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## **DIGITAL LEVELING USER’S GUIDE**

Utilizing the Leica NA Series of Digital Levels  
in Accordance with FGCS Specifications  
and the Input Formats and Specifications of the  
National Geodetic Survey Data Base



Prepared and Written by  
Orland W. Murray  
Geodetic Technician  
National Geodetic Survey  
Instrumentation and Methodologies Branch  
Corbin, Virginia

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**U.S. DEPARTMENT OF COMMERCE**  
**National Oceanic and Atmospheric Administration**  
National Ocean Service  
National Geodetic Survey



## **POLICIES AND RECOMMENDATIONS**

### **NGS POLICY REGARDING GRADIENT TEMPERATURE MEASUREMENTS**

The Federal Geodetic Control Subcommittee (FGCS) specifications require that the air temperature gradient be determined at each setup of leveling for First Order, Class I and II, and Second Order, Class I standards of accuracy. The observed gradient temperatures along with a partial refraction correction value, determined independent of temperature, are used by the NGS ABSTRA program. The gradient is determined by measuring the air temperature at two heights, usually 0.3 meter and 1.3 meters above the ground. National Geodetic Survey (NGS) level crews accomplish this by placing two aspirated thermistor probes on the level tripod at the two required heights. The probes or sensors are connected to a digital display unit and a battery power supply which powers the aspirator fans in the probe assemblies. These measuring units were designed and hand built by the NGS Instrumentation and Methodologies Branch in Corbin, Virginia. Unfortunately, the production of these systems is no longer possible and previous units are very scarce. Currently the I&M Branch is attempting to find commercial off-the-shelf replacements for these units or a commercial entity that will manufacture them.

In the interim, owing to the unavailability of these units, NGS will accept First and Second order leveling data without observed gradient temperature measurements provided the following condition is met. The software used to process the data must have the ability to compute a partial refraction correction value, setup by setup, accumulated over the section, then pass it on to the NGS ABSTRA program. ABSTRA will then generate predicted gradient temperatures, based on the refraction model developed by Sanford Holdahl of the NGS, and write them to the \*43\* record of the Bluebook file (\*.HGZ). The user must contact NGS for preapproval before the data will be accepted.

NOTE: It will still be necessary for the user to measure a starting and ending air temperature, to the nearest degree, for each section of leveling. These observed temperatures are for computing thermal expansion corrections of the Invar rods.

### **RECOMMENDATIONS**

Read this user's guide thoroughly, as well as, the manufacturer's operator's manual. The better understanding of how the instrument and software function, the better will be its application to the leveling project and the better will be the results. Three other documents that are recommended for reading and reference are:

NOAA Manual NOS NGS 3, Geodetic Leveling, August 1981, M. Christine Schomaker, Lt., NOAA and Ralph Moore Berry. This manual has a wealth of information on leveling that is still applicable whether running conventional levels or digital levels.

VFPROC Vertical Control Field Data Processing System, NOAA, C&GS, NGSD, Version 3.00, December 1992. This manual will be needed to explain how to install and run the VFPROC software used in processing the digital leveling data.

Input Formats and Specifications of the National Geodetic Survey Data Base, Volume I. Horizontal Control Data and Volume II, Vertical Control Data. Both volumes are needed since all of the ANNEXS containing equipment codes, time zones, etc., are part of the Horizontal Control volume.

All three of these publications and the VFPROC software is available from NGS Information Services. There may be a nominal fee for some of the items. Contact the Information Services center at:

NOAA, National Geodetic Survey, N/NGS12  
1315 East-West Highway, Station 9202  
Silver Spring, MD 20910-3282  
phone: (301) 713-3242; Fax:(301) 713-4172 [Mon.-Fri., 7:00 a.m. - 4:30 p.m. EST]  
email: info\_center @ ngs.noaa.gov

or visit the National Geodetic Survey web page at: [www.ngs.noaa.gov](http://www.ngs.noaa.gov) There is a wealth of information available at this web page pertinent to all aspects of geodetic surveying.

## LEVELING PROJECT - REQUEST PROCEDURES

If your a company, organization, or state or federal agency planning a leveling project that you would like incorporated into the National Geodetic Survey (NGS) data base and your state does not have an NGS geodetic advisor, it will be necessary for you to contact NGS and explain your intentions. Before the project will be accepted it must meet preapproval. NGS will request information about your project, reconnaissance, and equipment to be used. Upon approval a line accession number, like L12345, will be provided to identify the data set or sets of your project. You will also be provided a two character job code, like \*MI\*, for the project. These two items will be used to identify and archive your project's data. To initiate your project contact your state NGS geodetic advisor.

To initiate your project if you do not have an advisor contact::

Mr. Robert Siclari, NGS  
Project Development Branch  
Phone: (301) 713 - 3194 ext 130  
email: bobs@ngs.noaa.gov

Other informational contacts:

John H. Till, NGS  
Phone: (301) 713 - 3191 ext 124  
email: johnt@ngs.noaa.gov

Orland W. Murray, NGS, I&M Br.  
Phone: (540) 373 - 7605  
email: murrayow@ngs.noaa.gov

Bruce R. Ward, NGS  
Phone: (301) 713 - 3198 ext 121  
email: bruce@ngs.noaa.gov

Katherine S. Koepsell, NGS  
Phone: (301) 713 - 3184 ext 116  
email: kathyk@ngs.noaa.gov

Submit Data and Project Report to:

Leveling only:

Deborah D. Brown  
Phone: (301) 713 - 3184 ext 128  
email: debbieb@ngs.noaa.gov

Leveling for GPS project:

Madeline White  
NGS Project Ahalysis Br.  
Phone: (301) 713 - 3211  
email: madeline@ngs.noaa.gov

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**Disclaimer.** Although the content of this document involves the use of Leica digital levels, it is not an endorsement by the National Geodetic Survey of Leica digital levels over any other brand. At a later time, this document will be expanded to include many of the other brands that have become available for precise leveling including Zeiss, Topcon, and perhaps Sokkia.

# **DATA COLLECTION AND POST PROCESSING LEICA DIGITAL LEVELING DATA USING NABOOK AND VFPROC SOFTWARE**

## **INTRODUCTION**

The introduction of digital bar-code leveling several years ago brought about some interesting changes in the way leveling data is obtained. Conventional leveling requires the observer to optically read a graduated rod for both height above the footplate and stadia for distance to the rod. Digital leveling uses an imaging system which interprets the bar-coding on the level rod to determine the height above the footplate and the distance to rod. The observer points the level at the bar-code rod, brings the image into focus, and pushes a button to take the measurements and the data is collected to an on-board recording module. This eliminates reading errors, observer fatigue errors and the need of a manual recorder person. Digital levels also presented a few problems that needed to be addressed by the National Geodetic Survey (NGS).

First, it was necessary to test these new level instruments to determine that they met the degree of precision and accuracy required by leveling specifications established by the Federal Geodetic Control Subcommittee (FGCS). The results of the tests required some changes to the specifications to incorporate the new technology (See Appendix A for the digital leveling specifications).

Second, because the digital levels acquire leveling data in a format different from previous conventional leveling observations, new software was needed to collect, analyze and process the data to get it into the NGS standard format, commonly called the Bluebook format. Although a couple of NGS in-house programs were written, only one utilized digital leveling data collected to the on-board recording module. This program worked fairly good, but provided little quality control and required a lot of manual interaction to smooth the data for bluebook entry.

In 1998, Mr. Charles Whalen, retired former Chief of NGS's Vertical Branch, wrote several programs to collect, quality control and bluebook digital leveling data collected to the on-board recording module. Software versions for both the Leica NA series of digital levels and the Zeiss digital levels are available from Whalen and Associates. These programs require specific bluebook information to be recorded along with the leveling observations. The programs CONSTANT and NABOOK reformat the data into preliminary bluebook records, create a field book of the observed data and perform quality control checks on the data. Final processing of the leveling data requires several NGS in-house programs to complete the blue booking process. The programs are RODCAL, READROD, MAKEFILE, READFILE, DDPROC and ABSTRA and are part of a system of programs called Vertical Control Field Data Processing System (VFPROC) currently used by NGS's vertical field party to process data from the NI002 optical level. Use of these programs will be discussed in more detail later.

It is important to note that all of the above programs run on a personal computer (PC) and are utilized after the level data has been observed. Actual data collection uses the on-board features and programs of the digital level. These features consist of SET command functions, the FB leveling program, and use of CODE field records to store data not generated by the instrument but required to complete the data, i.e. station identifiers (Survey Point Serial Numbers - SPSN), temperatures, etc.

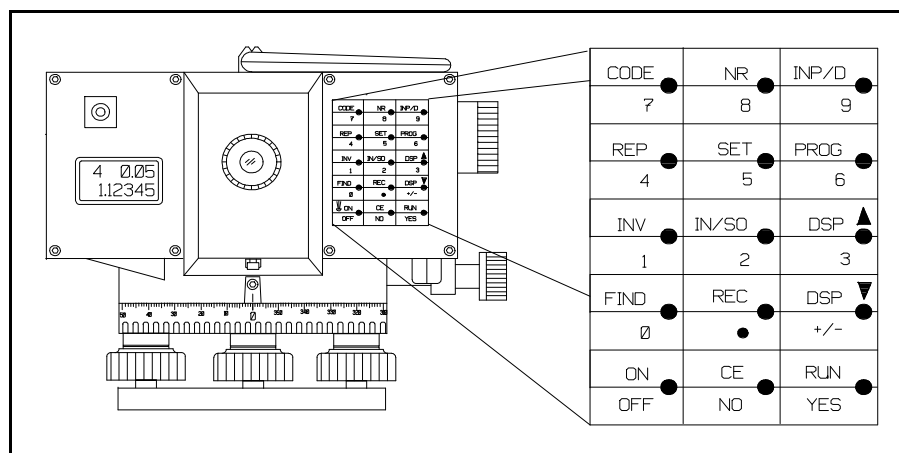
This manual was written to supplement Mr. Whalen's instructions and clarify the use of the NGS programs for those with no prior experience with the software. A chronological approach is taken to describe the phases of instrument setup, leveling observations, data collection, quality control, editing incorrect data, and final processing of the bluebook leveling records.

## 1. Setting Up Digital Level Internally for Precise Leveling (First Order Class II)

The following discussion on setting up the digital level currently only applies to the Leica NA3003 level with Version 3.2 or later firmware installed. A later version of this documentation will address the other Leica digital levels.

The NA3003 level has an intimidating array of multi-function keys, built-in software and parameter setting menus that can take some time to become familiar with. To minimize the learning curve, the following discusses how to set up the level for running levels using the recording module (REC MOD) and the on-board FB leveling program. Refer to the NA3003 Manual for a description of the display and keyboard. The list below shows the NA3003 SET COMMANDS which are used to configure the instrument prior to beginning leveling.

Each SET COMMAND is annotated with notes and the setting that should be used for First Order Class II leveling. The notes are written in *italics* to distinguish them from the SET COMMANDS. The SET COMMANDS are accessed by pressing the SET key on the NA3003. After pressing the



Leica NA series Keyboard

SET key, use the Up/Dn arrows (DSP • and DSP –) keys to scroll through the SET menus. To select an item that has been scrolled to, press the RUN key. This will activate the item and show the first option if there is more than one for that SET COMMAND. Again use the Up/Dn arrows (DSP • and DSP –) keys to scroll through the options. To activate an option, again press the RUN key.

### SET COMMANDS FOR LEICA LEVELS

**TEST** -> Battery/Version  
Use to check battery status

**MEASURE** -> Mean (n). n=1 to 99

*Mean value (1stCls2 set to 99 measurements and monitor standard deviation in display.  
Use this method for 1st Order Class 2 leveling.*

**Mean Fm** (n min/ n max/ Fm/20m)

*Mean value with standard deviation of mean value (1stCls2 set min to 3, max to 10, 0.7 mm standard deviation at 20 meters)*

**Median (n).** n=1 to 99

*Median*

**INCREM.** -> show INCR  
enter INCR  
enter ind.pt.no.

*Set to **SHOW** increment*

**FIX** -> standard | all

*Set to **All***

**RECORD** -> off | module | serial

*Set to **MODULE** to record data to recording module*

**CONFIG** ->

**DSP TIME** -> 1..9 secs

*Leave at default of **3 seconds***

**INT TIME** -> 0 Normal Integration Time

*Set to **0** for Normal Integration Time*

Integration Time (user value) 3 to 9 (seconds) Longer

*Use a **longer integration time** when measurements get difficult due to vibration or refraction*

**BEEP** -> high | low | off

*Set to **high***

**KEY** -> Dist | Input

*Set to **DIST** - allows distance to rod to be measured independent of a rod measurement by pressing the INP/D key on NA3003*

**ROD** -> 3m/2m | 4m/2.7m

*Set to **3m/2m** for 3m invar rods*



**EARTH C.** -> off | on

*Set earth curvature to **OFF***

**ACCURACY** standard / extended

*Set to **standard***

**TOL** -> Dist.tol.off |

Input dist.tol |

*Input distance tolerance to **5.0 m***

Input station tol.

*Input station tolerance to **0.3 mm** (First Order Class II specifications for BFFB program used for single run leveling)*

**AUTO-OFF** -> 5 min. | off

*Set auto-off to **5 minutes***

**UNIT** -> m | ft | inch

*Set to **m for meters***

**COMM** -> **BAUD** -> 9600...300

*Comm is **not used** at this time.*

A good practice would be to check these settings periodically, at least, once a week if not more frequently. The settings should remain in the level instrument until manually changed. Be careful when checking that you do not change any.

## 2. Field Observations and Data Storage

Although the digital level instrument obtains and stores the measurement values, other information is required to both identify the measurement data and supply instrument, rods, observer, and temperature information that is required to create the NGS' bluebook records. To store this information along with the measurement data, it is necessary to use Info Codes which are provided as part of the instrument software design. The following codes and listed items are used to record this information. Each Code field provides the entry of four items of numeric data only. See the NA3003 manual for more information on entering Info Codes.

**Code 1 - Beginning of Day or Change in Observer/Instrument Type** - Note: Enter a new Code 1 & 2 if observer or instrument type is changed during the day. See Code 9999 below.

INFO 1 - Date (MMDDYY)

INFO 2 - Observer's code number (1, 2, or 3, etc.)

INFO 3 - Instrument type number (like 2000, 2002, 3000, 3003, etc.)

INFO 4 - Temperature code ( 0 for EC or I for EF)

**Code 2 - Equipment Used** Enter a new Code 1 & 2 if equipment is changed during the day. See also Code 9999 below.

- INFO 1 - Instrument serial number (like 90810)
- INFO 2 - Collimation error in seconds of arc (no decimal, like -58 for -5.8")
- INFO 3 - Rod 1 serial number (like 25458)
- INFO 4 - Rod 2 serial number (like 25534)

**Code 11 - Start of Leveling Section**

- INFO 1 - Time (HHMM, 24 hour local)
- INFO 2 - Rod on mark ( 1 or 2)
- INFO 3 - Temperature (no decimal, key 75 for 75.0 degrees, omit if recording temperatures for gradient)
- INFO 4 - Blank, no entry

**(Record SPSN as point number for FIRST BACKSIGHT of each section.)**

**Code 22 - Reject Previous Backsight and Foresight (No Data Entries)**

**Code 33 - Temperature (End of each setup if recording two temperatures for gradient, else omit.)**

- INFO 1 - Lower probe (no decimal, key 761 for 76.1 degrees)
- INFO 2 - Upper probe (no decimal, key 750 for 75.0 degrees)
- INFO 3 - Blank, no entry
- INFO 4 - Blank, no entry

**(Record SPSN as point number for LAST FORESIGHT of each section.)**

**Code 99 - End of Section**

- INFO 1 - Time (HHMM, 24 hour local)
- INFO 2 - Rod on mark (1 or 2)
- INFO 3 - Temperature (no decimal, key 75 for 75.0 degrees, omit if recording temperatures for gradient)
- INFO 4 - Wind & sun code, like 21 (See *wind & sun codes below*)

*Note: If wind code is a zero, enter only the SUN code. A leading zero cannot be entered and the wind/sun two digit code will be interpreted as a 20 and not a 02 as it should be.*

**WIND CODE:**

- 0 - If wind speed averaged less than 10 km/hr (6 miles/hour)
- 1 - If wind speed averaged 10 to 25 km/hr (6 to 15 miles/hour)
- 2 - If wind speed averaged greater than 25 km/hr (15 miles/hour)

**SUN CODE:**

- 0 - If less than 25 percent of the setups are performed in sunny conditions.
- 1 - If 25 to 75 percent of the setups are performed in sunny conditions.
- 2 - If more than 75 percent of the setups are performed in sunny conditions.

**Code 11** - Once a level section is completed, a new one is started by entering a new Code 11 as above. Continue with Code 11s and Code 99s for all following sections.

**Code 9999** - End of day (no data entries) *Note: Use a Code 9999 also when changing observers or equipment. Before entering a Code 1 & 2 for changing either observers or equipment, enter a Code 9999. NOTE: See Appendix H for a detailed daily check list and CODE field entry. Print a copy of this check list and take it to the field for reference. Also, for each section of levels fill out a Backup Recording Sheet (See Appendix G for a filled out example and blank form to use).*

### 3. Field Checks and Specifications for Electronic Bar-Code Leveling

#### A. Leveling Specifications

Appendix A contains the current specifications for electronic bar-code leveling. The level observer should fully read and understand the *FGCS Specifications and Procedures to Incorporate Electronic/Bar-Code Leveling Systems, Version 4.0*. The following are highlights from the current specifications for First Order Class II leveling that the level observer should keep in mind.

