character extension and a period separating the filename from the extension. The working *Setup Document Files* are to record *setup information* and calibration and measurement results and the archived *Setup Document Files* to record only *setup information*. When NIST's gage block calibration customers return gage blocks sets for calibrations, the technical user, who calibrates and measures gage blocks, retrieves the *setup information* from the archived *Setup Document Files* to create new working *Setup Document Files*. Using archived *Setup Document Files* eliminates re-entering all *setup information*, provides information about the gage blocks previously calibrated and measured, and helps with spotting new and missing gage blocks. The user stores all working *Setup Document Files* in the working file storage device and folder, which is *C:\Gage\Work*, and the archived *Setup Document Files* in the *Historys* storage device and folder, which is *C:\Gage\Historys*, and on labeled floppy diskettes. For continuity reasons, the typically assigns common filenames to *Folder Document Files*, *Report Document Files*, and *Setup Document Files* for every NIST's gage block calibration customers' calibration. The three-character extension for working *Setup Document Files* is "ids" and for archived *Setup Document Files* is "idh."

Table 6.10-1 The *Setup* Program's Control Menu Functions

Name of Function	Function Description
<i>Program Preface</i> .	This function displays the <i>Setup</i> program's introductory statement.
<i>Setups</i>	This function switches between <i>Setup Document Files</i> in respective <i>Setup Document File</i> windows.
<i>New</i>	This function opens a copy of a new <i>Setup Document File</i> into a new <i>Setup Document File</i> window.
<i>Open</i>	This function opens a copy of a <i>Setup Document File</i> into a new <i>Setup Document File</i> window. <i>Setup Document Files</i> include working <i>Setup Document Files</i> in the working file storage device and folder, which is <i>C:\Gage\Work</i> , and archived <i>Setup Document Files</i> from the <i>Historys</i> storage device and folder, which is <i>C:\Gage\Historys</i> , and on labeled floppy diskettes. This function copies, deletes, moves, and renames <i>Setup Document Files</i> in file storage devices and folders.
<i>View</i>	This function opens the <i>Setup Document File</i> editing window with the current <i>Setup Document File</i> .
<i>Print</i>	This function prints one copy of the current <i>Setup Document File</i> to the printer.
<i>Store</i>	This function stores a copy of the current <i>Setup Document File</i> in the current <i>Setup Document File</i> window to a working file, such as <i>Filename.ids</i> , and stored in the DOS ASCII text file storage format. When a file already exists, a prompt first appears about overwriting the current <i>Setup Document File</i> to this file or storing the current <i>Setup Document File</i> to a new file.
<i>Archive</i>	This function archives a copy of the current <i>Setup Document File</i> in the current <i>Setup Document File</i> window to an archived file, such as <i>Filename.idh</i> , and stored in the DOS ASCII text file storage format. When a file already exists, a prompt first appears about overwriting the current <i>Setup Document File</i> to this file or storing the current <i>Setup Document File</i> to a new file.

Table 6.10-1 The <i>Setup</i> Program's Control Menu Functions	
Name of Function	Function Description
<i>Exit SETUP</i>	This function stops the Setup program and loads and runs the Branch program. When a <i>Setup Document File</i> is in the current <i>Setup Document File</i> window, a prompt first appears about storing the current <i>Setup Document File</i> and an affirmative response causes the function to store the current <i>Setup Document File</i> and close the current <i>Setup Document File</i> window.

The **Setup** program stores *setup information* in *Setup Document Files*. The configuration of working *Setup Document Files*, as Table 6.10-2 shows, with *setup information*, each totaling fourteen fields and extending 80 characters. This *setup information* is the gage blocks' testing status, nominal sizes, identification or serial numbers, master type, material codes, thermal coefficients of expansion, observed nominal deviations and uncertainties, testing dates, observers' initials, and testing method codes. The configuration of archived *Setup Document Files*, as Table 6.10-3 shows, with *setup information*, each totaling eight fields and extending 80 characters, the first field and single column of characters is blank when not remarked, and columns 39 through 78 are blank. This *setup information* is the gage blocks' testing status, nominal sizes, identification or serial numbers, master type, material codes, thermal coefficients of expansion, and testing method codes. In Table 6.10-2 and Table 6.10-3, all columns not specified are blank. The technical user, who calibrates and measures gage blocks, stores working *Setup Document Files* in the working file storage device and folder, which is *C:\Gage\Work*. The user stores archived *Setup Document Files* and *History Document Files* in the *Historys* storage device and folder, which is *C:\Gage\Historys*, and on labeled floppy diskettes. The listing of a sample working *Setup Document File*, as Table 6.10-4 shows, has the customer summary sheet information for an anonymous NIST gage block calibration customer. The listing of a sample archived *Setup Document File*, as Table 6.10-5 shows, has the customer summary sheet information for an anonymous NIST gage block calibration customer.

Table 6.10-2 Configuration of Working <i>Setup Document Files</i>	
Column	Field Description
1	This field has the testing status (Yes: <i>Blank</i> , No: <i>Asterisk</i> , Remarked: <i>Exclamation Point</i>).
2-11	This field has the gage block nominal size (English: <i>in inches</i> , Metric: <i>in millimeters</i>).

Table 6.10-2 Configuration of Working <i>Setup Document Files</i>	
Column	Field Description
13-18	This field has the gage block identification or serial number (zero to six characters accepted, "NONE" for no identification or serial number is recommended).
20	This field has the master gage block type (English: 1, Metric: 2).
22-25	This field has the gage block material code, four numeric digit characters with leading zeros displayed (Steel: 0001, Ceramic: 0002, Chrome Carbide: 0003, Tungsten Carbide: 0004, Stainless Steel: 0005, and Other: 0006).
27-31	This field has the gage block material thermal coefficient, in parts per million.
33-37	<p>This field has the gage block material elastic constant, in 10^{-8} foot-pounds per inch squared.</p> <p>The elastic deformation constants are in foot-pounds per inch squared. To derive the compression constants, use the following formula:</p> $V_c (1 \cdot 10^8) = (1 - \sigma^2) / (\pi \cdot E)$ <p>where σ is Poisson's ratio and E is the Young's modulus, in foot-pounds/inch², of the material of the object. Poisson's ratio is</p> $\sigma = (E / (2 \cdot G)) - 1$ <p>where E is the complete elliptic integral of second class with modulus e and G, in foot-pounds/inch², is the modulus of rigidity of the material of the object. Do not confuse this integral with E, the Young's modulus. Modulus e is the eccentricity of the ellipse of contact and, by definition, is</p> $e = (1 - b^2 / a^2)^{1/2}$ <p>where the quantities a and b are parameters for the materials of the object and the comparator probe, respectively. These quantities are generally unknown and are determined from tables furnished in "Elastic Compression of Spheres and Cylinders at Point and Line Contacts" by Puttock and Thwaite (National Standards Laboratory Technical Paper No. 25, Commonwealth Scientific and Industrial Research Organization, Australia, 1969) [33].</p>
39-43	This field has the observed nominal deviation, in nanometers.
45-49	This field has the observed uncertainty, in nanometers.

Table 6.10-2 Configuration of Working <i>Setup Document Files</i>	
Column	Field Description
68-71	This field has the year for the testing date, four numeric digit characters with leading zeros displayed, century mandatory.
72-73	This field has the month for the testing date, two numeric digit characters with leading zeros displayed (January: 01, February: 02, March: 03, April: 04, May: 05, June: 06, July: 07, August: 08, September: 09, October: 10, November: 11, December: 12).
74-75	This field has the day of the month for the testing date, two numeric digit characters with leading zeros displayed (1 st Day of Month: 01, 2 nd Day of Month: 02, 3 rd Day of Month: 03, . . . , 31 st Day of Month: 31).
76-78	This field has the observer’s initials, one to three alphanumeric characters accepted, all initials recommended. The observer is the technical user, who calibrates and measures gage blocks, which includes NIST’s gage block calibration customers’ gage blocks.
79-80	This field has the testing method code (Exempt: 0 , Interferometry: 1, 3-2 Design: 2, 3-4 Design: 3, 3-6 Design: 4, 4-4 Design: 5, 4-6 Design: 6, 5-4 Design: 7, 6-4 Design: 8, 7-4 Design: 9, 8-4 Design: 10, 9-4 Design: 11, 10-4 Design: 12, 11-4 Design: 13, ABCA Design: 14, 4-1 Design: 15).

Table 6.10-3 Configuration of Archived <i>Setup Document Files</i>	
Column	Field Description
1	This field has the testing status (Yes/No: <i>Blank</i> , Remarkd: <i>Exclamation Point</i>).
2-11	This field has the gage block nominal size (English: <i>in inches</i> , Metric: <i>in millimeters</i>).
13-18	This field has the gage block identification or serial number (zero to six characters accepted, “NONE” for no identification or serial number is recommended).
20	This field has the master gage block type (English: 1, Metric: 2).

Table 6.10-3 Configuration of Archived <i>Setup Document Files</i>	
Column	Field Description
22-25	This field has the gage block material code, four numeric digit characters with leading zeros displayed (Steel: 0001, Ceramic: 0002, Chrome Carbide: 0003, Tungsten Carbide: 0004, Stainless Steel: 0005, and Other: 0006).
27-31	This field has the gage block material thermal coefficient, in parts per million.
33-37	<p>This field has the gage block material elastic constant, in 10^{-8} foot-pounds per inch squared.</p> <p>The elastic deformation constants are in foot-pounds per inch squared. To derive the compression constants, use the following formula:</p> $V_c (1 \cdot 10^8) = (1 - \sigma^2) / (\pi \cdot E)$ <p>where σ is Poisson's ratio and E is the Young's modulus, in foot-pounds/inch², of the material of the object. Poisson's ratio is</p> $\sigma = (E / (2 \cdot G)) - 1$ <p>where E is the complete elliptic integral of second class with modulus e and G, in foot-pounds/inch², is the modulus of rigidity of the material of the object. Do not confuse this integral with E, the Young's modulus. Modulus e is the eccentricity of the ellipse of contact and, by definition, is</p> $e = (1 - b^2 / a^2)^{1/2}$ <p>where the quantities a and b are parameters for the materials of the object and the comparator probe, respectively. These quantities are generally unknown and are determined from tables furnished in "Elastic Compression of Spheres and Cylinders at Point and Line Contacts" by Puttock and Thwaite (National Standards Laboratory Technical Paper No. 25, Commonwealth Scientific and Industrial Research Organization, Australia, 1969) [33].</p>
79-80	This field has the testing method code (Exempt: 0, Interferometry: 1, 3-2 Design: 2, 3-4 Design: 3, 3-6 Design: 4, 4-4 Design: 5, 4-6 Design: 6, 5-4 Design: 7, 6-4 Design: 8, 7-4 Design: 9, 8-4 Design: 10, 9-4 Design: 11, 10-4 Design: 12, 11-4 Design: 13, ABCA Design: 14, 4-1 Design: 15).

Table 6.10-4 Listing of a Sample Working <i>Setup Document File</i>											
	Column:	10	20	30	40	50	60	70	80		
		▼	▼	▼	▼	▼	▼	▼	▼		
Row:		1234567890123456789012345678901234567890123456789012345678901234567890123456789012									
0001:	5.000000	3456	1	0001	11.50	0.955	73	64.5			19980615ATR03
0002:	6.000000	B546	1	0001	11.50	0.955	241	73.2			19980615ATR03
0003:	7.000000	43	1	0001	11.50	0.955	-354	75.9			19980615ATR03
0004:	8.000000	444	1	0001	11.50	0.955	-4	76.4			19980615ATR03
0005:	10.000000	MBZ3	1	0001	11.50	0.955	359	85.7			19980615ATR03
0006:	12.000000	9912	1	0001	11.50	0.955	32	88.4			19980615ATR03
0007:	16.000000	FFG887	1	0001	11.50	0.955	-152	95.4			19980615ATR03
0008:	20.000000	0132	1	0001	11.50	0.955	172	101.3			19980615ATR03

Table 6.10-5 Listing of a Sample Archived <i>Setup Document File</i>											
	Column:	10	20	30	40	50	60	70	80		
		▼	▼	▼	▼	▼	▼	▼	▼		
Row:		1234567890123456789012345678901234567890123456789012345678901234567890123456789012									
0001:	5.000000	3456	1	0001	11.50	0.955					03
0002:	6.000000	B546	1	0001	11.50	0.955					03
0003:	7.000000	43	1	0001	11.50	0.955					03
0004:	8.000000	444	1	0001	11.50	0.955					03
0005:	10.000000	MBZ3	1	0001	11.50	0.955					03
0006:	12.000000	9912	1	0001	11.50	0.955					03
0007:	16.000000	FFG887	1	0001	11.50	0.955					03
0008:	20.000000	0132	1	0001	11.50	0.955					03

6.11 The *Spectrum* Program

The calibration and measurement of gage blocks at NIST depends on interferometry, which the technical user, who calibrates and measures gage blocks, uses the *Spectrum* program to analyze interferometric measurements from the gage block interferometers and to print the results and the *Setup* program is then used to record the results. Through interferometric measurements of NIST’s master gage blocks, NIST transfers the unit of length defined from the speed of light to its master gage blocks, which are then used for its mechanical intercomparison

process [1]. The *Spectrum* program calculates the optical lengths of gage blocks based on interferometric measurements, which are individual readings, or estimates of fringe fractions, obtained using single wavelength and multicolor interferometry. When computing optical lengths of gage blocks, the *Spectrum* program compensates for both linear thermal expansion and phase shifts between the reference flat, which the NIST technical staff refers as an *optical flat* or *platen*, and the gage block surfaces.

The use of the *Spectrum* program is a practical approach to analyzing single wavelength and multicolor interferometry. When prompted by the *Spectrum* program, the technical user, who calibrates and measures gage blocks, enters information about the gage block (e.g., nominal length, best-known length, identification or serial number, manufacturer, material, phase correction), the platen (e.g., manufacturer, material, phase correction), the interferometer correction (e.g., obliquity angle correction), the environmental conditions (e.g., gage block temperature, air temperature, atmospheric pressure, humidity), and the interferometer wavelengths and respective fringe fractions observed and uncertainties. The fringe fractions observed are the interferometric measurement readings. For each fringe fraction, the *Spectrum* program adds the fringe fraction observed to the whole number of expected fringes the gage block's known length contains. The *Spectrum* program compensates for both linear thermal expansion and phase shifts between the reference flat, which the NIST technical staff refers as an *optical flat* or *platen*, and the gage block surfaces. Using the environmental conditions and corrections, the *Spectrum* program calculates the actual wavelength for single wavelength interferometry and wavelengths for multicolor interferometry. Then, using the fringe fractions observed, the *Spectrum* program shows feasible lengths of the gage block near its nominal length where wavelengths agree. Typically, the user accepts as the true gage block length the length at which wavelengths agree within 0.030 micrometers [32,34-35]. When the gage block wavelengths' fringe fractions do not overlap with the *Spectrum* program's best fit method, the user assumes operator error and re-measures the gage block.

The *Spectrum* program helps the technical user, who calibrates and measures gage blocks, to compute the optical lengths of gage blocks if the user knows very well the lengths of gage blocks. When measuring gage blocks interferometrically, the user typically derives the lengths of gage blocks derived from mechanical measurements and then comparing the relative lengths of currently measured gage blocks to lengths of one or more transfer standards such as master gage blocks. To ensure quality assurance, the user compares past and present calibration and measurement results.