- a. A valid check connection (line tie) must be made to a minimum of six bench marks, three at each end of a leveling line (see Appendix A).
- b. Maximum collimation error, single line of sight, should not exceed 0.05 mm/m (10 arc seconds). Collimation error determinations are required at the beginning of each day. Collimation data must be recorded with the leveling data and the daily updated value must be used during daily data capture. Collimation procedures will be discussed later.
- c. Level rod bubble verticality must be maintained to within 10' minutes (See Checking and Adjusting Rod and Instrument Leveling Bubbles).
- d. Sections between and to new bench marks will be DOUBLE RUN.
- e. Difference of forward and backward sight lengths should never exceed 5 meters per setup or 10 meters per section.
- f. Maximum sight length from level instrument to rod is 60 meters which is also the maximum sighting range of the NA3003.
- g. Minimum ground clearance of the line of sight is 0.5 meter.
- h. An even number of setups is required per section when using leveling rods without detailed calibration. Bar-code rods do not have detailed calibrations.
- i. The temperature gradient for the vertical range of the line of sight should be determined at each setup via temperature probes and readout mounted on the tripod. **Note: If post processing software can generate predicted temperatures based on Holdahl's model then this specification may be excepted (Contact NGS for permission).**
- j. Maximum section misclosure - algebraic sum of forward and backward running of a section not to exceed  $4/D$  where D is the shortest one-way length of section in kilometers (km).
- k. Maximum loop misclosure -  $5/E$  where E is the length of the loop in km.

- I. Use multiple reading option to obtain each observation (rod reading) with a minimum of 3 readings having a standard deviation of 0.1 mm or less. This specification must be monitored by the observer. The SET MEASURE -> Mean (n). n=1 to 99 command will continue to take rod readings and display the number of readings, standard deviation and mean. It is the responsibility of the observer to watch the display and when a minimum of 3 readings or more is taken and the standard deviation is less than or equal to 0.1 mm, he presses the REC key to record the results. This specification may be amended at a later time.

## B. Field Checks

### a. NA3003 Collimation Check

According to specifications, a collimation check MUST be performed DAILY when using an electronic bar-code instrument. Collimation error is a systematic error and is the amount that the level's line of sight deviates from a truly horizontal line of sight. It is expressed either in arc seconds or millimeters per meter. For First Order Class II leveling, the maximum allowed is 10" arc seconds which is 0.05 mm/m.

Because the NA3003, by design, applies the collimation error correction to each rod measurement once it is determined by the internal program P CHECK & ADJUST and stored, it was decided to use this NA3003 program rather than an external or post-processed collimation check program.

Newer NA3003 with the latest firmware from Leica provide programs for several variations of the collimation check. Before beginning the collimation check, allow the instrument to acclimate to the outside temperature (see Leica manual, Section 1.3 of Chapter 1). To perform the collimation check refer to Section 7.1 CHECK & ADJUST, Chapter 7 in the Leica Manual. All the steps are well described. The two peg test Procedure "A x x B" is probably the easiest method and does not require turning or moving the rods.

When the prompt "store newColl?" is reached, respond with a YES to store the new collimation. Respond with a NO to the "adjust reticle?" prompt. Next, use the Up/Dn arrow (DSP • and DSP –) keys to display the absolute collimation. It may be necessary to re-select the "P CHECK & ADJUST" program to do this.

Once the absolute collimation is displayed, write the value with its sign in the space provided on the field backup recording sheets. This value will be also stored with the CODE 2 Item 2 each day.

If during the course of the workday the level instrument is dropped or banged, a collimation check should be immediately performed as a check on the operating condition of the instrument.

If the collimation exceeds the 10" arc seconds specification, take another collimation check to validate it, and if it still exceeds 10 arc seconds, it will have to be returned to LEICA for adjustment.

### b. Section closures or check against published differences of elevation.

Once a section is double run, a section closure can be made by algebraically summing the forward and backward differences of elevation. The result should be less than or equal to 4 mm times the square root of the kilometer distance of the shortest one way running of the section (First-Order, Class II Specs.) . See Appendix F for multiple runnings (3 or more) of a section.

#### 4. Transferring Data from REC module to PC

a. Use Leica instructions and software. If using Version 3.2 or later of Leica software, the GIF-10 is not required. The data can be transferred to a PC using a serial cable that connects directly to the level instrument. The program TRANSINT.EXE is provided to perform this task. See the section in the NA3003 manual for more details.

b. File naming convention - file management is important and this system generates quite a number of files. Choose a naming convention identifies the data, like date and a letter code for the crew or observer (52099A1.RAW). Use an naming convention that the computer will sort chronologically. As you will see in the section of the manual on processing the data, this will be a great aid to managing the data files. The NABOOK program requires data files to have the extension \*.RAW.

c. If using the Leica GIF10 recording module PC interface device, use the software for your PC provided by Leica to transfer the data files. Again use a file naming convention that will allow the computer to sort the files in chronological order.

#### Leveling Tips

##### Connection to Vertical Control Network (Line Tie)

The FGCS specifications require that First Order Class II leveling must be tied to the national network by a three mark tie. Although this connection (line tie) should be specifically addressed in the project instructions, the following may clarify the line tie procedure.

The line tie establishes the validity of the previously leveled Vertical Control Network bench marks and provides good elevations from which to compute the elevations of the new bench marks.

To verify the validity of the elevations of the network bench marks, perform single run level sections between a minimum of three adjacent network bench marks and compare the observed section differences of elevation (DEs) with the difference of elevations computed from the published elevations of the network bench marks or , if available, make the check using the previously observed field differences of elevation. The misclosure between your new work and the old published work is checked against the same specifications as if the sections were double run. For First Order Class II, it is 4 mm times the square root of the kilometer distance of the shortest running of the section (see Appendix A).

If the misclosure check exceeds the specifications, it is possible to perform what is called a "jump tie". In this case, the observed DEs of two adjacent sections are algebraically summed providing a DE between the first and third BMs, skipping the second BM. This effectively creates a new section running that "jumps" over the middle BM. If the misclosure between this observed DE and the DE computed from the published elevations of the first and third BMs meets the specifications, this "jump" section is considered good. However, this work only counts as a tie to two network BMs (one section). Since the requirements are a tie to a minimum of three network BMs, another adjacent section must still be run to meet the three mark tie specification. Note: BMs that do not check in a jump tie situation, must be run back and tied to one of the marks that is good.

Normal 3 Mark Network Tie:

```

( < ) ) ) Single Run ) ) - ) ) > < ( ) ) Double Run New ) ) ) >>
BM1           BM2           BM3           NEW BM           NEW BM
1/4-----1/4-----1/4-----1/4-----1/4
    Check Ok    Check Ok
    
```

3 Mark Network Tie using a Jump Tie:

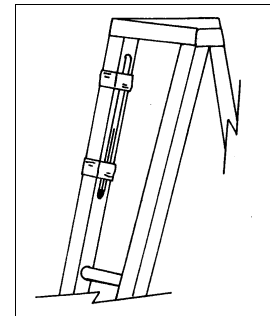
```

( < ) ) ) Single Run with Jump Tie ) ) ) > < ( ) ) Double Run New ) ) ) >>
BM1           BM2           BM3           BM4           NEW BM           NEW BM
1/4 Bad Check 1/4 Bad Check 1/4-----1/4-----1/4-----1/4
€ <-----> € <-----> € Check Ok
| Rerun   or   Rerun   |
.-----
                Check Ok
    
```

Measuring the Air Temperature and Temperature Gradient

Air Temperature

The air temperature must be measured at the beginning and end of each section of leveling. These temperatures are used to correct for the thermal expansion of the rod invar strip. To measure the air temperature, use a mercury thermometer with a range of at least -10E to 45E C (14E to 113E F), accurate to ± 0.1E C (± 0.2E F). Mount it rigidly in a shaded, protected place on the tripod. If a pair of special thermistors are available for measuring the temperature gradient, use the top thermistor for this measurement (See the Geodetic Leveling Manual section 3.6.1 for more information on temperatures).



Thermometer mounted on tripod

Temperature Gradient

Specifications require the observation of temperatures at two heights for each setup of leveling. The purpose of the temperatures is to monitor the temperature gradient of the air near and below the level line of sight and apply a partial refraction correction later in post processing. This is accomplished using a set of aspirated temperature probes and a Doric LCD display unit mounted on the tripod (see Figure 3-69, page 3-50 of Manual of Geodetic Leveling).

The temperature probe fans are powered by the four C-cell batteries, and turned on by the ON/OFF switch. The Doric LCD display is powered by an internal 9 volt battery, and is turned on by its push buttons. Both the fans and Doric LCD are low power consumers. Thus it is recommended that once both units are turned on, they be left on for the rest of the workday rather than turned off while moving between each setup. Otherwise the observer/recorder may forget to turn the fans back on, possibly resulting in erroneous temperatures. If the voltage meter gets much below five volts, all the C-cell batteries should be tested and the weak batteries replaced.

The heights of the probes above the ground are important. To assure they are at the correct heights, set up the tripod at a height for a normal observer and measure the heights from the probe straight down to the ground. The top probe should be 1.3 meters and the bottom probe 0.3 meters above the ground. Change the position of the probes to maintain these heights for taller and shorter observers.

A CODE 33 field using INFO 1 and INFO 2 is used for entry of these temperatures at the end of each good setup. Be aware of which temperature, top or bottom, the program is asking for and enter accordingly. The probes should be allowed to acclimate to the outside temperature with their fans on before readings are taken.

It is important whether the temperature gradient is positive, top temperature lower than bottom, or negative, top temperature higher than bottom. ONLY PERFORM LEVELING WHEN A POSITIVE TEMPERATURE GRADIENT IS PRESENT. The probes naturally have a spread of up to 0.3EC. Thus the high probe can read slightly higher than the low probe without there really being a negative temperature gradient.

However if the temperatures are unreasonably different, this may be an indication of a failure in the temperature probes or fans which aspirate them. First check to make sure the power switch is on. Then check the voltage meter. If the voltage meter is registering no voltage, it might be because one of the C-cell batteries is not making contact. Finally check the fans. A fan can become obstructed by dirt or a blade of grass. It is possible to free a stopped fan by manually turning it with a small stick, after the fan's power switch has been turned off. Also over time, the probe itself may get dirty. It can be cleaned using a q-tip and alcohol. The probe is the small reddish match-head like object in the center of the aspirator tube. Be very gentle when cleaning it.

Be aware of how the wind is blowing into the aspirator tubes. The fans suck the air into the tubes from the opposite end of the tube. Thus always point the end opposite the fans into wind. This will prevent the wind from working against the fans and altering the temperatures.

Finally, be sure that the Doric display is set to the temperature units, F (Fahrenheit) or C (Celsius), recorded in the equipment setup. Although either units can be used, Celsius is recommended. The units used are recorded in CODE 1, INFO 4 (See Item 2, page 4 - Field Observations and Data Collection).

The temperatures are important. Use good judgement when observing them.

### Stable Turning Points

Stable turning points are a must in precise leveling. If possible, always use the turning pins driven vertically and solidly into the ground to support the leveling rods. Always drive the turning pin with its drive cap on to protect the top of the turning pin. Only use the turning plates (turtles) when pins cannot be driven. Use the turtles on concrete or a cleared out spot in the dirt. Do not use them on grass or asphalt. After placing the turtle, step on it with your full weight to settle it.

When setting the leveling rod on the turning pin, use the footplate keeper to prevent the rod from slipping sideways off the pin. Be careful not to get the keeper in between the rod footplate and the top of the pin.

### Setting the Rod on a Bench Mark

When setting the leveling rod on a bench mark disk, remove the footplate keeper and set the footplate directly on the disk making sure that the edges are not catching on any of the concrete around the disk. If nothing is catching, turn the rod side to side to find the high point on the disk. Once satisfied that the high point has been found, extend the brace poles and plumb the rod.

If a high point cannot be established or the footplate is catching on the concrete, it will be necessary to use the 20 mm offset plugs. These are machined magnetic plugs which are placed on the footplate of the leveling rod to lift it above an obstruction or establish a high point on a very flat disk with no definable high point. If the disk is flat, center the 20 mm plug in the center of the disk.

**IMPORTANT NOTE!!!** Always use the plugs in pairs. In other words, if it is necessary to use a 20 mm plug on a disk, be sure to put a plug on the other rod at the same time, otherwise, a 20 mm error will occur in the leveling. Just as important is removal of the plugs after the setup is completed. At this time, the I&M Branch has very few of these machined offset plugs, so take care not to lose them. Call the NGS I&M Branch for information about acquiring a set.

Once the plugs are in place, take the normal setup observations. Make a note on the field recording sheet whenever the 20 mm plugs are used. The plugs can also be used with the 60 CM invar strip ( See - Appendix F).

### Leveling to a Vertical Bench Mark

To accommodate leveling to a bench mark set vertically in a wall, a 60 cm invar bar-code strip is provided. Such a situation is pictured in Diagram 2, Figure 3-78, page 3-62 of the Manual of Geodetic Leveling. It is good practice when approaching a vertical bench mark to set the foresight rod of the preceding setup near the vertical mark. Set the level near to the height of the vertical bench mark. Read the backsight rod and point to the vertical mark. Have the rodperson hold the invar strip with the reference mark on the strip in coincidence with the horizontal line on the vertical bench mark. Check the verticality of the invar strip with the vertical crosshair in the level. Once verticality is established, check again with the rodperson that the invar's reference mark is still good, and then read the foresight invar strip. Do the same when leaving the vertical bench mark to continue leveling. **Note:** The reference point on the 60 cm invar bar-code strip is the metal pointer attached near the bottom of the strip, not the bottom of the strip itself. (See Appendix F for more info on using the 60 cm invar strip).

### Adjusting the Leveling Bubbles (NA3003 and Bar-code Rods)

#### NA3003

Although the NA3003 is a self-leveling instrument, the leveling bullseye bubble should be kept in good adjustment to assure the working range of the compensator is maintained. If the range is exceeded, error message number 58 will appear in the display of the NA3003.

To adjust the bubble, center it in the circle and then reverse the instrument 180 degrees. If it stays in the circle, it is good for that axis. Next, rotate the level 90 degrees and check it. If the bubble is in good adjustment, it should stay in the circle when the level is rotated a full 360 degrees. To adjust the bubble, level it in one axis, then rotate 180 degrees. Using the small allen wrench included with the level, turn the screw or screws on the bottom of the instrument case that align with the axis until half the amount the bubble is out is removed. Relevel the instrument and rotate 180 degrees. If ok, check the axis at 90 degrees. Keep adjusting until the bubble stays in the circle regardless of where the level is turned.

#### BAR-CODE RODS

Adjusting the leveling bubbles on the rods can be accomplished most easily by the following method. Setup the rod and center the bubble in the bubble circle. Set up the NA3003 at a distance



from the rod where most of the rod is in the field of view. Level the NA3003. Using the tangent knob, align the vertical crosshair along the left or right side edge of the invar strip. If the rod is level (plumb), the vertical crosshair and the edge of the invar strip should be in coincidence. If not, have the rodperson adjust the rod until it is in coincidence. Using an adjusting pin, have the rodperson turn the screw or screws beneath the bubble until the bubble is centered in the circle. Next, have the rodperson turn the rod 90 degrees to the NA3003 and center the bubble with the brace poles. Check the vertical crosshair alignment with the edge of the rod casing. If its not in coincidence, have the rodperson adjust the rod until it is in alignment and then again adjust the bubble with the bubble screws. Keep checking the rod until it stays vertical in all positions when the bubble is centered.

Bear in mind that because the location of contact between the rod's footplate and the turning pin is generally not perfectly centered below the rotation point where the brace poles are attached, the rod may go out of plumb when reversed or rotated. It is important to always relevel the rod after turning it. When turning a rod resting on a turtle, care must be taken not to disturb the turtle.

Check the bubbles once a week or whenever the instrument or rods are banged or dropped.

### SHADING THE LEVEL INSTRUMENT

LEICA in their User's Manual recommends that for precise leveling the level instrument should be shaded from direct sun light at all times including the tripod. In practice, this would require another person on the level crew just for this purpose. In this day of diminishing budgets, the luxury of having enough personnel is not possible. As remedy for the shading problem, the Instrumentation and Methodologies Branch of NGS, designed a shade that mounts on the instrument and blocks about ninety per cent of the direct sunlight off from the instrument. The shade is light weight and does not appear to affect the observations or operation of the level instrument. Feedback from users employing the shade has been very positive especially in Florida where sight lengths had to be shortened most of the time due to sun. Of course, this shade does not protect the tripod. See Appendix K for a description and drawings of this shade. If you have the personnel, use a large umbrella and shade the instrument and as much as the tripod as possible. Otherwise, have one of the shades made at a machine shop.

## DATA PROCESSING

### Hardware requirements

An IBM/PC compatible computer capable of running DOS programs.

### Software requirements

#### A. From Whalen and Associates

CONSTANT. This program provides HEADER. BLU and NA.DO files for use by NABOOK. This program is provided with NABOOK

NABOOK. This program processes the output files from the NA2000/3000 series instruments, checks the records for proper sequence, outputs an edit file with an "A" appended to the root of the file name, a "\*.BOK" file containing field book pages and a ".BLU" file containing blue book records including partial refraction corrections needed for computing refraction corrections with NGS program ABSTRA (below). The program obtains the line title from the '11' record of the HEADER. BLU file. It obtains the observer initials and height of instrument in centimeters, for each observer number, from the NA. DO file.

DOSXMSF.EXE. Extended memory manager needed to run NABOOK. Path to this file is necessary for NABOOK to run. It provides access to memory above the DOS limits.

#### Optional Whalen & Associates Programs Available

ABSTRACT. This program is needed if you want to use program ADJUSTB, below. This program reads a ".HGZ" file in text format, and writes a summary file (.SUM), unknown file (.UNK) and an observation file (.OBS) to disk for an adjustment with ADJUSTB. The user constrains one or more heights in the ".OBS" file before an adjustment. A similar program is available for those who use program StarLev.

ADJUSTB. This program accepts files with the ".UNK" and ".OBS" extensions from ABSTRACT and does a least squares adjustment. Theoretically the program is capable of doing a vertical network adjustment with up to 99,999 unknowns. It has only been tested to date with approximately 8,400 unknowns. The program saves a file with extensions ".ADJ", with survey point serial numbers, bench mark designations, adjusted elevations in meters, and estimated standard error of each adjusted elevation with respect to the constrained elevations. It saves a file with the extension ".PRT" containing the adjusted heights in meters and feet, observations and their residuals, standard error of unit weight, 95%confidence limits on a variance of one, etc.

#### B. National Geodetic Survey

VFPROC software. See VFPROC, Vertical Control Field Data Processing System NOAA/CGS/NGS, Ver. 3.00, Dec. 1992 for a description and use of the following software.

RODCAL    ABSTRA  
READROD   DDPROC  
MAKEFILE  
READFILE

## INSTALLING AND SETTING UP SOFTWARE

### A. INSTALLING

#### 1. CONSTANT, NABOOK, AND DOSXMSF

Make a directory, like C:\NABOOK, and copy the files CONSTANT.EXE, NABOOK.EXE and DOSXMSF.EXE to this directory.

#### 2. VFPROC PROGRAMS

Install the VFPROC software by following the installation instructions in the VFPROC manual. NOTE: Be sure that the "SET VERTPGM = X:\VERTPGM", where X is the drive to which the software is installed, is contained in the AUTOEXEC.BAT file. The installation program should ask to install this SET command automatically.

### B. SET UP FOR NABOOK

1. CONSTANT. Before NABOOK can be run, it is necessary to run the CONSTANT.EXE program. This program creates the HEADER.BLU and NA.DO files for use by NABOOK. NOTE: CONSTANT.EXE can be run at any time for editing and updating, but has to be run at least once prior to running NABOOK.

a. The HEADER.BLU file created by the CONSTANT program consists of the following records (*Notes about records in italics*):

:

Data Set Identification Record - *This must be the first record of every data set submitted. Contains the job code, obs type, submitting agency (abbreviation and name), date data set created.*

\*10\* Line Information Record - *This must be the leading record of each leveling line included in the job.*

\*11\* Line Title Record (Optional) \*12\*, \*13\*, \*14\* Line Title Continuation Records - *Use the \*11\* record to give the title of the line (or of area network or special project of which the line is a part).*

\*15\* Comment Record (Optional) - *Use this record for any comments pertinent to the leveling line. In the case of digital leveling where the collimation correction is applied to the observations by the instrument a comment similar to that in the following example HEADER.BLU contents is required by NGS.*

#### EXAMPLE CONTENTS OF HEADER.BLU FILE

```
*MI*VERTOBS MDOT MICHIGAN DEPARTMENT OF TRANSPORTATION 19990520
*10*L25391 1 1999051719990819MM4 12MI TWBMDOT 2
*11*LEVEL LINE REED CITY VIA BIG RAPIDS VIA LANSING TO JACKSON
*15*COLLIMATION CHECK TAKEN DAILY AND STORED INTERNALLY IN THE NA3003 AND
*15*USED TO CORRECT EACH ROD READING. THE TANGENT OF THE COLLIMATION X
*15*1000 IS STORED IN THE 40 RECORD COLS 65-69
```

SEE APPENDIX C for an example run of CONSTANT showing input for the HEADER.BLU file.

b. The NA.DO file created by the CONSTANT program consists of information needed by the NABOOK program. Because the Leica digital levels only allow numeric data to be stored in the CODE info fields, it is necessary to have the NA.DO file to equate observer initials to observer numbers. Also, a title for the field book, the letter code for the time zone of the project, the number of observers, the average heights of the observers, and the heights of the temperature probes are stored in the NA.DO file.

**EXAMPLE CONTENTS OF NA.DO FILE**

```
*11*MICHIGAN DIGITAL LEVELING USING THE LEICA NA3003

R
8
  1          SWH          140
  2          CAK          136
  3          TMS          144
  4          GMB          140
  5          JAS          138
  6          TWB          138
  7          DBE          144
  8          JWG          144
130

30
```

SEE APPENDIX C for an example run of CONSTANT showing input for the NA.DO file.

**C. SET UP FOR VFPROC**

As with the NABOOK program the ABSTRA program, which is part of the VFPROC system of programs used by NGS, requires several files to be created prior to running the ABSTRACT program. These files are the rod calibration files and the instrument data file, xxxxx.cal and inst.dat respectively. The x's in the x.cal file are the serial numbers of the rods, i.e. 27368.cal would be the filename for rod serial number 27368.

Normally, for NGS level rods, a detailed calibration file will exist which means the rod was calibrated at every graduation. The bar-coded rods do not have detailed calibrations. Despite this, the VFPROC software still requires a rod calibration file. (See section 8.5.1 of the VFPROC manual to see how to create a ".cal" file for rods without detailed calibrations).

a. Contents of rod cal file for Leica Invar rod sn:26685 filename:26685.cal (text file)

```
RD39626685 95010100000CM
```

Running the program RODCAL.EXE will convert the rod cal file in text, 26685.cal, to binary. This must be done for both rods. This produces a binary file with the extension ".rod" and names the file 26685xxx.rod. Example rod cal files should be included with this package. If this is the case, just edit the included xxxx.cal files by adding the serial number of your rods and a date. Rename the file to your rod's serial number and run RODCAL.EXE on the file. This should yield the rod cal files for your specific rods.

b. Along with the rod calibration files, the VFPROC programs require a file containing information about the leveling instruments used in the observations. This file must be named "INST.DAT" and reside in the directory identified by the VERTPGM environment variable, usually C:\VERTPGM. The format must conform to the \*20\* record format listed in the "Input Formats and Specifications of the National Geodetic Survey Data Base, Volume II". (See Appendix C of the VFPROC manual - The Instrument Information File for file content).

Example Contents of an INST.DAT file:

000010*20*24392563	LEICA WILD	NA3003	NGS	990101200
000020*20*24291258	LEICA WILD	NA2002	ITD	981001200
000030*20*24391807	ZEISS	DINI11T	NGS	990101200

c. NOTE on VFPROC Software - MAKEFILE and READFILE Programs. Since most of the VFPROC programs work with files in BINARY format rather than TEXT format, it is necessary to convert the files from binary to text to view and edited. READFILE converts the data file from Binary to Text and MAKEFILE converts from Text to Binary. See the VFPROC manual for more information as to which files must be in binary format.

#### D. DATA PROCESSING

There are several phases to data processing the digital leveling data. If these phases are executed deliberately and in a timely manner, data management will stay organized and the final project preparation for submission to NGS will require only a minimum of work. There are two objectives to be considered here. One, is to quality control the data and assure that it meets the specifications for the leveling survey and two, is to format the data for entry into the NGS data base system.

##### a. Phase I - Daily Processing of RAW Data Files

Phase one is the daily processing of the raw data files. This includes transferring the files from the instrument to the PC, uniquely naming the files, archiving the original raw data files, running the files through the NABOOK program, editing, correcting and rerunning NABOOK, archiving the processed files (\*.RAW, \*.BOK, and \*.BLU).

##### b. Phase II - Processing Data by Line or Part of a Survey, Part 1

Phase II involves merging or appending a group of daily RAW data files into a single file. Assign the appended file the accession number for the survey or part, like L12345.RAW, and run the file through NABOOK, edit and correct, and rerun it through NABOOK, if necessary. Finally, insert the HEADER.BLU file at the top of appended L12345.BLU file, created by NABOOK, and add the JOB CODE to the end. Save this file as L12345.TXT. This could be called the preliminary bluebook file.

NOTE: Phase I and Phase II, Part 1, involve using an editor, the CONSTANT program, and the NABOOK program. When appending the RAW files, append them in the order they occur in the level line. The data must form a single line or network. All the above, is preparation for running the data through the NGS program ABSTRA.

What NABOOK does:

a. Checks for correct record sequence and creates an EDIT file which has the same name as the \*.RAW file only with the letter "A" appended to it.

- b. Checks data to determine that it meets specifications for Order and Class of leveling.
- c. Creates a fieldbook file with extension \*.BOK. The fieldbook file contains the data formatted into a readable format and displays relevant error messages about the data.
- d. Computes partial refraction corrections with or without observed gradient temperatures.
- e. Creates the bluebook records for each section of the leveling and writes them to a file with the same name as the RAW file only with the extension \*.BLU. These records consist of the \*40\*, \*41\*, and \*43\* records.

I

#### c. Phase III - Processing Data by Line or Part of a Survey, Part 2

Phase III requires the use of several VFPROC programs, MAKEFILE, ABSTRA and READFILE. MAKEFILE will convert the preliminary bluebook file, L12345.TXT, from Phase II into a binary file format which is required for the ABSTRA program. Rename the output file from MAKEFILE by adding the extension \*.HGZ, i.e. L12345.HGZ.

The ABSTRA program produces two products, an abstracted data file and a field abstract listing. The field abstract listing is used to aid in ongoing quality control of the leveling project. The abstracted data file is one of the data file formats required by the NGS Vertical Network Branch. Both of these will be submitted to NGS at the end of the project.

Although the ABSTRA program will run without it, the control point description file, \*.HA, should be generated prior to running ABSTRA using the VFPROC program DESC.EXE (See Chapter 6 - Control Point Description Entry - in the VFPROC manual for more on writing descriptions). Inclusion of the \*.HA file when running ABSTRA provides data to further analyze observational data. ABSTRA generates two files: the \*.HGZ file containing the abstracted data and \*30\* records when the \*.HA file is included and the \*.ABS file containing the field abstract listing and a list of all the errors found by ABSTRA (See Chapter 7 - Field Abstract Generation for details of running the ABSTRA program and analysis of the error messages. See, also, Appendix I for an example field abstract file listing).

When all of the data has been run through ABSTRA and all errors have been corrected, the final \*.HGZ file for the survey project or part is generated. This file along with the description files, raw data files, fieldbook files, and various hardcopy will be submitted to the NGS Vertical Control office for further processing.

#### D. Correcting Errors in the Data

- a. RAW data file sequence errors. When NABOOK is run, the program will display an error message to the monitor if it detects errors in record sequence or missing records. Use a editor to open the edit file. The edit file is created by NABOOK when sequence errors occur. It will have the same name as the RAW file (51199A.RAW) with a letter" A "appended to the end of the filename before the extension (edit file 51199AA.RAW). Open the edit file with an editor and look for editing messages like, "FOLLOWING RECORD 1 IS OUT OF ORDER" or "FOLLOWING RECORD 11 IS OUT OF ORDER" (See example edit file in Appendix D). It may be easier to print out the edit file for reference. Next open the copy of the RAW file with an editor and check the records indicated by the edit file messages. After making the corrections, run the corrected RAW file through NABOOK again. If no out of sequence or missing records are found, NABOOK will create the \*.BOK and \*.BLU files.

b. Error codes in the fieldbook file (\*.BOK).

Error Codes (First Order/Class II) :

A = backsight distance exceeds tolerance of 60.0 meters

B = foresight distance exceeds tolerance of 60.0 meters

*Although the maximum sight distance for the NA3003 is 60 meters, it is still possible to take a measurement beyond this distance. The on-board software will not warn you of this, so it is important to keep an eye on the display when distances approach the 60 m limit. This will occur on overcast days when the visibility is very good.*

C = sight imbalance exceeds tolerance of 5.0 meters

*This error occurs when the difference between the backsight distance and the foresight distance exceeds 5.0 meters. The tolerance for this can be stored using the SET COMMANDS. The software will inform the observer when this condition is met and the observer can adjust the imbalance. As a result, It is unlikely that this error will appear very often in the data.*

D = sum of sight imbalances for section exceeds tolerance of 10.0 meters

*This error is the result of the algebraic sum of the imbalances for each setup accumulating to over 10 meters before the end of the section is reached. This can be monitored by recalling the distance information using the up/dn arrow keys. The display will contain two lines. The upper line will have something like "d -0.8" and the lower line will have "D 407.3" displayed. The value next to D is the sum of the backsight distances and foresight distances. The value next to "d" is the accumulated imbalance or the difference between the sum of backsights and the sum of the foresights. This must be kept under 10 meters. This can be accomplished by adjusting the foresight on the next setup to be shorter or longer depending upon the sign of the accumulated imbalances. If it + (plus) shorten the foresight, if it is - (minus) add to the foresight distance. If this is not adhered to the #D flag will be displayed in the fieldbook output.*

G = setup elevation difference exceeds 3.5 meters

*The Leica series of digital levels has the capability of taking a measurement when the line of sight is above the top or below the bottom of the rod. This is not recommended for precision leveling. To maintain a good usable portion of the rod use the 1% rule. The 1% rule of thumb is to reduce the effective staff length on top and on the bottom be 1% of the distance to the staff. In this way the field of view should be 80% full of the coded staff. Example for a 3m Invar staff:*

*Distance = 10 m: Max. staff reading = 2.90 (3m - 10cm)*

*Min. staff reading = 0.10 m*

*Distance = 20 m: Max staff reading = 2.80 (3m -20cm)*

*Min staff reading = 0.20 m*

H = temperature gradient is out of range

*To be acceptable the difference between the upper and lower temperatures must*

*be between -3.0 to 1.0 degrees centigrade (-5.4 to 1.8 degrees Fahrenheit).*

I = change in temperature gradient between setups exceeds the tolerance

*The difference between temperature gradients of successive setups must be between -3.0 to 3.0 degrees centigrade (-5.4 to 5.4 Fahrenheit).*

**NOTE:** *Error codes H and I must be monitored by the observer during leveling observations since the on-board software does not provide a means for checking these range differences.*

K = rod reading below 0.5 meter

*Specifications require that no rod readings should be made below 0.5 m on the rod. This is to avoid very bad refraction influences below this height. However, there are occasions where reading below 0.5 m is unavoidable. Cases where the rod is elevated above the ground and when using the invar strip on vertically set bench marks. So long as the line of sight is not passing through the air below 0.5 m, the reading can be accepted. Be sure to make a note on the backup sheet explaining the situation.*

L = standard error of mean reading exceeds tolerance of 0.1 mm

*Use multiple reading option to obtain each observation (rod reading) with a minimum of 3 readings having a standard deviation of 0.1 mm or less. This specification must be monitored by the observer. The SET MEASURE -> Mean (n). n=1 to 99 command will continue to take rod readings and display the number of readings, standard deviation and mean. It is the responsibility of the observer to watch the display and when a minimum of 3 readings or more is taken and the standard deviation is less than or equal to 0.1 mm, he presses the REC key to record the results. This specification may be amended at a later time.*

M = minimum number of sets in mean reading is less than tolerance of 2

*A set of measurements was recorded with only two multiple readings. Although does not meet specifications, if it is 0.1 mm or less, make a note in project report and it will be most likely be accepted by NGS.*

Technically all of the above errors should be avoided by good field procedures. If the specifications are not met, that section of leveling should be rerun. However, determining the effect of the error versus the cost of the rerun may influence the decision to rerun or not. Use good and reasonable judgement on this and report details of your decision in the project report. Or, call NGS about it.



## E. FLOWCHARTS OF DATA PROCESSING

a. Daily processing of data from the field, see Figure #2 flow chart.

1. Data files from the field must be assigned the extension ".RAW", as in raw data. The file prefix can be anything useful to the survey organization as long as it follows the normal DOS file naming procedures and limitations. For instance, it could be a date followed by a team letter or number, if more than one observing unit is working on the survey (980903A..RAW, or 090398A..RAW).