The *Spectrum* program has a *Control Menu* with seventeen functions, as Table 6.11-1 shows. The technical user, who calibrates and measures gage blocks, uses the *Control Menu* functions to do the following:

- Enter gage block information (e.g., nominal length, best-known length, identification or serial number, the manufacturer, material, phase correction)

- Enter platen information (e.g., the manufacturer, material, phase correction)
- Enter the interferometer correction (e.g., obliquity angle correction)
- Enter environmental conditions (e.g., gage block and air temperature, atmospheric pressure, humidity)
- Enter interferometer wavelengths and respective fringe fractions observed and uncertainties
- Compute the gage block’s feasible lengths near its nominal length where wavelengths agree and then display and print results

Table 6.11-1 The <i>Spectrum</i> Program’s Control Menu Functions	
Name of Function	Function Description
<i>Program Preface .</i>	This function displays the <i>Spectrum</i> program’s introductory statement.
<i>Gage Block Nominal Size</i>	This function prompts the computer user to enter a master gage block type (e.g., English, metric), nominal length or size (e.g., inches for English gage blocks, millimeters for metric gage blocks), and the best-known length in terms of correction, which is nanometers for both master gage block types.
<i>Gage Block Best Known Length . . .</i>	This function prompts the computer user to enter the best-known length in terms of correction, which is nanometers for both master gage block types.
<i>Gage Block Serial Number</i>	This function prompts the computer user to enter a gage block’s identification or serial number.
<i>Gage Block Manufacturer</i>	This function prompts the computer user to select a gage block’s manufacturer.
<i>Gage Block Material</i>	This function prompts the computer user to select a gage block’s material (e.g., steel, ceramic, chrome carbide, tungsten Carbide, stainless steel, other) and enter the thermal coefficient of expansion, in parts per million per Celsius degree.
<i>Gage Block Phase Correction</i>	This function prompts the computer user to enter a gage block’s phase correction, in nanometers.
<i>Platen and Phase Correction</i>	This function prompts the computer user to select a gage block’s manufacturer and enter a gage block’s phase correction, in nanometers.

Table 6.11-1 The <i>Spectrum</i> Program's Control Menu Functions	
Name of Function	Function Description
<i>Instrument and Correction</i>	This function prompts the computer user to select a gage block's manufacturer and enter a gage block's obliquity angle correction, in parts per million.
<i>Gage Block Temperature</i>	This function prompts the computer user to enter a gage block's temperature, in degrees Celsius.
<i>Air Temperature</i>	This function prompts the computer user to enter the air temperature, in degrees Celsius.
<i>Atmospheric Pressure</i>	This function prompts the computer user to enter the atmospheric pressure, in millimeters of mercury.
<i>Vapor Pressure</i>	This function prompts the computer user to enter the humidity, or vapor pressure, in millimeters of mercury.
<i>Wavelengths</i>	This function prompts the computer user first to select the laser light source and the spectrums used to estimate fringe fractions and second to enter the laser light source's spectrums' respective fringe fractions observed and uncertainties. When using undefined spectrums, the computer user is prompted to enter the spectrums' respective names and wavelengths, in nanometers.
<i>Fringe Fractions and Errors</i>	This function prompts the computer user to enter the laser light source's spectrums' respective fringe fractions observed and uncertainties.
<i>Compute and Report</i>	This function computes the gage block's feasible lengths near its nominal length where wavelengths agree and then prompts the computer user about displaying and printing results.
<i>Exit SPECTRUM</i>	This function stops the <i>Spectrum</i> program and loads and runs the <i>Branch</i> program..

The *Spectrum* program gets the laser light sources' menu's title and the laser light sources' respective names and wavelengths, in nanometers, from the DOS ASCII text file, named *Laser.ini*. The *Laser.ini* file resides in the *Gage* folder, which is the current and customary program folder for the *NIST Gage Block Calibration Software System* under normal operations. As Table 6.11-2 shows, the *Laser.ini* file contains the laser light sources' menu's title and the

laser light sources’ respective names and wavelengths, in nanometers. The listing of the *Laser.ini* file, as Table 6.11-3 shows, has the latest *NIST Gage Block Calibration Software System’s* laser light sources’ respective names and wavelengths, in nanometers.

Table 6.11-2 Configuration of the <i>Laser.ini</i> File	
Column	Field Description
1-40	This field has the laser light sources’ menu title, first row only.
1-16	This field has the name of laser light source. Exception: Use “Laser Not Used” for the last menu item on last row only.
18-29	This field has the wavelength of laser light source, in nanometers. Exception: Use “0.00000000” for the last menu item on last row only.

Table 6.11-3 Latest Listing of the <i>Laser.ini</i> File								
Column:	10	20	30	40	50	60	70	80
Row:	12345678901234567890123456789012345678901234567890123456789012345678901234567890123456789012	▼	▼	▼	▼	▼	▼	▼
0001:	LASERS							
0002:	Spectra Physics	632.99096254						
0003:	Tropel	632.99148600						
0004:	Coherent	632.99124500						
0005:	Iodine Stablized	632.99123100						
0006:	ZEISS HP HeNe	632.99133500						
0007:	HILGER HP HeNe	632.99136400						
0008:	1981 LASER CAL.	632.99141700						
0009:	Laser Not Used	0.00000000						

The *Spectrum* program gets the gage block manufacturers’ menu’s title and the gage block manufacturers’ respective names and materials’ names and thermal coefficients of expansion, in parts per million per Celsius degree, from the DOS ASCII text file, named *Manufact.ini*. The *Manufact.ini* file resides in the *Gage* folder, which is the current and customary program folder for the *NIST Gage Block Calibration Software System* under normal operations. As Table 6.11-4 shows, the *Manufact.ini* file contains the laser light sources’ menu’s

0001:	GAGE BLOCK MANUFACTURERS AND MATERIALS			
0002:	Brown and Sharpe	Steel	11.500 ppm/C	50.80 nm
0003:	Carl Zeiss	Steel	11.500 ppm/C	48.30 nm
0004:	Cary	Steel	11.500 ppm/C	36.00 nm
0005:	CEJohansson	Steel	11.500 ppm/C	50.80 nm
0006:	Doall	Steel	11.500 ppm/C	28.90 nm
0007:	Ellstrom	Steel	11.500 ppm/C	58.40 nm
0008:	Fonda Gage	Steel	11.500 ppm/C	63.50 nm
0009:	Hommell	Steel	11.500 ppm/C	43.20 nm
0010:	Jansson	Tungsten Carbide	4.600 ppm/C	17.70 nm
0011:	Kuroda	Steel	11.500 ppm/C	33.00 nm
0012:	Matrix	Steel	11.500 ppm/C	30.50 nm
0013:	Opus	Tungsten Carbide	4.600 ppm/C	10.40 nm
0014:	Pratt and Whitney	Steel	11.500 ppm/C	50.80 nm
0015:	Select	Tungsten Carbide	4.600 ppm/C	13.30 nm
0016:	Mitutoyo	Steel	11.500 ppm/C	28.90 nm
0017:	Mitutoyo	Ceramic	9.250 ppm/C	16.50 nm
0018:	Van Keuren	Steel	11.500 ppm/C	58.40 nm
0019:	Webber	Steel	11.500 ppm/C	58.70 nm
0020:	Webber	Ceramic	9.250 ppm/C	17.80 nm
0021:	Webber	Chrome Carbide	8.400 ppm/C	32.00 nm
0022:	Other Manufacturer	Other Material	0.000 ppm/C	0.00 nm

The *Spectrum* program gets the platens' menu's title and the platens' respective names and phase corrections, in nanometers, from the DOS ASCII text file, named *Platen.ini*. The *Platen.ini* file resides in the *Gage* folder, which is the current and customary program folder for the *NIST Gage Block Calibration Software System* under normal operations. As Table 6.11-6 shows, the *Platen.ini* file contains the platens' menu's title and the platens' respective names and phase corrections, in nanometers. The listing of the *Platen.ini* file, as Table 6.11-7 shows, has the latest *NIST Gage Block Calibration Software System's* platens' respective names and corrections, in nanometers.

Table 6.11-6 Configuration of the <i>Platen.ini</i> File	
Column	Field Description
1-40	This field has the name of platens menu title, first row only.
1-16	This field has the name of platen. Exception: Use "Other" for the last menu item on last row only.

Table 6.11-6 Configuration of the *Platen.ini* File

Column	Field Description
18-21	This field has the phase correction of platen, in nanometers. Exception: Use "0.0" for the last menu item on last row only.

Table 6.11-7 Latest Listing of the *Platen.ini* File

Column:	10	20	30	40	50	60	70	80
Row:	1	2	3	4	5	6	7	8
0001:	PLATENS							
0002:	Hilger 4	30.5						
0003:	Hilger 6	19.7						
0004:	Hilger 7	25.8						
0005:	Hilger 19	20.8						
0006:	Hilger 23	21.6						
0007:	Hilger 25	21.6						
0008:	Z1	43.2						
0009:	Z2	55.9						
0010:	Quartz 1	0.0						
0011:	Quartz 2	0.0						
0012:	Other	0.0						

The *Spectrum* program gets the spectrum lines' menu's spectrum lines' respective names and wavelengths, in nanometers, from the DOS ASCII text file, named *Spectrum.ini*. The *Spectrum.ini* file resides in the *Gage* folder, which is the current and customary program folder for the *NIST Gage Block Calibration Software System* under normal operations. As Table 6.11-8 shows, the *Spectrum.ini* file contains the spectrum lines' respective names and wavelengths, in nanometers. The listing of the *Spectrum.ini* file, as Table 6.11-9 shows, has the latest *NIST Gage Block Calibration Software System's* spectrum lines' respective names and wavelengths, in nanometers.