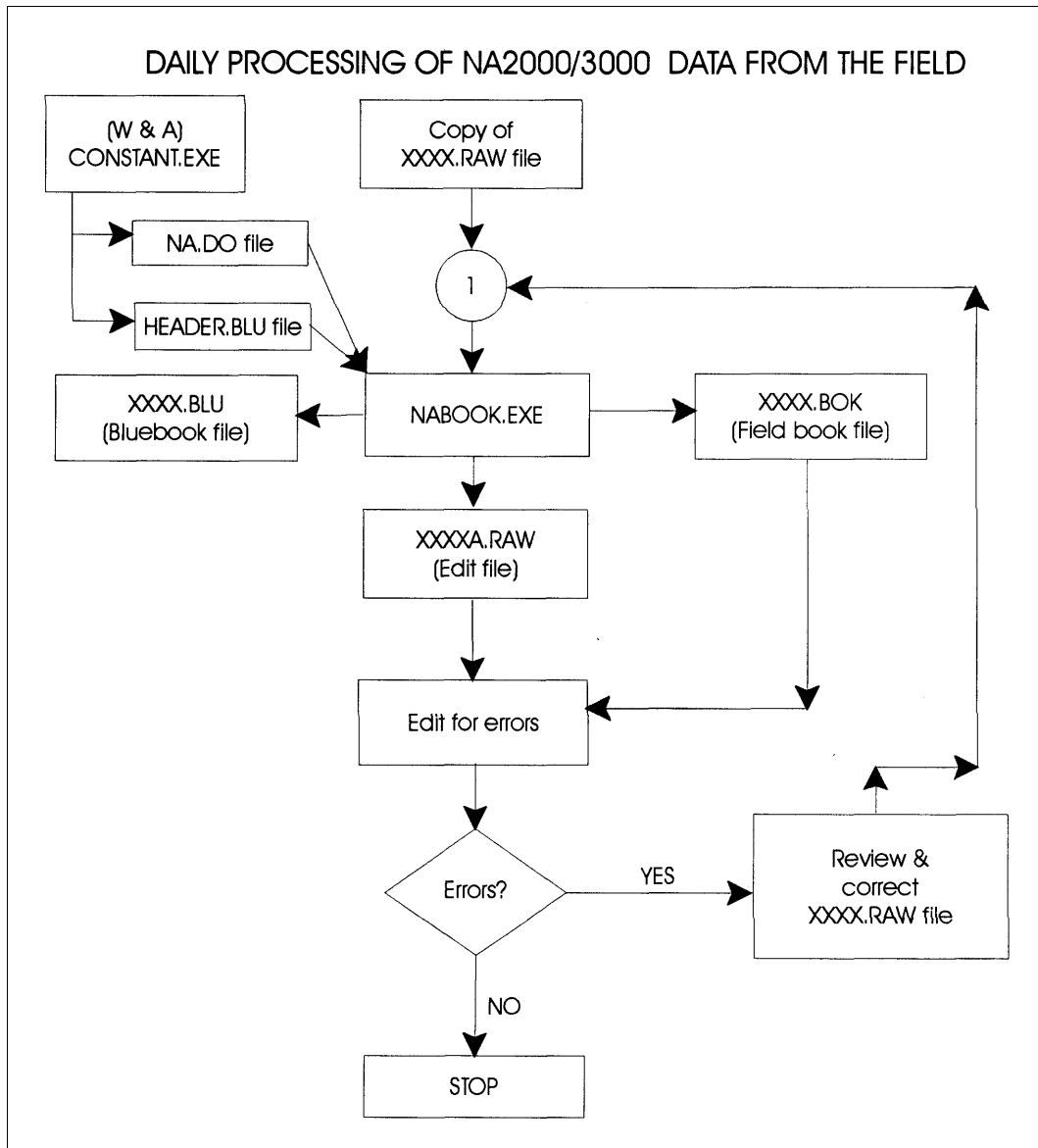


Figure 2

2. At the start of data processing for the survey, run program CONSTANT to obtain NA. DO and HEADER. BLU files for NABOOK. If the Accession Number is not yet available for the '10' record use something temporary like L99999. It can be corrected later. If the heights of instrument are not known in centimeters, use something approximate, like 150. Average height of instrument is calculated from the rod readings in program NABOOK and printed at the end of the field book pages for each day. These average heights can be meaned for each observer for the survey and used to replace the approximate height of instrument in the NA. DO file with a text editor.

3. Run the daily ".RAW" file with NABOOK. NABOOK will print an error message to the monitor if it detects errors in record sequence or missing records. If this happens, review the edit file, which will have an "A" appended to the file name root, for error messages. Correct the copy of the ".RAW" data file if needed, and rerun NABOOK on the file copy, not on the edit file. Also edit the field book XXXX. BOK file for errors and if needed, correct the copy of the ".RAW" data file before rerunning NABOOK.

b. Processing data by line or part of a survey, Part 1, see Figure #3 flow chart

1. Append all edited raw data files for a line or part of a survey using DOS commands, a Windows append utility, or a text editor. Assign the appended file the accession number for the survey line or part. L12345.RAW will be used in this example.. Keep in mind that you are appending for an ABSTRA run so the survey data must form a single line or network.

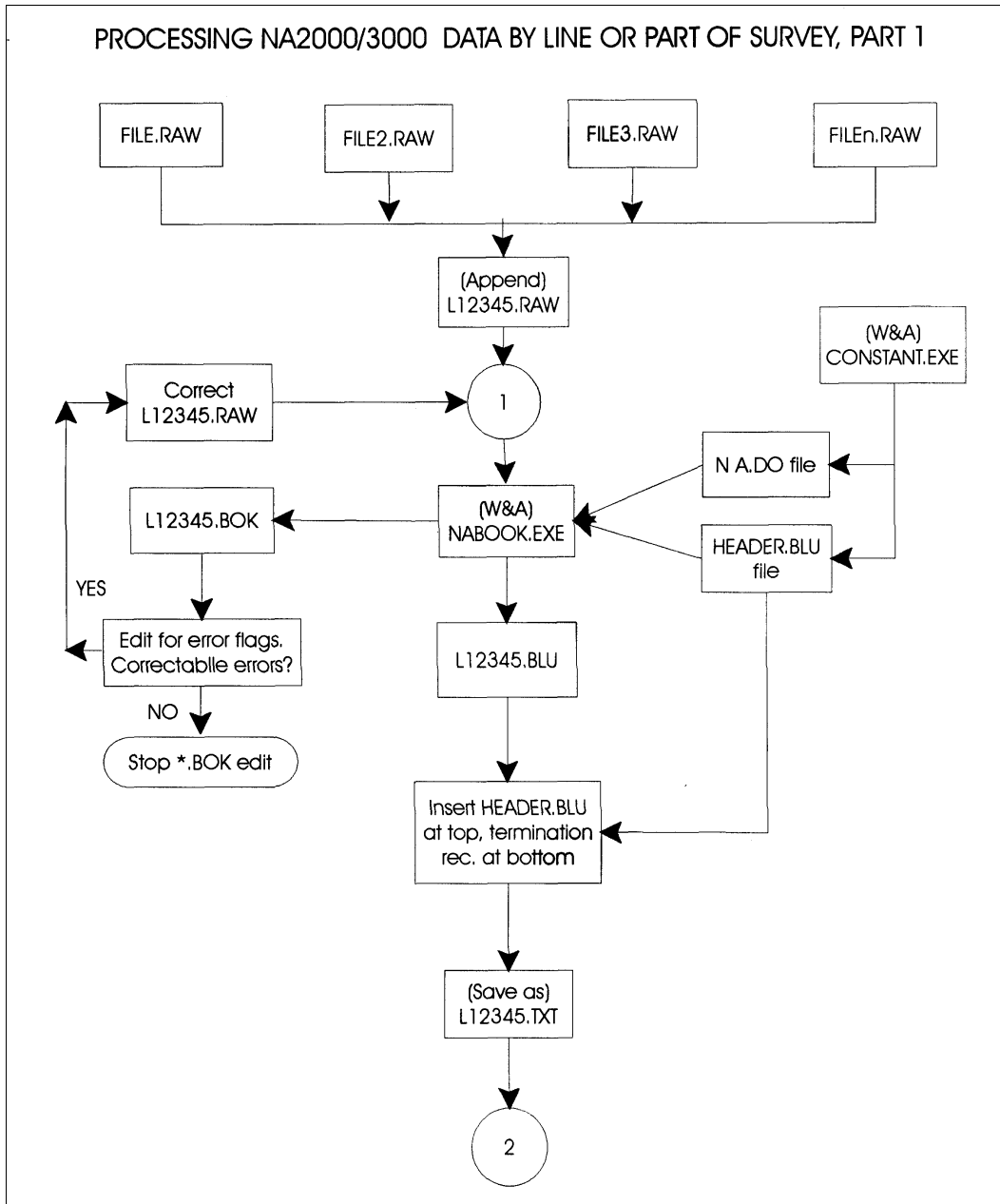


Figure 3

2. If necessary, rerun CONSTANT with updated survey information, to create NA. DO or HEADER. BLU files for the appended file.
3. Use NABOOK to process the appended file, even though the parts have been processed separately.
4. Edit the L12345.BOK file for error flags and errors. If there are correctable errors, correct the appended raw data file and rerun with NABOOK.
5. When there are no more correctable errors, insert the HEADER. BLU file at the top of the L12345.BLU bluebook file and add a termination record at the bottom of the file with a text editor. The termination record is the job code, preceded and followed by asterisks in columns 7 through 10. Save the resulting file with the extension ".TXT".

c. Processing data by line or part of a survey, Part 2, See Figure #4 flow chart.

1. Run MAKEFILE on L12345.TXT to convert it to a binary with extension ".HGZ" (L12345.HGZ) for input to ABSTRA. By this time the description file, L12345.HA should have been prepared and edited. Bench mark names and coordinates are obtained from the description file.
2. Run L12345.HA and L12345.HGZ with ABSTRA. The program will ask for the start SPSN, the end SPSN and the elevation of the starting bench mark. ABSTRA writes a new ".HGZ" file over the old one, with \*30\* records added at the top and with refraction corrections on the \*43\* records if it is run with the ".HA" file. Bench mark coordinates are needed for computing the refraction corrections, and for computing inversed distances between bench marks to compare with the observed distances. ABSTRA also writes an abstract file to disk with extension ".ABS" (like L12345.ABS).
3. Edit the L12345.ABS file for correctable errors. If there are any, go back to part 1 and correct the L12345. RAW file and reprocess.
4. When the L12345.ABS file is acceptable, run L12345.HGZ through READFILE to convert it to a text file. Name the output file with an extension ".LST" (L12345.LST) so it won't get confused with the L12345.TXT file of part 1. This completes the processing for a project to be submitted to NGS (See section - submitting project data to NGS).
5. If you are going to use Whalen and Associates ADJUSTB program, run L12345.LST through ABSTRACT to create summary, unknown and observation files. ABSTRACT will apply all corrections available on the \*43\* records. If an observation is rejected on the \*43\* record it will be assigned a negative number for the number of observations in the ".OBS" file so it will be given zero weight in ADJUSTB. Edit the observation file (L12345.OBS) to constrain one or more heights for the survey.
6. Run L12345.OBS and L12345.UNK with ADJUSTB to obtain adjusted heights for the survey. Edit the L12345.PRT file for errors. If there are large normalized residuals, reject the largest one by setting the number of measurements for the observation in the L12345.OBS file to a negative value, and rerun the adjustment. Continue until all remaining residuals are acceptable.

PROCESSING NA2000/3000 DATA BY LINE OR PART OF SURVEY, PART 2

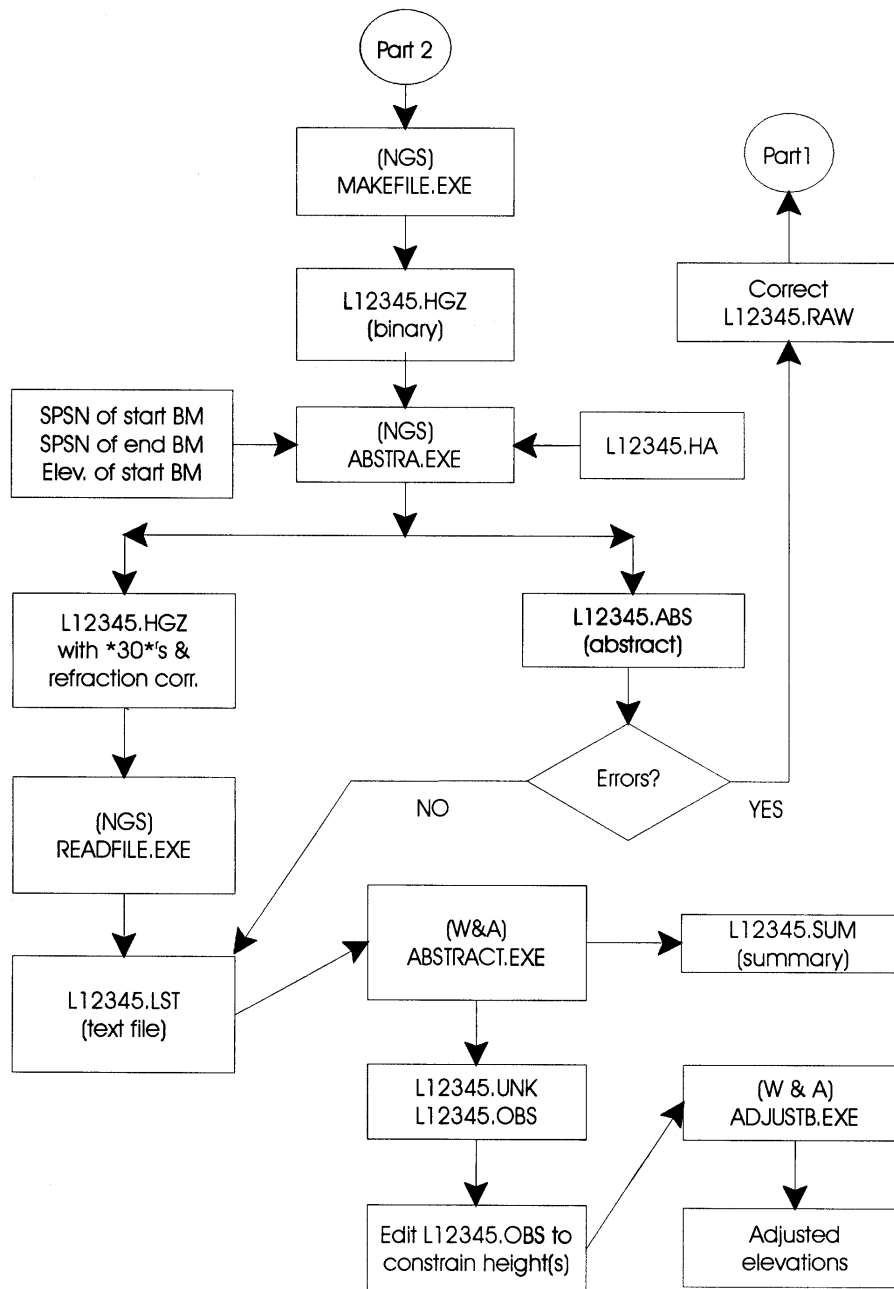


Figure 4

## F. SUBMITTING DATA AND PROJECT REPORT TO NGS

Upon completion of the project, the following should be submitted to NGS:

1. A project report describing the project (See Annex K, page K-4, of the Input Formats and Specifications of the National Geodetic Survey Data Base, Volume I. Horizontal Control Data, for a Report Outline for a Vertical Control Projects). This outline is a good reference for preparing a project report. Also, see Appendix J of this manual for Bluebook policy and Vertical Control Project Outline and Example.
2. File copy of all RAW data files.
3. File copy of NA.DO file.
4. File copy of HEADER.BLU
5. File copy of final fieldbook file \*.BOK
6. File copy (Binary) of description file, \*.HA
7. File copy (Binary) of final bluebook file, \*.HGZ
8. File copy of final Abstract file, \*.ABS (date and time)
9. File copy of INST.DAT
10. File copies of the Invar Rod calibration files, \*xxx.x.rod, for each rod.
11. A copy of the Invar Rod calibration certificates.
12. Any maps or sketches with bench marks plotted that would clarify or identify the project area.

## **APPENDIX A**

### **FGCS Specifications and Procedures to Incorporate Electronic Digital/Bar-Code Leveling Systems**

**FGCS Specifications and Procedures to Incorporate  
Electronic Digital/Bar-Code Leveling Systems**

**3.5 Geodetic Leveling**

Geodetic leveling is a measurement system comprised of elevation differences observed between nearby rods. Geodetic leveling is used to extend vertical control.

**Network Geometry**

Order Class	First I	First II	Second I	Second II	Third
Bench mark spacing not more than (km)	3	3	3	3	3
Average bench mark spacing not more than (km)	1.6	1.6	1.6	3.0	3.0
Line length between network control points not more than (km)	300 <sup>a</sup>	100 <sup>a</sup>	50 <sup>a</sup>	50 <sup>a</sup>	25 <sup>b</sup>
Minimum bench mark ties	6	6	4	4	4

<sup>a</sup> Electronic Digital/Bar-Code Leveling Systems, 25 km

<sup>b</sup> Electronic Digital/Bar-Code Leveling Systems, 10 km

As specified in above table, new surveys are required to tie to existing network bench marks at the beginning and end of the leveling line. These network bench marks must have an order (and class) equivalent to or better than the intended order (and class) of the new survey.

First-order surveys are required to perform valid check connections to a minimum of six bench marks, three at each end. All other surveys require a minimum of four valid check connections, two at each end.

A valid "check connection" means that the observed elevation difference agrees with the published adjusted elevation difference within the tolerance limit of the new survey. Checking the elevation difference between two bench marks located on the same structure, or so close together that both may have been affected by the same localized disturbance, is not considered a proper check.

In addition, the survey is required to connect to any network control points within 3 km of its path. However, if the survey is run parallel to existing control, then the following table specifies the maximum spacing of extra connections between the survey and the existing control.

When using Electronic Digital/Bar-Code Leveling Systems for area projects, there must be at least 4 contiguous loops and the loop size must not exceed 25 km. (Note: This specification may be amended at a future date after sufficient data have been evaluated and it is proven that there are no significant uncorrected systematic errors remaining in Electronic Digital/Bar-Code Leveling Systems.)

S)))))))))Q



**Surveys Run Parallel to Existing Control Network**

Distance, survey to control network	Maximum spacing of extra connections (km)
less than 0.5 km	5
0.5 km to 2.0 km	10
2.0 km to 3.0 km	20

**Instrumentation**

Order Class	First I	First II	Second I	Second II	Third
-------------	---------	----------	----------	-----------	-------

**Leveling instrument**

Minimum repeatability of line of sight	0.25" <sup>c</sup>	0.25" <sup>c</sup>	0.50" <sup>c</sup>	0.50" <sup>d</sup>	1.00"
Leveling rod construction	IDS <sup>g</sup>	IDS <sup>g</sup>	IDS <sup>e</sup> or ISS	ISS	Wood or Metal

**Instrument and rod resolution (combined)**

Least count (mm)	0.1 <sup>c</sup>	0.1 <sup>c</sup>	0.5-1.0 <sup>c,f</sup>	1.0 <sup>d</sup>	1.0 <sup>d</sup>
------------------	------------------	------------------	------------------------	------------------	------------------

IDS Invar, double-scale  
ISS Inver, single-scale

<sup>c</sup> For Electronic Digital/Bar-Code Leveling Systems, 0.40" and 0.01 mm.

<sup>d</sup> For Electronic Digital/Bar-Code Leveling Systems, 0.80" and 0.1 mm.

<sup>e</sup> If optical micrometer is used.

<sup>f</sup> 1.0 mm if 3-wire method; 0.5 mm if optical micrometer.

<sup>g</sup> For Electronic Digital/Bar-Code Leveling Systems, Invar, single-scale.

Leveling rods must be one piece. A turning point consisting of a steel turning pin with a driving cap should be utilized. If a steel pin cannot be driven, then a turning plate ("turtle") weighing at least 7 kg should be substituted. In situations allowing neither turning pins nor turning plates (sandy or marshy soils), a long wooden stake with a double-headed nail should be driven to a firm depth.

According to at least one manufacturer's specifications, the electronic digital leveling instrument should not be exposed to direct sunlight. The manufacturer recommends using an umbrella in bright sunlight.

**Calibration Procedures**

Order Class	First I	First II	Second I	Second II	Third
<b>Leveling instrument</b>					
Maximum collimation error single line of sight (mm/m)	0.05	0.05	0.05	0.05	0.10
Maximum collimation error, reversible compensator-type instruments, mean of two lines of sight (mm/m)	0.02	0.02	0.02	0.02	0.04
Time interval between collimation error determinations not longer than (days)					
Reversible compensator	7	7	7	7	7
Other types	1	1	1	1	7 <sup>h</sup>
Maximum angular difference between two lines of sight, reversible compensator	40"	40"	40"	40"	60"
<b>Leveling rod</b>					
Minimum scale calibration standard	N <sup>i</sup>	N <sup>i</sup>	N <sup>i</sup>	M	M
Time interval between scale calibrations (yr)	3	3	--	--	--
Leveling rod bubble verticality maintained to within	10'	10'	10'	10'	10'

N -- U.S. National standard  
M -- Manufacturer's standard

<sup>h</sup> For Electronic Digital/Bar-Code Systems, collimation error determinations are required at the beginning of each day (0.05 mm/m = 10 arc seconds). Collimation data must be recorded with the leveling data and the daily updated value must be used during the daily data capture.

<sup>i</sup> For Electronic Digital/Bar-Code Rods, until the U.S. National Standard Testing Procedure is implemented, manufacturer's scale calibration standard is acceptable, provided the data used during the calibration are furnished in digital format.

Compensator-type instruments should be checked for proper operation at least every 2 weeks of use. Rod calibration should be repeated whenever the rod is dropped or damaged in any way. Rod levels should be checked for proper alignment once a week. The manufacturer's calibration standard should, as a minimum, describe scale behavior with respect to temperature.

**Field Procedures**

<b>Order Class</b>	<b>First I</b>	<b>First II</b>	<b>Second I</b>	<b>Second II</b>	<b>Third</b>
Minimal observation method	micrometer <sup>j</sup>	micrometer <sup>j</sup>	micrometer <sup>j</sup> or 3 wire	3-wire <sup>j</sup>	center wire <sup>j</sup>
Section running <sup>k</sup>	DR, DS, or MDS	DR, DS, or MDS	DR	DR	DR
Difference of forward and backward sight lengths never to exceed: per setup (m)	2	5	5	10	10
per section (m)	4	10	10	10	10
Maximum sight length (m) <sup>l</sup>	50	60	60	70	90
Minimum ground clearance of line of sight (m)	0.5	0.5	0.5	0.5	0.5
Even number of setups when not using leveling rods with detailed calibration	yes	yes	yes	yes	---
Determine temperature gradient for the vertical range of the line of sight at each setup	yes	yes	yes	---	---
Maximum section misclosure (mm)	3/D	4/D	6/D	8/D	12/D
Maximum loop misclosure (mm)	4/E	5/E	6/E	8/E	12/E
<b>3-vire method</b>					
Reading check (difference between top and bottom intervals) for one setup not to exceed (tenths of rod units)	---	---	2	2	3
Read rod 1 first in alternate setup method	---	---	yes	yes	yes
<b>Micrometer single-difference method</b>					
Reading check (difference between low and high scale) for one setup not to exceed (micrometer units)	---	---	3	4	5
Read rod 1 first in alternate setup method	---	---	yes	yes	yes

(continued)

Field Procedures (continued)

Order Class	First I	First II	Second I	Second II	Third
<b>Electronic Digital/Bar-Code method</b>					
<sup>a</sup> h <sub>1</sub> - <sup>a</sup> h <sub>2</sub> for one setup not to exceed (mm) for MDS procedure	0.30	0.30	0.60	0.70	1.30
Use multiple reading option to obtain each observation - minimum number of readings <sup>m</sup>	3	3	3	3	3
<b>Double-scale rods, DS procedure</b>					
Low-high scale elevation difference for one setup not to exceed (mm) With reversible compensator	0.40	1.00	1.00	2.00	2.00
Other instrument types: Half-centimeter rods	0.25	0.30	0.60	0.70	1.30
Full-centimeter rods	0.30	0.30	0.60	0.70	1.30

DS -- Double Simultaneous procedure; see summary of observing sequences

NDS - Modified, Double Simultaneous procedure; see summary of observing sequences

DR -- Double-Run

SP -- SPur, must be less than 25 km, - must be double-run

D --- shortest one-way length of section in km

E --- length of loop in km

<sup>j</sup> Electronic Digital/Bar-Code method permitted.

<sup>k</sup> For establishing a height of a new bench mark, double-run procedures must be used. Single-run methods can be used to relevel existing work provided the new work meets the allowable section misclosure.

<sup>l</sup> Maximum sight length permitted unless the manufacturer recommends a maximum sight length which is less.

<sup>m</sup> If the standard deviation exceeds 0.1 mm, continue making readings until it is less than 0.1 mm or repeat observation.

Double-run leveling may always be used, but single-run leveling procedures can only be used where it can be evaluated using published height values, i.e., the difference in published height values can be substituted for the backward running. DS and MDS procedures are recommended for all single-run leveling, but single-difference procedures are permitted.

Rods must be leap-frogged between setups (alternate setup method). The date, beginning and ending times, cloud coverage, air temperature (to the nearest degree), temperature scale, and average wind speed should be recorded for each section, plus any changes in the date, instrumentation, observer, or time zone.

When using the DS and MDS procedures, the instrument need not be off leveled/ releveled between observing the high and low scales when using an instrument with a reversible compensator. The low-high scale difference tolerance for a reversible compensator is used only for the control of blunders.

**Summary Of Observing Sequences**

DS Procedures

With double-scale rods,  
the following observing  
sequence should be used:

backsight, low-scale.  
backsight, stadia  
foresight, low-scale  
foresight, stadia  
off-level/relevel or  
reverse compensator  
foresight, high-scale  
backsight, high-scale

MDS Procedures

With bar-coded scale rods,  
the following observing  
sequence should be used:

backsight  
backnight distance, standard error  
foresight  
foresight, distance, standard error  
off-level/relevel  
  
foresight, standard error  
backsight, standard error

**Office Procedures**

Order Class	First I	First II	Second I	Second II	Third
<b>Section misclosures</b> (backward and forward)					
Algebraic sum of all corrected section misclosures of a leveling line not to exceed (mm)	3/L	4/L	6/L	8/L	12/L
Section misclosure not to exceed (mm)	3/D	4/D	6/D	8/D	12/D
<b>Loop misclosures</b>					
Algebraic sum of all corrected misclosures not to exceed (mm)	4/E	5/E	6/E	8/E	12/E
Loop misclosure not to exceed (mm)	4/E	5/E	6/	8/E	12/E

-----  
L -- shortest one-way length of leveling line in km  
D -- shortest one-way length of section in km  
E -- length of loop in km

The normalized residuals from a minimally constrained least squares adjustment will be checked for blunders. The observation weights will be checked by inspecting the post adjustment estimate of the variance of unit weight. Elevation difference standard errors computed by error propagation in a correctly weighted least squares adjustment will indicate the provisional accuracy classification. A survey variance factor ratio will be computed to check for systematic error. The least squares adjustment will use models that account for:

gravity effect or orthometric correction  
rod scale errors  
rod (Invar) temperature  
refraction -- need latitude and longitude accurate to at least 6"  
or (preferably) vertical temperature difference observations  
between 0.5 and 2.5 m above the ground  
earth tides and magnetic field  
collimation error<sup>a</sup>  
crustal motion

<sup>a</sup>For Electronic Digital/Bar-Code Leveling Systems, collimation data must be recorded with leveling data and updated value must be used during data capture.

## **APPENDIX B**

**SECTION CLOSURES  
FOR MULTIPLE (3 OR MORE) RUN SECTIONS  
ONE SETUP SECTIONS  
SECTIONS LESS THAN 100 M (0.1 KM)**

Table 3-1.--Tolerances for geodetic leveling

	First order class I	First order class II	Second order class I	Second order class II	Third order
<b>Lines of sight</b>					
Maximum sighting distance	50.0 m	60.0 m	60.0 m	70.0 m	90.0 m
Maximum imbalance, per setup	±2.0 m	±5.0 m	±5.0 m	±10.0 m	±10.0 m
per section	±4.0 m	±10.0 m	±10.0 m	±10.0 m	±10.0 m
<b>Leveling instrument</b>					
Maximum collimation error, single line of sight	<----- ±10.0" (C # ±0.05 mm/m) ----->				-----
Maximum collimation error, mean of two lines of sight	<----- ±4.0" (C # ±0.02 mm/m) ----->				-----
Maximum angular difference in two lines of sight	<----- ±40.0" (Q # ±0.20 mm/m) ----->				-----
Setting precision	±0.25"	±0.25"	±0.50"	±0.50"	-----
Minimum reading	±0.1 mm Micrometer required	±0.1 mm Micrometer required	±0.5 mm	±0.5 mm	-----
<b>Leveling rod</b>					
Plumbing accuracy	±10.0'	±10.0'	±10.0'	±10.0'	
Maximum scale unit	1.0 cm	1.0 cm	1.0 cm	1.0 cm	
Calibration accuracy	±0.05 mm	±0.05 mm	±0.05 mm	±0.05 mm	
<b>Agreement of observed elevation differences before correction, observed backward and forward during</b>					
One-setup section	±0.40 mm	±1.00 mm	-----	-----	-----
Two runnings of a section less than 0.10 km in length	±0.95 mm	±1.26 mm	±1.90mm	±2.53 mm	±3.79 mm
Two runnings of a section of one- way length $K$ : $T \times OK \text{ mm}$ , $T =$	±3.00	±4.00	±6.00	±8.00	±12.00
Three or more runnings of a section: Each accepted running must differ from the mean of all accepted runnings by no more than $t \times OK \text{ mm}$ , $t$ given below. For a section less than 0.10 km in length, let $K=0.10$ .					
Number of levelings:					
3	2.10	2.81	4.21	5.63	8.44
4	2.33	3.10	4.66	6.23	9.34
5	2.48	3.31	4.96	6.64	9.95
6	2.59	3.46	5.19	6.94	10.4
7	2.68	3.58	5.36	7.18	10.7
8	2.75	3.67	5.51	7.37	11.0
One leveling of a loop of one-way length $K$ , beginning and ending at the same point: $T \times OK \text{ mm}$ , $T =$	±4.00	±5.00	±6.00	±8.00	±12.00

Table 3-7.- Example of rejection procedure for first-order, class II leveling

Date	Direction (km)	Distance (m)	Elevation difference (m)	Difference from mean (mm)	Explanation
10/11	F	0.82	-2.43152		Two runnings of a section are made. Their difference is $B+F = 6.00$ mm. The tolerance is $3 \times 00.82 = \pm 2.72$ mm Since the difference exceeds the tolerance, the section is releveled.
10/12	B	0.83	2.43753		
10/11	F	0.82	-2.43152	+1.67	The mean of the three runnings and the differences from the mean are computed. The allowable difference is $2.20 \times 00.82 = \pm 1.90$ mm. The second and third runnings are both outside the allowable. Rejecting the worst leaves only two forward runnings, so the section is releveled.
10/12	B	0.83	2.43752 R	-4.33	
10/12	F	0.82	-2.43052	+2.67	
			Mean = 2.43319		
10/11	F	0.82	-2.43152	+2.90	The mean and differences are computed for all four runnings. The allowable is $2.33 \times 00.82 = \pm 2.11$ mm All are outside the allowable. Rejecting only the worst, the third running, a new mean is computed. The allowable for three runnings is, as before $\pm 1.90$ mm. Rejecting the worst, (the first) leaves only two backward runnings, so the section is releveled.
10/12	B	0.83	2.43752	-3.10	
10/12	F	0.82	-2.43052 R	+3.90	
10/13	B	0.82	2.43810	-3.68	
			Mean = 2.43442		
10/12	B	0.83	2.43752 R	+4.19	
10/12	F	0.82	-2.43052	-1.81	
10/13	B	0.82	2.43810	-2.39	
			Mean = 2.43571		
10/11	F	0.82	-2.43152	+3.64	The mean and differences are computed for the five runnings. The allowable is $2.48 \times 00.82 = \pm 2.25$ mm Rejecting the worst, a new mean is computed.
10/12	B	0.83	2.43752	-2.36	
10/12	F	0.82	-2.43052 R	+4.64	
10/13	B	0.82	2.43810	-2.94	
10/13	F	0.83	-2.43812	-2.96	
			Mean = 2.43516		
	F	0.82	-2.43152 R	+4.80	The allowable for four runnings is, as before, $\pm 2.11$ mm. The first running is rejected, and then a new mean computed. The allowable for three runnings is, as before, $\pm 1.90$ mm. Since all differences are within the allowable, and at least one forward running and one backward running are accepted, the section is closed.
	B	0.83	2.43752	-1.20	
	B	0.82	2.43810	-1.78	
	F	0.83	-2.43812	-1.80	
			Mean = 2.46320		
	B	0.83	2.43752	+0.39	
	B	0.82	2.43810	-0.19	
	F	0.83	-2.43812	-0.21	
			Mean = 2.43791		



## **APPENDIX C**

**EXAMPLE RUN OF CONSTANT PROGRAM  
SHOWING INPUT FOR  
HEADER.BLU AND NA.DO**

**EXAMPLE RUN OF CONSTANT ITEM 1 - BLUEBOOK RECORDS**

Embolded items are user entries.

Program CONSTANT, Version 1.00, 8-01-96  
Copyright 1996 by Whalen and Associates  
(301) 774-3822

\*\*\*\*\*

\***(1)** Bluebook records\*

\***(2)** Constants \*

\***(3)** Exit program \*

\*\*\*\*\*

Key selection 1, 2 or 3

? **1**

HEADER.BLU' file opened

Press any key to continue

\\\\\\\\Data set i.d. (\*jc\*) record\\\\\\\\

Key job code like 'cx':

**[MI]**

Agency abbreviation like 'USGS':

**[MDOT ]**

Full name of submitting agency :

**[MICHIGAN DEPARTMENT OF TRANSPORTATION ]**

\\\\\\\\\\\\ Line information (\*10\*) record \\\\\\\\\

Accession number like 'L22024':

**[L25391 ]**

Line part, if multiple part line like '11':

**[1 ]**

Is this a releveling of a line ([RETURN] = yes, n = no) ? **Y**

Key date field operations commenced

(ccyymmdd) like '19990329':

**[19990517]**

Key date field operations ended

(ccyymmdd), at least the year:

**[19990819]**

Section closure tolerance/km, mm, like 12.0 :

**[4.0 ]**

Order and class of survey,  
like '12' for 1st order class 2  
Order and class:  
**[12]**

key up to 3 2-char state and county codes for survey  
like 'CAVABC'(annex a of blue book)  
codes:  
**[MI ]**

Initials of chief of party :  
**[OWM]**

Abbreviation or name of survey agency  
Key 'ENTER' if previous is O.K. :  
**[MDOT ]**

\\\\\\Line title (\*11\*, \*12\*, \*13\* or \*14\*) records\\\\\\

Key line title, up to 4 records  
up to 70 characters per record  
Press [RETURN] for end record, if less than 4 records  
Title:  
**[LEVEL LINE REED CITY VIA BIG RAPIDS VIA LANSING TO JACKSON ]**

\\\\\\\\\\Comment (\*15\*) records\\\\\\\\\\\\\\\\\\\\

Key as many comment records as desired.  
Do not divide words between records.  
Press [RETURN] to exit.