Table 6.11-8 Configuration of the <i>Spectrum.ini</i> File	
Column	Field Description
1-16	This field has the name of spectrum line.
18-29	This field has the wavelength of spectrum line, in nanometers.

Table 6.11-9 Latest Listing of the <i>Spectrum.ini</i> File								
Column:	10	20	30	40	50	60	70	80
Row:	12345678901	23456789012	34567890123	45678901234	56789012345	67890123456	78901234567	89012345678
0001:	Cadmium Red	644.02491150						
0002:	Cadmium Green	508.72378400						
0003:	Cadmium Blue	480.12520700						
0004:	Cadmium Violet	467.94587600						
0005:	Krypton Orange	605.78021000						

The technical user, who calibrates and measures gage blocks, uses the *Edit* program to change the information in the *Spectrum* program's four configuration files, which are *Laser.ini*, *Manufact.ini*, *Platen.ini*, and *Spectrum.ini*. The user stores the working copies of these files in the *Gage* folder and backs up these files on labeled floppy diskettes. When these working files are corrupted or lost, the user restores the information from the backed up files, which eliminates re-entering all the information.

6.12 The *Gage_lib* Software Program Library

The *NIST Gage Block Calibration Software System's* calibration and measurement software programs use software routines, which are functions, from the *Gage_lib* software program library. The *Gage_lib* software program library, as Table 6.12-1 shows, contains three routines.

Table 6.12-1 The <i>Gage_lib</i> Software Program Library	
Name of Routine	Software Routine Description
<i>FNObserve\$</i>	<p>This function displays a single-page menu with labeled fields for complete measurement sets and prompts the computer user to enter data in valid fields. Layout parameters and detail features for display of record, data input and image parameters, field labels, and any starting or default values are precisely defined by values passed through the argument list. This function is so designed to allow the computer user to select any valid item by using a pointing device or arrow key to move the selection cursor to the item wanted. The computer user may choose to enter data in field by pressing the continue or enter key. This function does return the current position of the string-array pointer and the last keystroke responsible for returning control to the calling program. The Pause key can suspend program execution and the Stop key can stop the program. Screen height and width help determine number of items that can be displayed on the screen.</p>
<i>FNPcwrkst</i>	<p>This function has procedures that are specifiable by the calling program. These procedures will create, initialize, read, store, and verify the probe initialization file, initialize global program variables, and prompts the computer user to select the calibration baseline, the calibration method, the measurement method, and the probe calibration.</p>
<i>FNVolt\$</i>	<p>This function gets numeric information from the specified IEEE-488 device. This function is specifically designed to provide support to the Hewlett-Packard Model HP3478A and Model HP34401A digital multimeters. When the input and output (I/O) path is satisfactorily assigned to the device, all specified numeric values are accepted as input from the assigned I/O path, and a mean of these values is computed and assigned to a variable passed in the parameters list and an expected event-initiated statement is returned to the calling program that signify a successful measurement; otherwise, other assigned branch statements may be returned. When numeric values are not accepted as input from the assigned I/O path within the non-zero allotted time specified by way of the time passed through a variable in the parameter list, this function automatically interrupts measurements when measurements are not taken within specified allotted time and a branch statement signifying the function has aborted is returned to the calling program and control is returned to the calling program.</p>

Chapter 7

Using the *NIST Gage Block Calibration Software System*

*This chapter provides general instruction about using the **NIST Gage Block Calibration Software System** as a complete calibration system with custom integrated software to calibrate and measure gage blocks, which are length standards having standard features for accuracy, flatness, parallelism, dimensional stability, and excellent surface finish for exceptional wringing characteristics. The gage blocks have nominal lengths defined in the metric system, using millimeters, and in the English system, using the inch that equals 25.4 millimeters. In keeping with the NIST policy of the International System of Units (SI) for reporting length in this manual [16], the nominal lengths of gage blocks identify each by name or size. The gage blocks have flat and parallel opposing surfaces that are rectangular, square (Hoke), and circularly cross-sectional shaped. The American standards for gage blocks, which include the U.S. Federal Specification GGG-G-15C, the American National Standard ANSI/ASME B89.1.9M, and the U.S. Department of Defense Military Standard MIL-STD 45662A, gives suggested dimensions and tolerances for rectangular, square (Hoke), and circular cross-sectional shaped gage blocks [17-19]. It generalizes the methodical use of the **NIST Gage Block Calibration Software System**'s software programs for configuring system resources, creating and maintaining measurement history and related information and statistical process control of NIST's and its gage block customers' gage blocks, and measuring gage blocks using interferometric and mechanical intercomparison techniques.*

7.1 Introduction to Using the *NIST Gage Block Calibration Software System*

The technical user, who calibrates and measures gage blocks, uses the **NIST Gage Block Calibration Software System** as a complete calibration system with custom integrated software to calibrate and measure gage blocks, which the NIST technical staff refers as *master gage blocks*, as individual blocks or sets, both English and metric. In the sections ahead is an accounting of methodically using the **NIST Gage Block Calibration Software System**'s software

programs for configuring system resources, creating and maintaining measurement history and related information and statistical process control of gage blocks belonging to NIST and its gage block customers, and measuring gage blocks using interferometric and mechanical intercomparison techniques.

7.2 Starting the *NIST Gage Block Calibration Software System*

The *NIST Gage Block Calibration Software System* starts, in a full screen under Microsoft Windows 95, when the technical user, who calibrates and measures gage blocks, does any of the following:

- Click the icon identified “**NIST Gage Block Calibration Software System**” on the Microsoft Windows 95 desktop
- Click the Start button on the Microsoft Windows 95 desktop taskbar, point to Programs, and click the program identified “**NIST Gage Block Calibration Software System**”

When the user starts the *NIST Gage Block Calibration Software System*, the current folder changes to the *Gage* folder and TransEra High Tech Basic (HTBasic) Language System DOS Version 4.3 or higher starts. TransEra HTBasic Language System DOS Version 4.3 or higher looks for the *Autost* program, which resides in the *Gage* folder and contains command line switches to affect the behavior of TransEra HTBasic Language System DOS Version 4.3 or higher by configuring the running environment and loading device drivers. The last command line in the *Autost* program loads the *Branch* program, which resides in the *Htbutil* folder.

An alternative to starting the *NIST Gage Block Calibration Software System*, in a full screen under Microsoft Windows 95, is starting the system under Microsoft DOS Version 5.0 or higher. To start the *NIST Gage Block Calibration Software System* under Microsoft DOS Version 5.0 or higher, the technical user, who calibrates and measures gage blocks, places, as the last commands in the *Autoexec.bat* file, the commands for changing the current folder to the *Gage* folder and starting the programming environment of TransEra HTBasic Language System DOS Version 4.3 or higher.

7.3 Running the *NIST Gage Block Calibration Software System*

The *Branch* program displays continuously the *NIST Gage Block Calibration Software System*'s accessory software programs and calibration and measurement software programs on

the computer monitor among which the technical user, who calibrates and measures gage blocks, can select. When the user selects a program from the menu, the **Branch** program automatically loads and executes the program selected. When the user does not use the keyboard and mouse for 30 seconds, the **Branch** program starts the built-in screen saver that resembles twinkling stars in the midnight sky. To refresh the menu of programs' names and descriptions, the user presses any key on the keyboard or the mouse.

7.4 Configuring of the *NIST Gage Block Calibration Software System*

The **Config** program displays and sets the *NIST Gage Block Calibration Software System*'s file folder and peripheral device properties, which the technical user, who calibrates and measures gage blocks, uses the **Config** program's functions to edit. When running the *NIST Gage Block Calibration Software System* under normal conditions, the storage device and folders are the following:

- Accessory Software Program Folder C:\Htbutil Folder
- Calibration and Measurement Software Program Folder . . . C:\Gage Folder
- Working Storage Device and Folder C:/Gage/Work Folder

The normal interface select codes for the computer system's peripheral devices are the following:

- Monitor "1"
- Serial Printer "9"
- Parallel Printer "10"
- Plotter "705"

When the technical user, who calibrates and measures gage blocks, selects "Okay," the **Config** program tests the system configuration, stores file folder and peripheral device properties to the configuration file, named *Config.cfg*, in the current program folder, which is normally the C:\Gage folder, and loads and runs the **Branch** program.