Key record, no quotes needed:  
**[COLLIMATION CHECK TAKEN DAILY AND STORED INTERNALLY IN THE NA3003 AND ]**

Key record, no quotes needed:  
**[USED TO CORRECT EACH ROD READING. THE TANGENT OF THE COLLIMATION X ]**

Key record, no quotes needed:  
**[1000 IS STORED IN THE 40 RECORD COLS 65-69 ]**

**EXAMPLE RUN OF CONSTANT ITEM 2 - CONSTANTS**

Embolded items are user entries.

Program CONSTANT, Version 1.00, 8-01-96  
Copyright 1996 by Whalen and Associates  
(301) 774-3822

\*\*\*\*\*  
\*(1) Bluebook records\*  
\*(2) Constants \*  
\*(3) Exit program \*  
\*\*\*\*\*

Key selection 1, 2 or 3  
? **2**

\\Line title (\*11\*, \*12\*, \*13\* or \*14\*) records\\

Key line title, up to 4 records  
up to 70 characters per record  
Press [RETURN] for end record, if less than 4 records  
Title:

**[MICHIGAN DIGITAL LEVELING USING THE LEICA NA3003 ]**

Title:  
[ ]

Line name =  
MICHIGAN DIGITAL LEVELING USING THE LEICA NA3003  
Press any key to continue

[[[[[ TIME ZONE ]]]]]

[[[[[ TIME ZONE MENU ]]]]]

- 
- (Q) Eastern daylight savings time or Puerto Rico time
- (R) Eastern standard or Central daylight savings time
- (S) Central standard or Mountain daylight savings time
- (T) Mountain standard or Pacific daylight savings time
- (U) Pacific standard time
- (V) Alaska-Hawaii daylight savings time
- (W) Alaska-Hawaii standard time
- 

See Annex H of the Blue Book for other time zone letters.

Key time zone letter:  
**[R]**

Time zone = R  
Is that correct ([ENTER] = yes, n = no) ?

Key observer 1            Code number  
Key a negative observer code to end input.  
? **1**  
Key observer 1            initials  
? **SWH**  
Key observer 1            Average height of instrument, cm  
? **140**

Key observer 2            Code number  
Key a negative observer code to end input.  
? **2**  
Key observer 2            initials  
? **CAK**  
Key observer 2            Average height of instrument, cm  
? **136**

Key observer 3            Code number  
Key a negative observer code to end input.  
? **3**  
Key observer 3            initials  
? **TMS**  
Key observer 3            Average height of instrument, cm  
? **144**

Key observer 4            Code number  
Key a negative observer code to end input.  
? **6**  
Key observer 4            initials  
? **GMB**  
Key observer 4            Average height of instrument, cm  
? **140**

Key observer 5            Code number  
Key a negative observer code to end input.  
? **6**  
Key observer 5            initials  
? **JAS**  
Key observer 5            Average height of instrument, cm  
? **138**

Key observer 6            Code number  
Key a negative observer code to end input.  
? **6**  
Key observer 6            initials  
? **TWB**  
Key observer 6            Average height of instrument, cm  
? **138**

Key observer 7            Code number  
Key a negative observer code to end input.  
? **7**  
Key observer 7            initials  
? **DBE**  
Key observer 7            Average height of instrument, cm  
? **144**

Key observer 8            Code number  
Key a negative observer code to end input.  
? **8**  
Key observer 8            initials  
? **JWG**  
Key observer 8            Average height of instrument, cm  
? **144**

Key observer 9            Code number  
Key a negative observer code to end input.  
? **-9**

[[[[[ TEMPERATURE SENSOR HEIGHTS ]]]]]

Air temperatures are used to compute refraction corrections for leveling observations. The program allows for three temperature heights, top, middle and bottom. Key [RETURN] or [ENTER] for heights of sensors if they are not used.

Use defaults of 130 for top and 30 for bottom if temperatures not being recorded for refraction. In this case, temperatures will be estimated from Holdahl's model. Key [RETURN] or [ENTER] to accept the defaults.

Top temperature sensor height in centimeters:  
[130]

Middle temperature sensor height in centimeters  
Key [RETURN] or [ENTER] if it is not used.:  
[ ]

Bottom temperature sensor height in centimeters:  
[ 30]

\*\*\*\*\*  
\*(1) Bluebook records\*  
\*(2) Constants       \*  
\*(3) Exit program   \*  
\*\*\*\*\*

Key selection 1, 2 or 3  
? **3**

## **APPENDIX D**

### **EXAMPLES OF**

**RAW FILE FORMAT (ANNOTATED)**

**EDIT FILE (APPENDED A IN NAME)**

**OUTPUT OF FIELDBOOK FILE (\*.BOK)  
SHOWING EXAMPLE ERROR CODES**

WHALEN'S RECORD FORMAT FOR WILD ELECTRONIC LEVEL RECORDING  
BF OBSERVING SEQUENCE

(80 columns)

1 2 3 4 5 6 7 8  
12345678901234567890123456789012345678901234567890123456789012345678901234567890

(START OF DAY OR CHANGE IN OBSERVER/INSTRUMENT)

41/01 RECORD DDMMYY OBSERVER # INST. TYPE TEMP CODE #  
410002+00000001 42....+00071896 43....+00000001 44....+00002002 45....+00000001

(EQUIPMENT RECORD)

41/02 RECORD INST. # COLL. ERROR ROD I # ROD 2 #  
410003+00000002 42....+00091014 43....+00000013 44....+00025294 45....+00025286

(START OF SECTION)

41/11 RECORD HHMM ROD ON MARK TEMPERATURE (BLANK)  
410004+00000011 42....+00000840 43....+00000001 44....+00000078 45....+00000000

110001+00004051 83..16+00000000

11/331 SPSN (BACKSIGHT OBSERVATION)

110005+00004051 32..00+00017680 331106+00013163 52..06+0003+000

11/332 POINT # (FORESIGHT OBSERVATION)

110006+00000001 32..00+00017840 332106+00022020 52..06+0003+000 83..06-00008857

(ETC.)

110008+00000001 32..00+00025550 331106+00009703 52..06+0003+000  
110009+00000002 32..00+00024110 332106+00020786 52..06+0003+000 83..06-0019939  
110011+00000002 32..00+00019770 331106+00015385 52..06+0003+001  
110012+00004052 32..00+00016090 332106+00024078 52..06+0003+000 83..06-0028631

(END OF SECTION)

41/99 RECORD HHMM ROD ON MARK TEMPERATURE WIND & SUN  
410014+00000099 42....+00000845 43....+00000002 44....+0000007945....+00000021

41/9999 RECORD, END OF DAY (NO DATA ENTRIES)

410504+00009999 42....+00000000 43....+00000000 44....+0000000045....+00000000



**NABOOK EDIT FILE SHOWING RECORDS OUT OF SEQUENCE MESSAGES**

410001+00000001 42....+00051499 43....+00000005 44....+00003003 45....+00000001  
410002+00000002 42....+00282370 43....-00000025 44....+00026631 45....+00026683  
410003+00000011 42....+00001340 43....+00000001 44....+00000071  
410004+?......1  
110005+00000100 83..16+00000000  
110006+00000100 32..00+00030280 331108+00215583 52..08+0003+010  
110007+00000001 32..00+00030810 332108+00124193 52..08+0003+015  
110008+00000001 573..0-00000530 574..0+00061090 83..06+00009139  
110009+00000001 32..00+00031170 331108+00129053 52..08+0003+013  
110010+00000002 32..00+00032130 332108+00132709 52..08+0003+011  
110011+00000002 573..0-00001490 574..0+00124390 83..06+00008773  
110012+00000002 32..00+00042430 331108+00149396 52..08+0003+005  
110013+00000003 32..00+00045060 332108+00133820 52..08+0003+007  
110014+00000003 573..0-00004120 574..0+00211880 83..06+00010331  
110015+00000003 32..00+00028480 331108+00196274 52..08+0003+003  
110016+00000004 32..00+00027220 332108+00167976 52..08+0004+019  
110017+00000004 573..0-00002860 574..0+00267580 83..06+00013161  
110018+00000004 32..00+00010640 331108+00143490 52..08+0003+001  
110019+00000005 32..00+00009650 332108+00162789 52..08+0003+004  
110020+00000005 573..0-00001870 574..0+00287880 83..06+00011231  
110021+00000005 32..00+00009780 331108+00133128 52..08+0004+005  
110022+00000200 32..00+00010240 332108+00182403 52..08+0003+006  
110023+00000200 573..0-00002340 574..0+00307900 83..06+00006303  
410024+00000099 42....+00001404 43....+00000001 44....+00000072 45....+00000002  
**FOLLOWING RECORD 1 IS OUT OF ORDER.**  
410025+00000001 42....+00051499 43....+00000008 44....+00003003 45....+00000001  
410026+00000002 42....+00282370 43....-00000025 44....+00026631 45....+00026683  
410027+00000011 42....+00001410 43....+00000001 44....+00000072  
410028+?......1  
110029+00000200 83..16+00000000  
110030+00000200 32..00+00015210 331108+00189782 52..08+0003+004  
110031+00000001 32..00+00016600 332108+00136890 52..08+0003+008  
110032+00000001 573..0-00001390 574..0+00031810 83..06+00005289  
110033+00000001 32..00+00015770 331108+00143392 52..08+0003+002  
110034+00000002 32..00+00016000 332108+00016444 52..08+0003+006  
110035+00000002 573..0-00001620 574..0+00063580 83..06+00017984  
410036+00000099 42....+00001421 43....+00000001 44....+00000075 45....+00000002  
**FOLLOWING RECORD 1 IS OUT OF ORDER.**  
410037+00000001 42....+00051499 43....+00000009 44....+00003003 45....+00000001  
**FOLLOWING RECORD 11 IS OUT OF ORDER.**  
410038+00000011 42....+00001427 43....+00000001 44....+00000075  
410039+?......1  
110040+00000300 83..16+00000000  
110041+00000300 32..00+00013770 331108+00021908 52..08+0003+008  
410042+!....331  
110043+00000300 32..00+00013770 331108+00021914 52..08+0003+002  
110044+00000001 32..00+00013360 332108+00146761 52..08+0003+001  
110045+00000001 573..0+00000400 574..0+00027130 83..06-00012485  
110046+00000001 32..00+00026180 331108+00152600 52..08+0003+008  
110047+00000002 32..00+00026650 332108+00167512 52..08+0003+009  
110048+00000002 573..0-00000070 574..0+00079960 83..06-00013976  
110049+00000002 32..00+00018280 331108+00143751 52..08+0003+003  
110050+00000003 32..00+00018450 332108+00147575 52..08+0003+003  
110051+00000003 573..0-00000240 574..0+00116700 83..06-00014358  
110052+00000003 32..00+00023500 331108+00117628 52..08+0004+013

110053+00000100 32..00+00022850 332108+00216834 52..08+0003+000  
110054+00000100 573..0+00000410 574..0+00163040 83..06-00024279  
410055+00000099 42....+00001445 43....+00000001 44....+00000075 45....+00000002  
**FOLLOWING RECORD 1 IS OUT OF ORDER.**  
410056+00000001 42....+00051499 43....+00000002 44....+00003003 45....+00000001  
**FOLLOWING RECORD 11 IS OUT OF ORDER.**  
410057+00000011 42....+00001448 43....+00000001 44....+00000075  
410058+?......1  
110059+00000100 83..16+00000000  
110060+00000100 32..00+00022820 331108+00215645 52..08+0003+008  
110061+00000001 32..00+00023520 332108+00116450 52..08+0003+005  
110062+00000001 573..0-00000690 574..0+00046340 83..06+00009920  
110063+00000001 32..00+00018950 331108+00131983 52..08+0003+001  
110064+00000002 32..00+00017360 332108+00123409 52..08+0003+008  
110065+00000002 573..0+00000900 574..0+00082660 83..06+00010777  
110066+00000002 32..00+00026050 331108+00162798 52..08+0003+012  
110067+00000003 32..00+00022030 332108+00143160 52..08+0003+005  
110068+00000003 573..0+00004910 574..0+00130740 83..06+00012741  
110069+00000003 32..00+00019700 331108+00128697 52..08+0003+008  
110070+00000300 32..00+00020530 332108+00013187 52..08+0003+006  
110071+00000300 573..0+00004080 574..0+00170970 83..06+00024292  
410072+00000099 42....+00001504 43....+00000001 44....+00000075 45....+00000002  
**FOLLOWING RECORD 1 IS OUT OF ORDER.**  
410073+00000001 42....+00051499 43....+00000008 44....+00003003 45....+00000001  
**FOLLOWING RECORD 11 IS OUT OF ORDER.**  
410074+00000011 42....+00001508 43....+00000001 44....+00000075  
410075+?......1  
110076+00000300 83..16+00000000  
110077+00000300 32..00+00007670 331108+00026896 52..08+0003+001  
110078+00000001 32..00+00007870 332108+00158302 52..08+0003+002  
110079+00000001 573..0-00000200 574..0+00015540 83..06-00013141  
110080+00000001 32..00+00023820 331108+00155513 52..08+0003+011  
110081+00000002 32..00+00024580 332108+00203938 52..08+0003+007  
110082+00000002 573..0-00000960 574..0+00063940 83..06-00017983  
410083+00000022  
410084+!....331  
110085+00000001 32..00+00023820 331108+00155521 52..08+0003+004  
110086+00000200 32..00+00024590 332108+00203930 52..08+0003+003  
110087+00000200 573..0-00000970 574..0+00063950 83..06-00017981  
410088+00000099 42....+00001516 43....+00000001 44....+00000076 45....+00000002  
410089+00009999

NABOOK FIELDBOOK OUTPUT FILE SHOWING ERROR FLAGS

TH 104 FROM JCT OF TH 12 TO JCT OF TH 9 AT SUNBURG  
 Electronic Digital/Bar-Code Leveling Observations

Date mmdyy	Observer Initials	Instrument Type	Instrument Number	Rod 1 No.	Rod 2 No.	Coll. Sec.
071896	CPF	2002	91014	25294	25286	1.3

Time, hhmm: 0846, Zone: R, Rod on Mark: 2, Temperature: 79.0 F

BS/ FS	Point No.	Rod Reading m	Dist m	T Hi T Lo F	No. Obs.	Sigma mm	Delta h /Sum m	Dist. /Sum m	Delta D /Sum m	Com- ments
BS-	4052	2.3113	116.89	.0	3	.0	.4322	233.33	.45	#A
FS	1	1.8791	116.44	.0	3	.3	.4322	233.33	.45	#BL
BS-	1	2.0419	27.12	.0	3	.0	1.0950	53.87	.37	
FS	2	.9469	26.75	.0	4	.0	1.5272	287.20	.82	
BS-	2	4.4049	23.71	.0	3	.0	3.5339	47.39	.03	
FS	3	.8710	23.68	.0	3	.1	5.0611	334.59	.85	#G
BS-	3	2.7659	28.04	.0	3	.1	2.3614	56.42	-.34	
FS	4	.4045	28.38	.0	3	.0	7.4225	391.01	.51	#K
BS-	4	2.6102	24.88	.0	3	.1	1.9077	49.73	.03	
FS	5	.7025	24.85	.0	3	.1	9.3302	440.74	.54	
BS-	5	2.6893	26.62	.0	3	.0	2.0170	53.32	-.08	
FS	6	.6723	26.70	.0	3	.0	11.3472	494.06	.46	
BS-	6	2.6590	26.36	.0	3	.1	1.9699	52.10	.62	
FS	7	.6891	25.74	.0	3	.0	13.3171	546.16	1.08	
BS-	7	2.9015	23.09	.0	3	.0	1.7667	46.00	.18	
FS	8	1.1348	22.91	.0	3	.0	15.0838	592.16	1.26	
BS-	8	2.8427	54.83	.0	3	.1	1.8586	104.93	4.73	#A
FS	9	.9841	50.10	.0	4	.1	16.9424	697.09	5.99	#BC
BS-	9	1.6303	22.87	.0	3	.1	-.8696	48.41	-2.67	
FS	10	2.4999	25.54	.0	3	.1	16.0728	745.50	3.32	
BS-	10	1.0265	11.56	.0	4	.0	-1.6470	26.23	-3.11	
FS	11	2.6735	14.67	.0	4	.0	14.4258	771.73	.21	
BS-	11	.7109	13.26	.0	5	.0	-1.9729	26.28	.24	
FS	12	2.6838	13.02	.0	3	.0	12.4529	798.01	.45	
BS-	12	.8679	110.72	.0	4	.0	-3.4759	122.06	99.38	#A
FS	13	4.3438	11.34	.0	3	.0	8.9770	920.07	99.83	#C
BS-	13	1.0218	15.01	.0	4	.0	-.9522	28.84	1.18	
FS	14	1.9740	13.83	.0	3	.0	8.0248	948.91	101.01	
BS-	14	1.6991	19.95	.0	3	.0	.5335	40.21	-.31	
FS	15	1.1656	20.26	.0	3	.0	8.5583	989.12	100.70	
BS-	15	2.7584	13.27	.0	1	.0	1.9402	26.70	-.16	#M
FS	16	.8182	13.43	.0	6	.0	10.4985	1015.82	100.54	
BS-	16	2.5157	14.38	.0	3	.1	1.6730	29.50	-.74	
FS	17	.8427	15.12	.0	3	.0	12.1715	1045.32	99.80	
BS-	17	4.0363	4.71	.0	5	.0	2.8236	19.90	-10.48	
FS	63	1.2127	15.19	.0	6	.0	14.9951	1065.22	89.32	#D