7.5 Knowing the Basics About Calibrating Gage Blocks

The technical user, who calibrates and measures gage blocks, understands gage blocks are length standards having standard features for accuracy, flatness, parallelism, dimensional stability, and excellent surface finish for exceptional wringing characteristics. The gage blocks have nominal lengths defined in the metric system, using millimeters, and in the English system,

using the inch that equals 25.4 millimeters. In keeping with the NIST policy of the International System of Units (SI) for reporting length in this manual [16], the nominal lengths of gage blocks identify each by name or size. The gage blocks have flat and parallel opposing surfaces that are rectangular, square (Hoke), and circularly cross-sectional shaped. The American standards for gage blocks, which include the U.S. Federal Specification GGG-G-15C, the American National Standard ANSI/ASME B89.1.9M, and the U.S. Department of Defense Military Standard MIL-STD 45662A, gives suggested dimensions and tolerances for rectangular, square (Hoke), and circular cross-sectional shaped gage blocks [17-19].

The definition of gage block length is the perpendicular distance from a gaging point on one end of the block to an auxiliary true plane wrung to the other end of the gage block. To define the lengths of gage blocks belonging to NIST and its gage block customers, the technical user, who calibrates and measures gage blocks, uses the following standard reference conditions:

- Temperature 20 degrees Celsius
- Barometric pressure 101,325 pascal (1 atmosphere)
- Humidity or water vapor pressure 1,333 pascal (10 millimeter of mercury)
- Carbon dioxide content of air 0.03 percent

Among these environmental conditions, temperature affects the physical length of gage blocks greatly. Since the primary measurement of gage block length is the comparison with the wavelength of light, we need all these environmental conditions. Although the frequency of light for standard light is constant, its wavelength depends on temperature, barometric pressure, humidity, and carbon dioxide content of air [1,8].

Using the *NIST Gage Block Calibration Software System's Spectrum* program, the technical user, who calibrates and measures gage blocks, calibrates and measures gage blocks, which belong to NIST and its gage block customers, by interferometry according to the definition of gage block length. Every NIST master gage block carries a wringing layer with it, and this wringing layer the user transfers to every gage block they calibrate at NIST by mechanical intercomparison [1].

The technical user, who calibrates and measures gage blocks, uses the *NIST Gage Block Calibration Software System's Gage* program to find the mechanical lengths of gage blocks by mechanical intercomparison of gage blocks. This technique compares gage blocks to other gage blocks having known lengths determined by interferometry. The mechanical intercomparisons are measurements that use two designated points, one on each end of the gage blocks. Besides

temperature, deformation effects can greatly bias every mechanical measurement, which affects the physical length of gage blocks. Hosting deformation biases are the following:

- Effects of NIST's electro-mechanical gage block comparators' scale magnification and variable measuring forces and measuring probe tip geometry
- Gage blocks the user calibrates and measures each have different materials and contact elastic corrections

Before the user uses the **Gage** program to calibrate and measure NIST's gage block calibration customers' gage blocks, the user records probe calibration results using one of the **Probe** program's two calibration procedures and NIST's two or three sets of step master gage blocks. The **Gage** program, which the user uses to calibrate and measure NIST's gage block calibration customers' gage blocks, uses the recorded probe calibration results to automatically compensate measurements for effects of NIST's electro-mechanical gage block comparators' scale magnification and variable measuring forces and measuring probe tip geometry and the different materials and contact elastic corrections [1,33].

7.6 Knowing about NIST's Measurement Assurance Program

The *NIST Gage Block Calibration Software System* implements NIST's gage block measurement assurance program. The first part of NIST's gage block measurement assurance program is the continuous calibration and measurement of NIST's master gage blocks by interferometry under process control. The technical user, who calibrates and measures gage blocks, together through using the **Spectrum**, **Edit**, and **Intmap** programs, analyzes and records NIST's master gage block interferometric measurement results from the gage block interferometers and NIST's master gage block interferometric calibration history. After accumulating NIST's master gage block interferometric measurement results, the user plots control charts to individually check the variability of NIST's master gage blocks' interferometric calibration history. When the user use NIST's master gage blocks to calibrate and measure NIST's gage block calibration customers' gage blocks by mechanical intercomparison, NIST Reports' of Calibration report, for every calibration and measurement, the interferometric measurement uncertainty combined in quadrature with the mechanical intercomparison uncertainty. The second part of NIST's gage block measurement assurance program the user accomplishes, together through running the **Gage** program in *Gage* mode, to calibrate and measure NIST's gage block calibration customers' gage blocks by mechanical intercomparison and using the **Mecmap** program to analyze NIST's gage block mechanical intercomparison calibration history. Providing process control parameters for the mechanical intercomparison process and estimating measurement process variability is NIST's gage block mechanical intercomparison calibration history, which records the measured differences between the NIST's two master gage blocks used in every calibration and measurement and the derived standard deviations of every calibration and measurement. As the third part of NIST's gage block

measurement assurance program, the user uses the *History* program to authenticate past and present calibration and measurement results.

7.7 Calibrating NIST's Master Gage Blocks Using Interferometry

The calibration and measurement of gage blocks at NIST depends on interferometry, which the technical user, who calibrates and measures gage blocks, uses the *Spectrum* program to analyze interferometric measurements from the gage block interferometers and to print the interferometric measurement results. The user calls interferometric measurement results NIST's master gage block interferometric history. The *Spectrum* program calculates the optical lengths of gage blocks based on interferometric measurements, which are individual readings, or estimates of fringe fractions, obtained using single wavelength and multicolor interferometry, compensating for both linear thermal expansion and phase shifts between the reference flat, which the NIST technical staff refers as an *optical flat* or *platen*, and the gage block surfaces. Through interferometric measurements of NIST's master gage blocks, NIST transfers the unit of length defined from the speed of light to its master gage blocks, which are then used for its mechanical intercomparison process [1,8]. To archive NIST's master gage block interferometric calibration history, the user uses the *Edit* program to record interferometric measurement results to *Intmap Document Files*.

7.8 Archiving NIST's Master Gage Blocks' Interferometric History

The archiving of NIST's master gage block interferometric calibration history has the technical user, who calibrates and measures gage blocks, using the *Edit* program to record interferometric measurement results to *Intmap Document Files*. The *Intmap Document Files* organize into groups NIST's master gage blocks' interferometric calibration history gage blocks with common physical length characteristics, which improves the significance of the statistical analyses when using the *Intmap* program. The *Intmap Document Files* organize into groups NIST's master gage blocks' interferometric calibration history in the following way:

- GROUP 01 English Thins Sizes: 0.010 to 0.09375 Inches
- GROUP 02 English Gage Blocks Sizes: 0.100 to 0.107 Inches
- GROUP 03 English Gage Blocks Sizes: 0.108 to 0.126 Inches
- GROUP 04 English Gage Blocks Sizes: 0.127 to 0.146 Inches
- GROUP 05 English Gage Blocks Sizes: 0.147 to 0.500 Inches

- GROUP 06 English Gage Blocks Sizes: 0.550 to 4.000 Inches
- GROUP 07 English Long Blocks Sizes: 5.0 to 20.0 Inches
- GROUP 08 English 010 Series Thins Sizes: 0.01005 to 0.019 Inches
- GROUP 09 English 020 Series Thins Sizes: 0.02005 to 0.029 Inches
- GROUP 10 English 050 Series Thins Sizes: 0.05005 to 0.059 Inches
- GROUP 11 English Step Gage Block Sizes: 0.100 to 0.1001 Inches
- GROUP 13 Metric Thins Sizes: 0.10 to 0.95 Millimeters
- GROUP 14 Metric Gage Blocks Sizes: 1.00 to 1.09 Millimeters
- GROUP 15 Metric Gage Blocks Sizes: 1.10 to 1.29 Millimeters
- GROUP 16 Metric Gage Blocks Sizes: 1.30 to 1.49 Millimeters
- GROUP 17 Metric Gage Blocks Sizes: 1.50 to 2.09 Millimeters
- GROUP 18 Metric Gage Blocks Sizes: 2.10 to 2.29 Millimeters
- GROUP 19 Metric Gage Blocks Sizes: 2.30 to 2.49 Millimeters
- GROUP 20 Metric Gage Blocks Sizes: 2.50 to 10.0 Millimeters
- GROUP 21 Metric Gage Blocks Sizes: 10.5 to 20.0 Millimeters
- GROUP 22 Metric Gage Blocks Sizes: 20.5 to 50 Millimeters
- GROUP 23 Metric Gage Blocks Sizes: 60 to 100 Millimeters
- GROUP 24 Metric Gage Blocks Sizes: 125 to 500 Millimeters

The user enters the following information about NIST's master gage blocks into *Intmap Document Files*:

- Nominal sizes
- Identification or serial numbers
- Materials
- Test dates
- Interferometrically-derived nominal deviations, in nanometers
- Documentation and remarks

The user stores working *Intmap Document Files* in the working file storage device and folder, which is *C:\Gage\Intmaps*, and backs up these files on labeled floppy diskettes.

7.9 Analyzing NIST's Master Gage Blocks' Interferometric History

The use of the *Intmap* program to analyze NIST's master gage block interferometric calibration history is the first of the three parts of NIST's gage block measurement assurance program. The technical user, who calibrates and measures gage blocks, together through using the *Spectrum*, *Edit*, and *Intmap* programs, analyzes and records NIST's master gage block interferometric measurement results from the gage block interferometers and NIST's master gage block interferometric calibration history. After accumulating and recording NIST's master gage block interferometric measurement results into *Intmap Document Files*, the user uses the *Intmap* program to generate anew reports about NIST's master gage block interferometric calibration history and plots control charts to individually check the variability of NIST's master gage blocks' interferometric history. After running the *Intmap* program to analyze NIST's master gage block interferometric calibration history, the user uses the *Master* program to record the interferometric history results, which the user calls *master information*. The *Intmap* program simplifies efforts by the user to manage and statistically analyze NIST's master gage block interferometric calibration history, which the user routinely monitors to improve complete measurement confidence.

7.10 Setting Up and Managing NIST's Master Gage Blocks' Master Files

As part of the process of starting any NIST's gage block calibration customers' calibrations, the technical user, who calibrates and measures gage blocks, uses the *Master* program to record current information about NIST's master gage blocks, which the user calls *master information*, to *Master Document Files*. The *Master Document Files* organize into two groups NIST's master gage blocks' interferometric calibration and mechanical intercomparison control history in the following way:

- English Gage Blocks Sizes: 0.01 to 20 Inches
- Metric Gage Blocks Sizes: 0.1 to 500 Millimeters

The user enters the following information about NIST's master gage blocks into *Master Document Files*:

- Nominal sizes
- Identification or serial numbers
- Material codes

- Interferometrically-derived nominal deviations and standard deviations, in nanometers
- Mechanical intercomparison controls, within standard deviations, and total standard deviations, in nanometers

The user stores working *Master Document Files* in the working file storage device and folder, which is *C:\Gage\Masters*, and backs up these files on labeled floppy diskettes.

The technical user, who calibrates and measures gage blocks, uses the *Intmap* program to find the interferometrically-derived nominal deviations and standard deviations. First, to calibrate and measure NIST's master gage blocks by interferometry, the user uses the *Spectrum* program to analyze interferometric measurements from the gage block interferometers and to print the interferometric measurement results. Second, the user uses the *Intmap* program to analyze NIST's master gage blocks' interferometric calibration history and print the interferometric calibration history results. Third, the user uses the *Master* program to record the interferometric calibration history results to the *Master Document Files*.

The technical user, who calibrates and measures gage blocks, has one or two approaches to finding for NIST's master gage blocks' the master gage blocks' mechanical intercomparison controls, the master gage blocks' mechanical intercomparison within standard deviations, and the master gage blocks' mechanical intercomparison total standard deviations. For newly introducing master gage blocks or replacing NIST's master gage blocks, the only approach for finding NIST's master gage blocks' mechanical intercomparison controls, the master gage blocks' mechanical intercomparison within standard deviations, and the master gage blocks' mechanical intercomparison total standard deviations are the user uses NIST's electro-mechanical gage block comparators to measure every master gage block, which is being newly-introduced or replacement, and then to estimate the mechanical intercomparison controls, within standard deviations, and total standard deviations, which typically the user bases on a minimum of ten measurements each master gage block. The user records the estimated mechanical intercomparison controls, within standard deviations, and total standard deviations for NIST's master gage blocks to the *Master Document Files*. For NIST's master gage blocks used successfully to calibrate and measure NIST's gage block calibration customers' gage blocks by mechanical intercomparison for a minimum of one year and for ten different calibrations, the user uses the *Mecmap* program, which uses the recorded mechanical intercomparison control history for all NIST's gage block mechanical intercomparison calibrations and measurements, to compute NIST's master gage blocks' mechanical intercomparison controls, the master gage blocks' mechanical intercomparison within standard deviations, and the master gage blocks' mechanical intercomparison total standard deviations, and records the results to the *Master Document Files*.

7.11 Setting Up and Using NIST's Gage Block Customers' *Folder* and *Setup* Files for Calibrating NIST's Gage Block Customers' Gage Blocks

Before starting every NIST's gage block calibration customers' calibrations, the technical user, who calibrates and measures gage blocks, uses the ***Folder*** program to record customers' names and addresses, which the user calls *folder information*, to *Folder Document Files* and the ***Setup*** program to record customers' gage blocks' sizes, identification or serial numbers, and calibration and measurement information, which the user calls *setup information*, to *Setup Document Files*. This *folder information* has the following information about NIST's gage block customers' gage block calibrations:

- NIST test folder number
- Description of gage blocks calibrated and measured
- Primary identification or serial number of the gage block set
- Name and address, which includes their division or post office box number, street address, city, state, and U.S. Postal Service ZIP Code+4 within the United States and its territories
- Purchase order number
- Internal or group control number
- Date of the NIST Report of Calibration

This *setup information* has the following information about NIST's gage block customers' gage blocks:

- Testing status
- Nominal sizes
- Identification or serial numbers
- Master type
- Material codes
- Thermal coefficients of expansion, in parts per million
- Observed nominal deviations and uncertainties, in nanometers
- Testing dates
- Observers' initials
- Testing method codes

The user stores working *Folder Document Files* in the working file storage device and folder, which is *C:\Gage\Work*, and archived *Folder Document Files* in the *Historys* storage device and folder, which is *C:\Gage\Historys*, and on labeled floppy diskettes. The user stores all working *Setup Document Files* in the working file storage device and folder, which is *C:\Gage\Work*, and the archived *Setup Document Files* in the *Historys* storage device and folder, which is *C:\Gage\Historys*, and on labeled floppy diskettes. When NIST's gage block calibration customers return gage block sets for calibrations, the user retrieves archived *Folder Document Files* and *Setup Document Files*. This eliminates the user having to re-enter all *folder information* and *setup information* and it provides information about gage blocks previously calibrated and measured, which helps with spotting new and missing *folder information*, *setup information*, and gage blocks.

When calibrating gage blocks for NIST's gage block customers, the technical user, who calibrates and measures gage blocks, together setup and use *Folder Document Files* and *Setup Document Files*. To calibrate and measure gage blocks by interferometry, the user uses the ***Spectrum*** program to analyze interferometric measurements from the gage block interferometers and to print the results and the ***Setup*** program is then used to record the results. To calibrate and measure gage blocks by mechanical intercomparison, the user uses the *Gage* program to analyze measurements from the electro-mechanical gage block comparators, print the results, and record the results to the *Setup Document Files*. To create NIST Reports' of Calibration, the user runs the ***Report*** program, which uses the folder information from the *Folder Document Files* and the stored gage block calibration and measurement results from the ***Setup*** and ***Gage*** programs.