Time, hhmm: 0923, Rod on Mark: 2, Temperature: 85.0 F, SW: 00

Mean height of instrument for day, cm, & num. = 189 18

END OF DAY

Number of completed runnings in the field book = 1

Error Codes:

A = backsight distance exceeds tolerance of 50.0

B = foresight distance exceeds tolerance of 50.0

C = sight imbalance exceeds tolerance of 2.0

D = sum of sight imbalances for section exceeds tolerance of 4.0

G = setup elevation difference exceeds 3.5 meters

H = temperature gradient is out of range

I = change in temperature gradient between setups exceeds the tolerance

K = rod reading below 0.5 meter

L = standard error of mean reading exceeds tolerance of .1

M = minimum number of sets in mean reading is less than tolerance of 2

## **APPENDIX E**

**EXAMPLE CONTENTS OF A RAW DATA FILE  
AND ITS CORRESPONDING  
FIELDBOOK FILE (\*.BOK) AND BLUEBOOK FILE (\*.BLU)**

RAW DATA FILE - J138GMB.RAW

410001+00000001 42....+00051899 43....+00000005 44....+00003003 45....+00000001  
410002+00000002 42....+00282370 43....-00000019 44....+00026631 45....+00026683  
410003+00000011 42....+00001032 43....+00000001 44....+00000060  
410004+?......1  
110005+00009147 83..16+00000000  
110006+00009147 32..00+00007730 331108+00043221 52..08+0004+002  
110007+00000001 32..00+00009550 332108+00131453 52..08+0006+002  
110008+00000001 573..0-00001820 574..0+00017280 83..06-00008823  
110009+00000001 32..00+00045090 331108+00110025 52..08+0004+002  
110010+00000002 32..00+00043680 332108+00208455 52..08+0004+007  
110011+00000002 573..0-00000410 574..0+00106050 83..06-00018666  
110012+00000002 32..00+00048510 331108+00128353 52..08+0004+005  
110013+00000003 32..00+00050140 332108+00190870 52..08+0004+003  
110014+00000003 573..0-00002040 574..0+00204700 83..06-00024918  
110015+00000003 32..00+00053580 331108+00111000 52..08+0009+010  
410016+!....331  
110017+00000003 32..00+00053580 331108+00111014 52..08+0005+005  
110018+00000004 32..00+00053930 332108+00172225 52..08+0005+007  
110019+00000004 573..0-00002390 574..0+00312200 83..06-00031039  
110020+00000004 32..00+00059660 331108+00096098 52..08+0009+009  
110021+00000005 32..00+00059880 332108+00166518 52..08+0005+006  
110022+00000005 573..0-00001610 574..0+00432750 83..06-00038081  
110023+00000005 32..00+00059960 331108+00118086 52..08+0004+003  
110024+00000006 32..00+00059740 332108+00142890 52..08+0004+003  
110025+00000006 573..0-00003390 574..0+00554450 83..06-00040561  
110026+00000006 32..00+00059690 331108+00171633 52..08+0005+008  
110027+00000007 32..00+00059250 332108+00158641 52..08+0004+004  
110028+00000007 573..0-00003960 574..0+00674390 83..06-00039262  
110029+00000007 32..00+00054370 331108+00129303 52..08+0006+009  
110030+00000008 32..00+00050940 332108+00121578 52..08+0005+007  
110031+00000008 573..0-00000530 574..0+00779700 83..06-00038490  
110032+00000008 32..00+00038350 331108+00161485 52..08+0005+007  
110033+00000009 32..00+00040100 332108+00127847 52..08+0012+009  
110034+00000009 573..0-00002280 574..0+00858140 83..06-00035126  
110035+00000009 32..00+00029250 331108+00112540 52..08+0005+006  
110036+00000010 32..00+00028810 332108+00126935 52..08+0005+008  
110037+00000010 573..0-00001840 574..0+00916190 83..06-00036565  
110038+00000010 32..00+00039880 331108+00135349 52..08+0004+007  
110039+00000011 32..00+00047600 332108+00137832 52..08+0009+017  
110040+00000011 573..0-00009560 574..0+01003660 83..06-00036814  
410041+00000022  
410042+!....331  
110043+00000010 32..00+00044830 331108+00145086 52..08+0004+008  
110044+00000011 32..00+00042420 332108+00147541 52..08+0005+008  
110045+00000011 573..0+00000560 574..0+01003440 83..06-00036811  
110046+00000011 32..00+00019560 331108+00133733 52..08+0012+009  
110047+00000012 32..00+00018960 332108+00135113 52..08+0004+002  
110048+00000012 573..0+00001160 574..0+01041970 83..06-00036949  
110049+00000012 32..00+00014430 331108+00131479 52..08+0005+003  
110050+00000013 32..00+00011280 332108+00137299 52..08+0005+002  
110051+00000013 573..0+00004310 574..0+01067690 83..06-00037531  
110052+00000013 32..00+00023740 331108+00125270 52..08+0005+002  
110053+00009146 32..00+00026460 332108+00207016 52..08+0004+004  
110054+00009146 573..0+00001590 574..0+01117890 83..06-00045705  
410055+00000099 42....+00001148 43....+00000001 44....+00000060 45....+00000010  
410056+00009999

MICHIGAN DIGITAL LEVELING USING THE LEICA NA3003  
 Electronic Digital/Bar-Code Leveling Observations

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Date mmddyy	Observer Initials	Instrument Type	Instrument Number	Rod 1 No.	Rod 2 No.	Coll. Sec.
051899	GMB	3003	282370	26631	26683	-1.9

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Time, hhmm: 1032, Zone: R, Rod on Mark: 1, Temperature: 60.0 F

---

BS/ FS	Point No.	Rod Reading m	Dist m	T Hi T Lo F	No. Obs.	Sigma mm	Delta h /Sum m	Dist. /Sum m	Delta D /Sum m	Com- ments
BS-	9147	.4322	7.73	.0	4	.0	-.8823	17.28	-1.82	
FS	1	1.3145	9.55	.0	6	.0	-.8823	17.28	-1.82	
BS-	1	1.1003	45.09	.0	4	.0	-.9843	88.77	1.41	
FS	2	2.0846	43.68	.0	4	.1	-1.8666	106.05	-.41	
BS-	2	1.2835	48.51	.0	4	.1	-.6252	98.65	-1.63	
FS	3	1.9087	50.14	.0	4	.0	-2.4918	204.70	-2.04	
BS-	3	1.1100	53.58		9	.1				REJ BS
BS-	3	1.1101	53.58	.0	5	.1	-.6121	107.51	-.35	
FS	4	1.7223	53.93	.0	5	.1	-3.1039	312.21	-2.39	
BS-	4	.9610	59.66	.0	9	.1	-.7042	119.54	-.22	
FS	5	1.6652	59.88	.0	5	.1	-3.8081	431.75	-2.61	
BS-	5	1.1809	59.96	.0	4	.0	-.2480	119.70	.22	
FS	6	1.4289	59.74	.0	4	.0	-4.0561	551.45	-2.39	
BS-	6	1.7163	59.69	.0	5	.1	.1299	118.94	.44	
FS	7	1.5864	59.25	.0	4	.0	-3.9262	670.39	-1.95	
BS-	7	1.2930	54.37	.0	6	.1	.0772	105.31	3.43	
FS	8	1.2158	50.94	.0	5	.1	-3.8490	775.70	1.48	
BS-	8	1.6148	38.35	.0	5	.1	.3364	78.45	-1.75	
FS	9	1.2785	40.10	.0	12	.1	-3.5126	854.15	-.27	
BS-	9	1.1254	29.25	.0	5	.1	-.1440	58.06	.44	
FS	10	1.2694	28.81	.0	5	.1	-3.6565	912.21	.17	
BS-	10	1.3535	39.88		4	.1				REJ 22
FS	11	1.3783	47.60		9	.2				REJ 22
BS-	10	1.4509	44.83	.0	4	.1	-.0246	87.25	2.41	
FS	11	1.4754	42.42	.0	5	.1	-3.6811	999.46	2.58	
BS-	11	1.3373	19.56	.0	12	.1	-.0138	38.52	.60	
FS	12	1.3511	18.96	.0	4	.0	-3.6949	1037.98	3.18	
BS-	12	1.3148	14.43	.0	5	.0	-.0582	25.71	3.15	
FS	13	1.3730	11.28	.0	5	.0	-3.7531	1063.69	6.33	
BS-	13	1.2527	23.74	.0	5	.0	-.8175	50.20	-2.72	
FS	9146	2.0702	26.46	.0	4	.0	-4.5706	1113.89	3.61	

---

Time, hhmm: 1148, Rod on Mark: 1, Temperature: 60.0 F, SW: 10

---

Mean height of instrument for day, cm, & num. = 139 14  
 END OF DAY

Number of completed runnings in the field book = 1

Error Codes:

A = backsight distance exceeds tolerance of 60.0  
 B = foresight distance exceeds tolerance of 60.0  
 C = sight imbalance exceeds tolerance of 5.0  
 D = sum of sight imbalances for section exceeds tolerance of 10.0  
 G = setup elevation difference exceeds 3.5 meters  
 H = temperature gradient is out of range  
 I = change in temperature gradient between setups exceeds the tolerance  
 K = rod reading below 0.5 meter  
 L = standard error of mean reading exceeds tolerance of .1  
 M = minimum number of sets in mean reading is less than tolerance of 2

**NABOOK PRELIMINARY BLUEBOOK RECORDS - FILE J138GMB.BLU**

*40*990518242282370	39626631	39626683	140130	30	- .009R1032
*41*99051891479146R10321148F60.060.010	14				KM1.114MT -4.57055GMB
*43*990518914791461032					-319.799



## **APPENDIX F**

**LEICA 60 CM BAR-CODE INVAR SCALE (STRIP)  
AND ITS USE WITH THE LEICA DIGITAL LEVEL INSTRUMENTS  
(NA2000, NA2002, NA3000, NA3003)**

**LEICA 60 CM BAR-CODE INVAR SCALE (STRIP)  
AND ITS USE WITH LEICA DIGITAL LEVEL INSTRUMENTS  
(NA3000, NA3003, NA2000, NA2002)**

The Leica 60 cm bar-code Invar strip provides the means to access some elevation points not accessible using the bar-code leveling rods. Before the strip can be used for conventional leveling, it has to be modified with the addition of a reference index. The design of the strip, as it comes from the factory, has the bar-code on one side and the height reference line on the other side. This may be ok for industrial use, but not for leveling. The following describes a design that was created at the National Geodetic Survey's Instrumentation and Methodologies Branch in Corbin, Va. for use with their NA3003 digital leveling systems.

The Invar strip is needed to run levels to bench marks set vertically in walls, foundations, bridge abutments, or locations where the level rod cannot be placed.

**Fabricating and Attaching the Index (Drawing #1)**

Three components are needed to modify the Invar strip for leveling:

1. the Invar strip as it comes from the factory
2. the Invar strip index, which will be fabricated
3. a screw to attach the index to the Invar strip

These components are depicted in the attached drawing labeled "Drawing #1". Fabricating the index will require the services of a machinist. The idea of the index is to provide a visible height reference point that can be observed when looking at the front (bar-code side) of the Invar strip. The index described in the following is a piece of machined steel attached to the Invar strip in a way that prevents it from moving or twisting and that has a bottom edge that extends the height reference line beyond the outer sides of the Invar strip.

The index should be machined from a piece of steel about 1x1½x¼ inches. Drawing #1 shows two dimensioned views of the index, a front view and a bottom view. The dimensions shown are approximate and for illustrative purposes only. The overall size of the index is not that critical. It should be wide enough to extend the bottom edge at least a quarter of an inch beyond the sides of the strip and tall enough to allow attachment to the strip using the existing hole when the bottom edge is aligned with the height reference mark. First, a ⅜ inch deep groove the width (about 1 inch) of the Invar strip is milled into the steel. The Invar strip should set snugly into the groove. This will prevent the index from twisting and keep the bottom edge parallel to the reference line. After the groove is cut and the bottom edge aligned with the reference line, use the existing hole near the bottom of the Invar strip as a guide and drill a hole for the attachment screw (See Drawing #1). By using this hole, no modification to the Invar strip itself is required. Use a screw size that fits the existing 3 mm (0.118 in) hole as tightly as possible to prevent the index from moving. Drill and tap the hole in the index to match the screw. The remaining milling on the index is to outline the tabs. Remember, the important thing is that the bottom edge of the tabs on the index are aligned with the reference line on the back of the strip.

**Checking Index Location (Drawing #2)**

After fabricating and attaching the index to the Invar strip, it is necessary to check the location of the index to assure that it will provide the correct height reading. Find a stable elevated point at about the height (5.5 ft) of the level instrument onto which both the Invar strip and a level rod can be set (See Drawing #2). Set

up the level instrument 10-13 meters away and hold the Invar strip on the point using either the left or right tab and plumb the strip. Take several sets of height measurements and record the heights. Without moving the level, do the same for the other tab. Next, again without moving the level, set the level rod on the point, plumb and take several measurements. If the index is correctly attached to the Invar strip, all of the height readings should be very close, a tenth or hundredths of millimeters. If not, redo the test and, if necessary, adjust or modify the index so readings will be correct.

### **USING THE INVARI STRIP (Drawings #3 and #4)**

As stated earlier, the 60 cm bar-code invar strip is needed to establish elevations on points or marks that cannot be accessed using a standard leveling rod, such as, bench marks set vertically in foundations, bridge abutments, etc., or special elevation points required by a given survey. The index described above was designed primarily for vertically set bench marks, so it may not work for all situations.

Drawing #3 depicts using the invar strip on a vertically set bench mark disk. The 60 cm bar-code invar strip can only be observed at a distance of 20 meters or less. To use the invar strip on a vertically set bench mark, first find the point on the BM disk that will be leveled to, which on a standard NGS disk is the intersection of the horizontal line and shorter vertical line cast at the center of the disk. Hold the invar strip up the mark with the reference index close to the reference line on the disk. Set up the level instrument less than 20 meters away and at a height where when the line of sight of the leveled instrument intersects the invar strip about in the middle. Two people should hold the invar strip, one at the top to keep it plumb and one at the bottom to align the index to the mark. The strip can be plumbed in several ways:

1. By observing it through the instrument and aligning the left or right edge of the strip with vertical reticle line of the instrument.
2. Use a carpenter's level held up to the side of the strip.
3. Use a handheld level bubble.

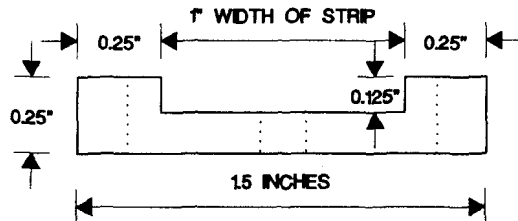
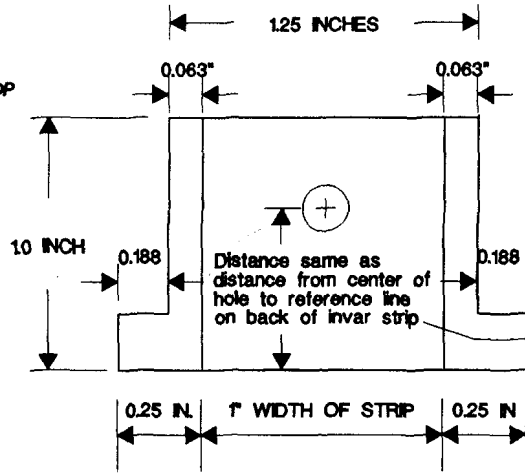
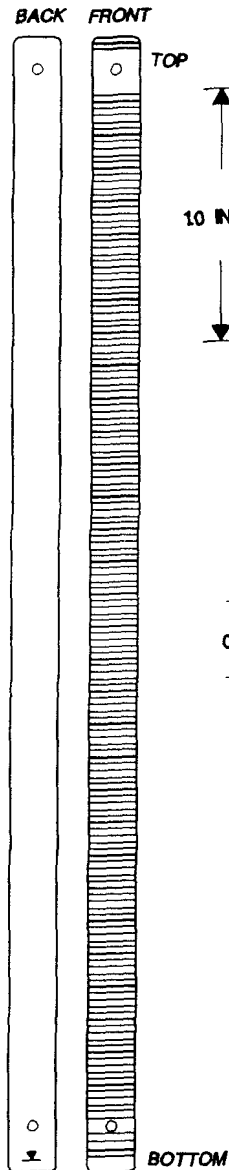
When near plumb, have the person at the bottom of the strip align the bottom of one of the index tabs with reference line on the disk (See Drawing #3). Once assured the index is aligned correctly, the top person check the plumb. If all is correct, press the measure button on the level and take the measurements. Note: The invar strip can also be read in an inverted or upside down position as can the level rods. The instrument, however, must be set for inverted readings. REMEMBER, always reference measurements to the bottom edge of the index tabs, plumb the invar strip and never use the bottom edge of the invar strip as a reference line.