7.12 Calibrating NIST's Gage Block Customers' Gage Blocks Using Interferometry

To calibrate and measure gage blocks by interferometry, the technical user, who calibrates and measures gage blocks, uses the ***Spectrum*** program to analyze interferometric measurements from the gage block interferometers and to print the results and the ***Setup*** program is then used to record the results. For every interferometric gage block calibration, the ***Spectrum*** program prompts the user to enter the following information:

- Gage block (e.g., nominal length, best-known length, identification or serial number, manufacturer, material, phase correction)
- Platen (e.g., manufacturer, material, phase correction)
- Interferometer correction (e.g., obliquity angle correction)
- Environmental conditions (e.g., gage block temperature, air temperature, atmospheric pressure, humidity)
- Interferometers' wavelengths and the respective fringe fractions observed and

uncertainties

The *Spectrum* program uses the information that the technical user, who calibrates and measures gage blocks, entered about the gage block, the platen, the interferometer correction, the environmental conditions, and the interferometers' wavelengths and the respective fringe fractions observed and uncertainties to calculate the optical lengths of gage blocks based on interferometric measurements, which are individual readings, or estimates of fringe fractions, obtained using single wavelength and multicolor interferometry. When measuring gage blocks interferometrically, the technical user, who calibrates and measures gage blocks, typically derives the lengths of gage blocks derived from mechanical measurements and then comparing the relative lengths of currently measured gage blocks to lengths of one or more transfer standards such as master gage blocks. When computing optical lengths of gage blocks, the *Spectrum* program compensates for both linear thermal expansion and phase shifts between the reference flat, which the NIST technical staff refers as an *optical flat* or *platen*, and the gage block surfaces. Then, using the fringe fractions observed, the *Spectrum* program shows feasible lengths of the gage block near its nominal length where wavelengths agree. Typically, the user accepts as the true gage block length the length at which wavelengths agree within 0.030 micrometers [32,34-35]. When the gage block wavelengths' fringe fractions do not overlap with the *Spectrum* program's best fit method, the user assumes operator error and re-measures the gage block. To ensure quality assurance, the user compares past and present calibration and measurement results.

7.13 Calibrating NIST's Gage Block Comparators

Before calibrating and measuring every NIST's gage block calibration customers' gage blocks by mechanical intercomparison, the technical user, who calibrates and measures gage blocks, calibrates NIST's electro-mechanical gage block comparators, using the *Probe* program to measure NIST's two or three eleven-piece sets of gage blocks, which the NIST technical staff refers as *step master gage blocks*, analyze the measurements, and print, plot, and record the measurements and probe calibration results that the *Gage* program uses to help the user better calibrate and measure NIST's gage block calibration customers' gage blocks. The three eleven-piece sets of gage blocks, which the NIST technical staff refers as *step master gage blocks*, each consists of a selection of rectangular gage blocks having nominal gage block sizes from 0.1 through 0.1001 inches, in increments of 0.00001 inches, one each of steel, chrome carbide, and tungsten carbide gage blocks. When the user uses the *Gage* program to calibrate and measure NIST's gage block calibration customers' gage blocks, the *Gage* program uses the probe calibration results the *Probe* program records to automatically compensate measurements for effects of NIST's electro-mechanical gage block comparators' scale magnification and variable measuring forces and measuring probe tip geometry. The *Probe* program records the measurements and probe calibration results of NIST's electro-mechanical gage block

comparators' calibrations to *Probe Document Files*, which are DOS ASCII text files.

The NIST technical staff, in 1996, decidedly changed the equipment and procedure that the user uses to calibrate NIST's electro-mechanical gage block comparators. The three eleven-piece sets of gage blocks, which the NIST technical staff refers as *step master gage blocks*, each consisting of a selection of rectangular gage blocks having nominal gage block sizes from 0.1 through 0.1001 inches, in increments of 0.00001 inches, one each of steel, chrome carbide, and tungsten carbide gage blocks replaces the single eleven-piece set of steel gage blocks, which the NIST technical staff also referred as *step master gage blocks*, consisting of a selection of rectangular gage blocks having nominal gage block sizes from 0.2 through 0.2001 inches, in increments of 0.00001 inches. This selection of rectangular gage blocks, having nominal gage block sizes from 0.1 through 0.1001 inches instead of from 0.2 through 0.2001 inches, offers the following advantages or improvements:

- Reduced thermal effects on calibration and measurement results
- Reduced costs (e.g., rectangular gage blocks having nominal gage block sizes from 0.2 through 0.2001 inches, in increments of 0.00001 inches, are more affordable)
- Improved availability (e.g., rectangular gage blocks having nominal gage block sizes from 0.2 through 0.2001 inches, in increments of 0.00001 inches, are available for these commonly used materials: steel, chrome carbide, and tungsten carbide)

These three eleven-piece sets of rectangular gage blocks having nominal gage block sizes from 0.1 through 0.1001 inches, in increments of 0.00001 inches, one each of steel, chrome carbide, and tungsten carbide gage blocks instead of a single eleven-piece set of steel rectangular gage blocks offer the advantage and improvement of directly measuring the actual penetration due to variable measuring forces and measuring probe tip geometry, which the *Gage* program uses to help the user better calibrate and measure NIST's gage block calibration customers' gage blocks.

7.14 Calibrating NIST's Gage Block Customers' Gage Blocks Using Mechanical Intercomparison

To calibrate and measure gage blocks by mechanical intercomparison, as Figure 7.14-1 shows, the technical user, who calibrates and measures gage blocks, uses the *Gage* program to analyze measurements from the electro-mechanical gage block comparators, print the results, and record the results to the *Setup Document Files*. The *Gage* program has two testing modes, the *Gage* mode to calibrate and measure NIST's gage block calibration customers' gage blocks and the *Test* mode to test the *NIST Gage Block Calibration Software System* and train personnel. To calibrate and measure NIST's gage block calibration customers' gage blocks, the user first uses the *Setup* program to record the *setup* information in *Setup Document Files*, which are DOS

ASCII text files. To calibrate and measure gage blocks by mechanical intercomparison, the user uses the **Gage** program in *Gage* mode to analyze measurements from the electro-mechanical gage block comparators, print the results, and record the results to the *Setup Document Files*. As part of the process to ensure quality assurance, the **Gage** program estimates short-term and long-term measurement process variability by measuring and recording the differences in length of the two master gage blocks used for every NIST's gage block calibration customers' gage blocks calibrated and measured by mechanical intercomparison and comparing past and present calibration and measurement results.

7.15 Analyzing NIST's Gage Block Customers' Gage Blocks' Calibration History

As part of the process to ensure quality assurance, the technical user, who calibrates and measures gage blocks, uses the **History** program to authenticate past and present calibration and measurement results, which occasionally requisite retests. Once authenticated, the user then merges and records the present calibration and measurement results to the *History Document Files* and creates NIST Reports' of Calibration. To create NIST Reports' of Calibration, the user runs the **Report** program, which uses the *folder information* from the *Folder Document Files* and the stored gage block calibration and measurement results from the **Setup** and **Gage** programs.

The technical user, who calibrates and measures gage blocks, uses the **History** program to manage and statistically analyze NIST's gage block calibration customers' gage block calibration history. To reduce risks of reporting inaccurate measurements and improve complete measurement confidence, the **History** program helps the user to routinely monitor the following:

- NIST's gage block calibration customers' gage block calibration history
- Individual gage blocks' history in NIST's gage block calibration customers' gage block calibration history
- Offsets of individual gage blocks' history, which are between the latest and all previous calibrations and measurements, in NIST's gage block calibration customers' gage block calibration history
- Gage block sets' offset, which is between averages of the latest and all previous calibrations and measurements, in NIST's gage block calibration customers' gage block calibration history



**Figure 7.14-1 Calibration and Measurement of Gage Blocks
by Mechanical Intercomparison in Progress**

7.16 Issuing NIST Reports' of Calibration for NIST's Gage Block Customers' Gage Block Calibrations

The issuing of NIST Reports' of Calibration to NIST's gage block calibration customers' completes every gage block calibration. To create NIST Reports' of Calibration, the technical user, who calibrates and measures gage blocks, runs the **Report** program, which uses the *folder information* from the *Folder Document Files* and the stored gage block calibration and measurement results from the **Setup** and **Gage** programs. The user uses the **Report** program to open, create, print, and store NIST's gage block calibration customers' NIST Reports' of Calibration.

7.17 Archiving NIST's Gage Block Mechanical Intercomparison Control History

The archiving of NIST's master gage blocks' mechanical intercomparison control history has the technical user, who calibrates and measures gage blocks, using the **Mecmap** program's *Mapsort* function to assemble *Mecmap Document Files*, by generating anew the mechanical intercomparison control history for all NIST's gage blocks' mechanical intercomparison calibrations and measurements from the **Gage** program's *Gagemap Document Files* selected. The *Mecmap Document Files* organize into groups NIST's master gage block mechanical intercomparison control history gage blocks with common physical length characteristics, which improves the significance of the statistical analyses when using the **Mecmap** program. The *Mecmap Document Files* organize into groups NIST's master gage block mechanical intercomparison control history in the following way:

- GROUP 01 English Thins Sizes: 0.010 to 0.09375 Inches
- GROUP 02 English Gage Blocks Sizes: 0.100 to 0.107 Inches
- GROUP 03 English Gage Blocks Sizes: 0.108 to 0.126 Inches
- GROUP 04 English Gage Blocks Sizes: 0.127 to 0.146 Inches
- GROUP 05 English Gage Blocks Sizes: 0.147 to 0.500 Inches
- GROUP 06 English Gage Blocks Sizes: 0.550 to 4.000 Inches
- GROUP 07 English Long Blocks Sizes: 5.0 to 20.0 Inches
- GROUP 08 English 010 Series Thins Sizes: 0.01005 to 0.019 Inches
- GROUP 09 English 020 Series Thins Sizes: 0.02005 to 0.029 Inches
- GROUP 10 English 050 Series Thins Sizes: 0.05005 to 0.059 Inches
- GROUP 13 Metric Thins Sizes: 0.10 to 0.95 Millimeters

- GROUP 14 Metric Gage Blocks Sizes: 1.00 to 1.09 Millimeters
- GROUP 15 Metric Gage Blocks Sizes: 1.10 to 1.29 Millimeters
- GROUP 16 Metric Gage Blocks Sizes: 1.30 to 1.49 Millimeters
- GROUP 17 Metric Gage Blocks Sizes: 1.50 to 2.09 Millimeters
- GROUP 18 Metric Gage Blocks Sizes: 2.10 to 2.29 Millimeters
- GROUP 19 Metric Gage Blocks Sizes: 2.30 to 2.49 Millimeters
- GROUP 20 Metric Gage Blocks Sizes: 2.50 to 10.0 Millimeters
- GROUP 21 Metric Gage Blocks Sizes: 10.5 to 20.0 Millimeters
- GROUP 22 Metric Gage Blocks Sizes: 20.5 to 50 Millimeters
- GROUP 23 Metric Gage Blocks Sizes: 60 to 100 Millimeters
- GROUP 24 Metric Gage Blocks Sizes: 125 to 500 Millimeters

In the *Mecmap Document Files* is the following information about NIST's gage block mechanical intercomparison control history for all NIST's gage block mechanical intercomparison calibrations and measurements:

- Nominal sizes
- Identification or serial numbers
- Master type
- Material codes
- Accepted master gage block mechanical intercomparison controls
- Accepted master gage block mechanical intercomparison within standard deviations
- Testing method codes
- Electro-mechanical gage block comparators' identification codes
- Observed temperatures
- Observers' initials
- Testing dates
- Statistical process control codes
- Observed master gage block mechanical intercomparison controls
- Observed master gage block mechanical intercomparison within standard deviations.

The user stores working *Mecmap Document Files* in the working file storage device and folder, which is *C:\Gage\Mecmaps*, and backs up these files on labeled floppy diskettes.

7.18 Analyzing NIST's Gage Block Mechanical Intercomparison Calibration History

The use of the *Mecmap* program is to analyze the mechanical intercomparison control history for all NIST's gage block mechanical intercomparison calibrations and measurements, which is the second of the three parts of NIST's gage block measurement assurance program. The technical user, who calibrates and measures gage blocks, uses the *Mecmap* program to open, analyze, and print the mechanical intercomparison control history for all NIST's gage block mechanical intercomparison calibrations and measurements, which the *Gage* program records during its uses in calibrations and measurements. After using the *Mecmap* program's *Mapsot* function to assemble *Mecmap Document Files*, the technical user, who calibrates and measures gage blocks, uses the *Mecmap* program to generate anew reports about NIST's gage block mechanical intercomparison calibration history and plots control charts to individually check the variability of NIST's gage block mechanical intercomparison calibration history. After running the *Mecmap* program to analyze NIST's gage block mechanical intercomparison calibration history, the user uses the *Master* program to record the mechanical intercomparison calibration history results, which the user calls *master information*. The *Mecmap* program simplifies efforts by the user to manage and statistically analyze NIST's gage block mechanical intercomparison calibration history, which the user routinely monitors to improve complete measurement confidence.

Chapter 8

References

*This chapter provides the references for this user documentation and the **NIST Gage Block Calibration Software System**. These references identify the gage blocks, instruments, and documentation that the NIST technical staff uses to perform gage block calibrations and measurements.*

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Appendix A.

The Accessory Software

This appendix documents the accessory software programs and their related files.

Accessory Software Programs

 In the **Htbutil Folder** are the following *accessory software programs*:


 **Branch**

 **Clock**

 **Config**


 **Edit**

 **Elastic**

 **Format**

 **Quit**

Accessory Software Program Libraries for all Software Programs

 In the **Htbutil Folder** are the following *accessory software program libraries*:

 **Main_lib**

 **Math_lib**

 **Tech_lib**

Accessory Software Program Configuration Files



In the ***Htbutil Folder*** are the following *accessory software program configuration files*:



Branch.txt for the ***Branch*** Program




Config.cfg for the ***Config*** Program

Appendix B.

NIST Gage Block Calibration and Measurement Software

This appendix documents the NIST Gage Block Calibration and Measurement software programs and their related files.

NIST Gage Block Calibration and Measurement Software Programs

 In the ***Gage Folder*** are the following *calibration and measurement software programs*:

 ***Autost***

 ***Folder***

 ***Gage***

 ***History***

 ***Intmap***

 ***Master***

 ***Mecmap***


 ***Probe***

 ***Report***

 ***Setup***


 ***Spectrum***


NIST Gage Block Calibration and Measurement Software Program Library


 In the **Gage Folder** is the following *calibration and measurement software program library*:

 **Gage_lib**

Accessory Software Program Configuration Files

 In the **Gage Folder** are the following *accessory software program configuration files*:

 **Branch.txt** for the **Branch** Program

 **Config.cfg** for the **Config** Program

Appendix C.

NIST Gage Block Calibration and Measurement Software's Configuration Files

This appendix documents the configuration files the NIST Gage Block Calibration Software System uses.



In the ***Gage Folder*** are the following *calibration and measurement software configuration files*:



Federal.ini



Gbkupmap.ini

Appendix D.

NIST Gage Block Calibration and Measurement Software's *Mecmap* Program's Configuration File

This appendix documents the configuration file the NIST Gage Block Calibration and Measurement Software's Mecmap Program uses.



In the ***Gage Folder*** is the following *calibration and measurement software configuration file that the Mecmap program uses:*




Mecmap.ini

Appendix E.

NIST Gage Block Calibration and Measurement Software's *Probe* Program's Configuration Files

This appendix documents the configuration files the NIST Gage Block Calibration and Measurement Software's Probe Program uses.

 In the **Gage Folder** are the following *calibration and measurement software configuration files that the Probe program uses:*



Probe.ini



Probe.log



Probef1.ini



Probef2.ini



Probef3.ini



Probef4.ini



Probef5.ini



Probef6.ini



Probef7.ini



Probef8.ini



Probef9.ini

Appendix F.

NIST Gage Block Calibration and Measurement Software's *Report* Program's NIST Reports' of Calibration Documentation Files

This appendix documents the NIST Reports' of Calibration documentation files the NIST Gage Block Calibration and Measurement Software's Report Program uses.



In the **Gage Folder** are the following *calibration and measurement software documentation files that the Report program uses:*



Heading.txt



Ending.txt



Repteng.txt



Reptmet.txt



Rept1all.txt




Rept2all.txt

Appendix G.

NIST Gage Block Calibration and Measurement Software's *Spectrum* Program's Configuration Files

This appendix documents the configuration files the NIST Gage Block Calibration and Measurement Software's Spectrum Program uses.

 In the **Gage Folder** are the following *calibration and measurement software configuration files that the Spectrum program uses:*



Federal.ini



Laser.ini



Manufact.ini



Platen.ini



Spectrum.ini