To use the invar strip on a horizontally set bench mark or elevation point, it may be necessary to use a spacer ("plug"). NGS uses calibrated metal 20 mm cylinders (See Drawing #4). Some spacers are magnetic so that they will stick to the steel footplate of a level rod. The spacers are most always used in pairs, one on the backsight rod and the other on foresight rod or invar strip. They raise the rod and invar strip equal amounts so that the difference of elevation between backsight and foresight remains correct. Remember to remove them before reading the next setup. If one is left on, an error, the height of the spacer, will be introduced into the level observations on the next setup. If only one spacer is available, place it first on the backsight rod and take the level measurements, then move it to the foresight and take the measurements.

# REFERENCE INDEX FOR LEICA 60 CM INVARI STRIP

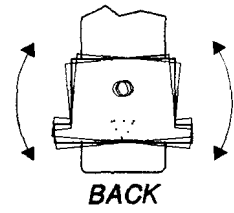
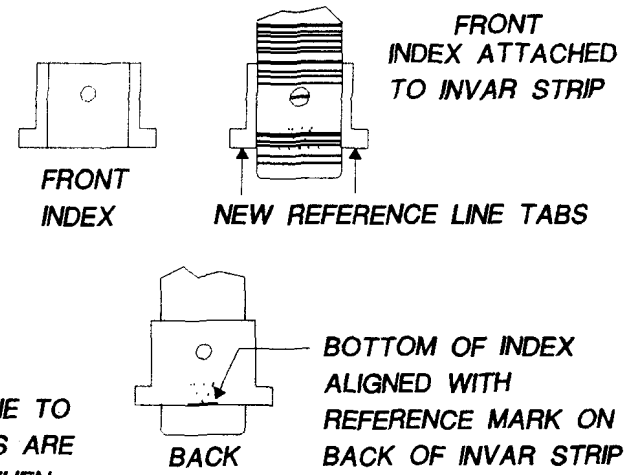
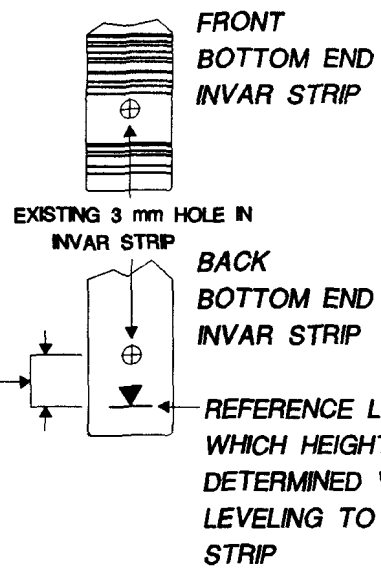
60 CM INVARI  
SCALE OR STRIP

## INDEX DIMENSIONS



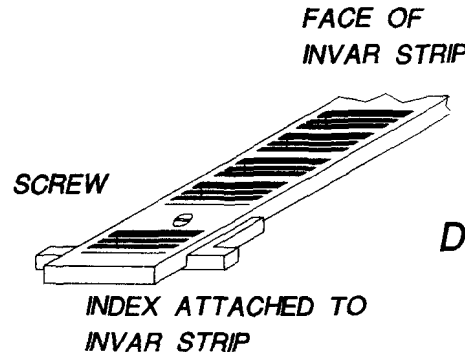
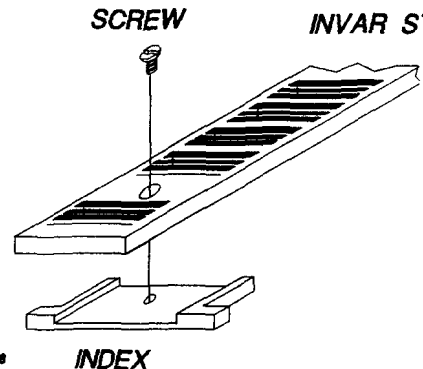
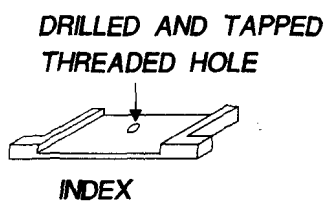
INDEX FRONT

INDEX BOTTOM



INDEX MUST BE ATTACHED WITH THE BOTTOM EDGE ALIGNED AND PARALLEL WITH THE REFERENCE LINE ON THE INVARI STRIP. IT WILL NOT WORK CORRECTLY IF TILTED SINCE THE TABS WOULD BE HIGHER AND LOWER THAN THE REFERENCE LINE.

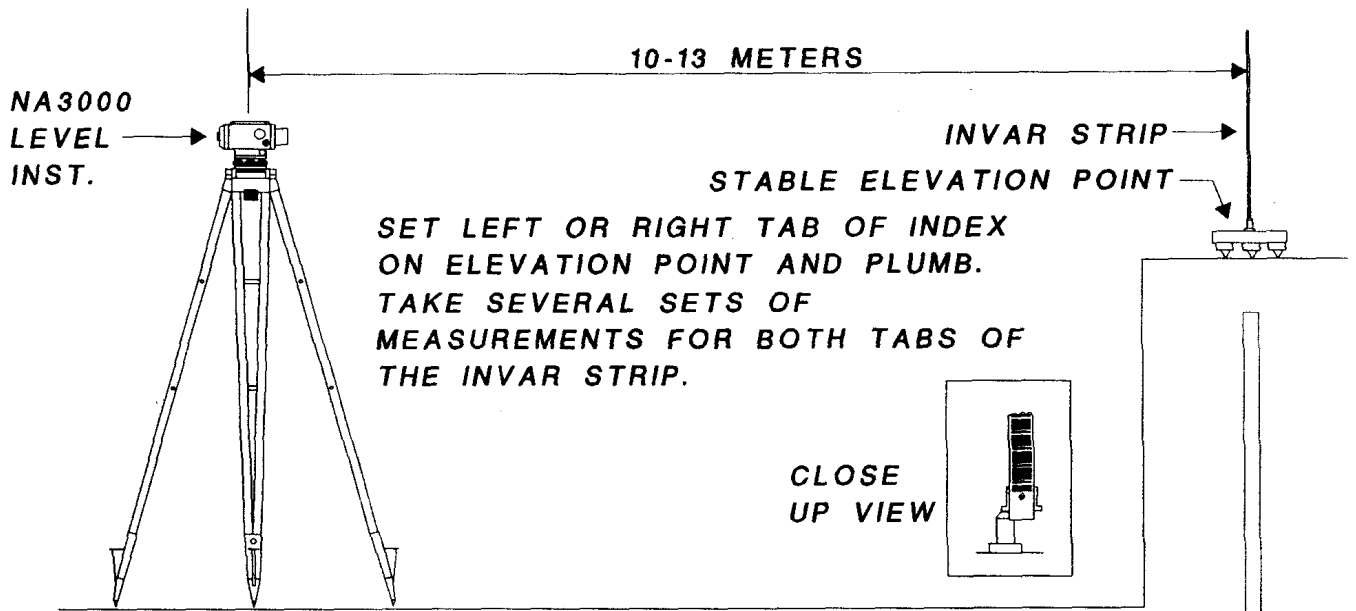
USE A SCREW THE FITS THE SIZE OF THE EXISTING HOLE.



DRAWN BY ORLAND W. MURRAY, NGS, IBM BPL 1/26/96

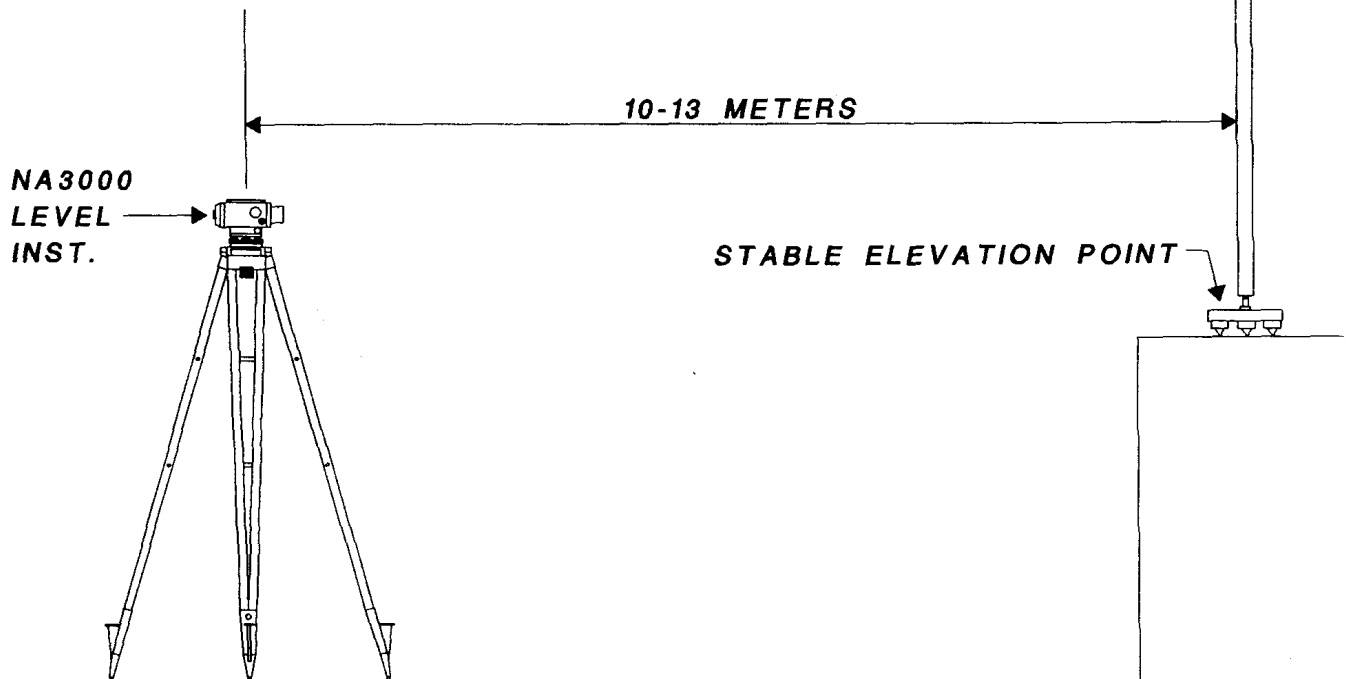
DRAWING #1

# CHECKING LOCATION OF INDEX ON INVAR STRIP

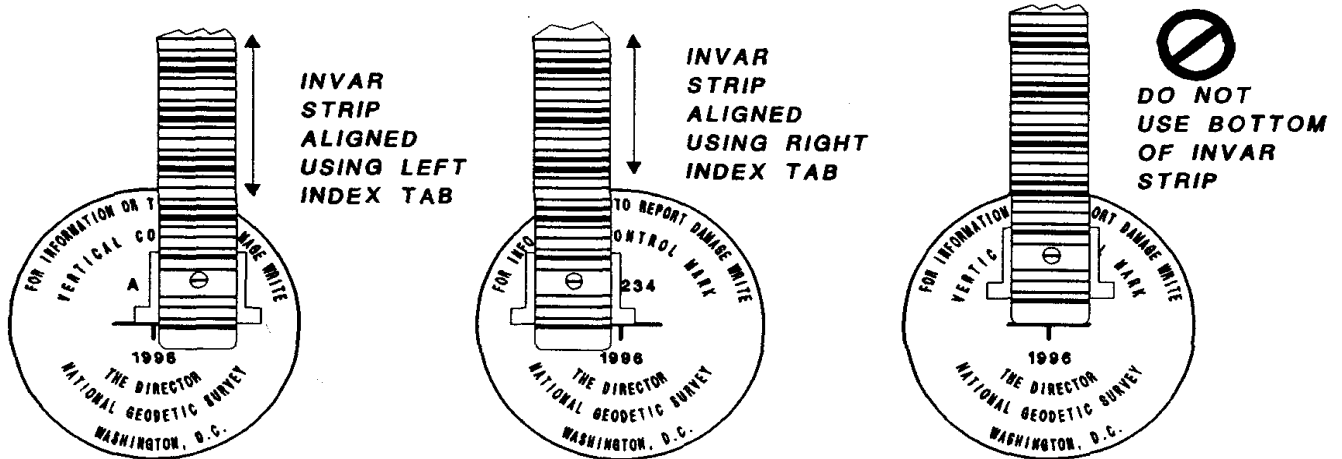
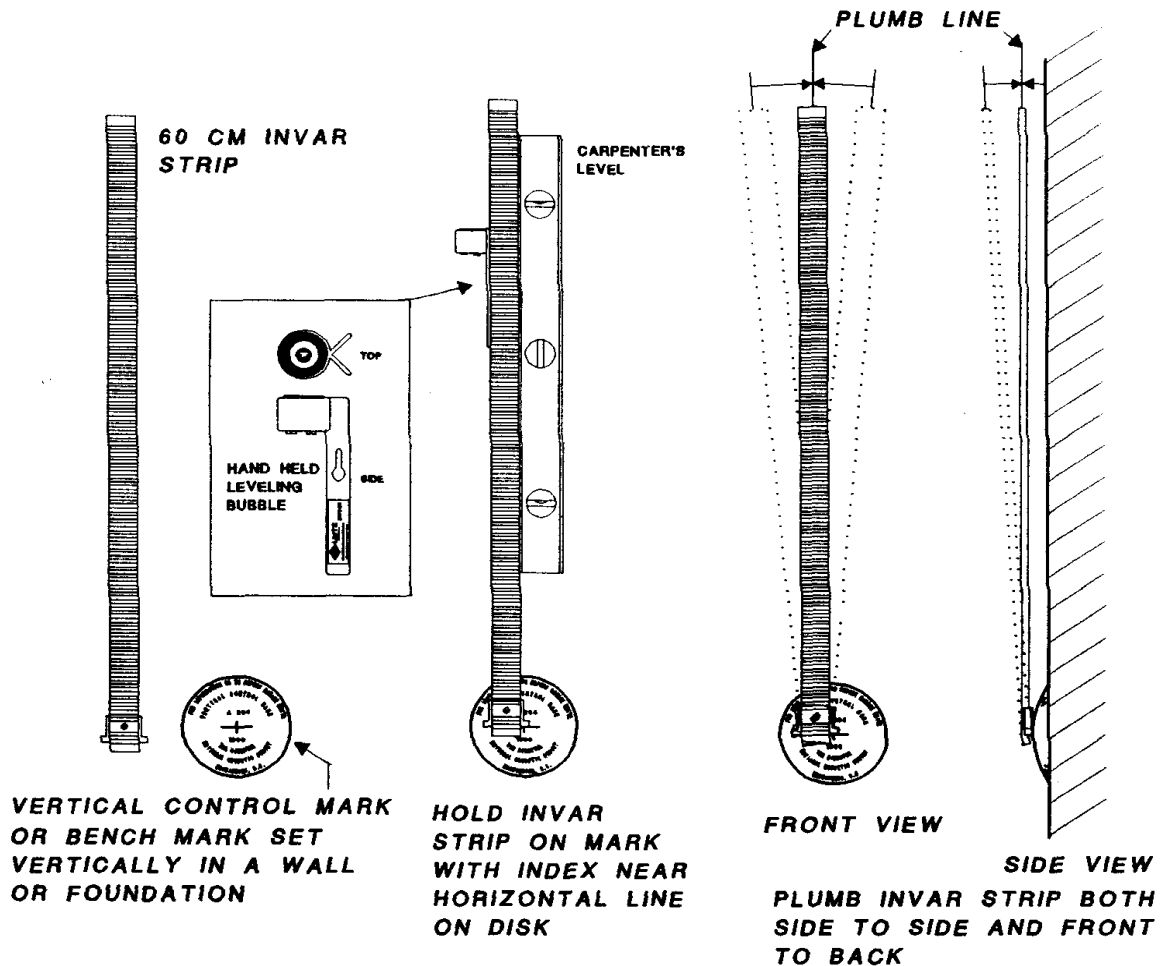


WITHOUT MOVING THE LEVEL, TAKE DOWN THE INVARI STRIP AND SET THE LEVEL ROD ON THE ELEVATION POINT AND PLUMB. TAKE SEVERAL SETS OF HEIGHT MEASUREMENTS. COMPARE THESE TO THE HEIGHTS FOR THE INVARI STRIP. IF THE INDEX IS LOCATED CORRECTLY, THE HEIGHTS SHOULD BE VERY CLOSE.

3 METER  
INVARI  
LEVEL  
ROD

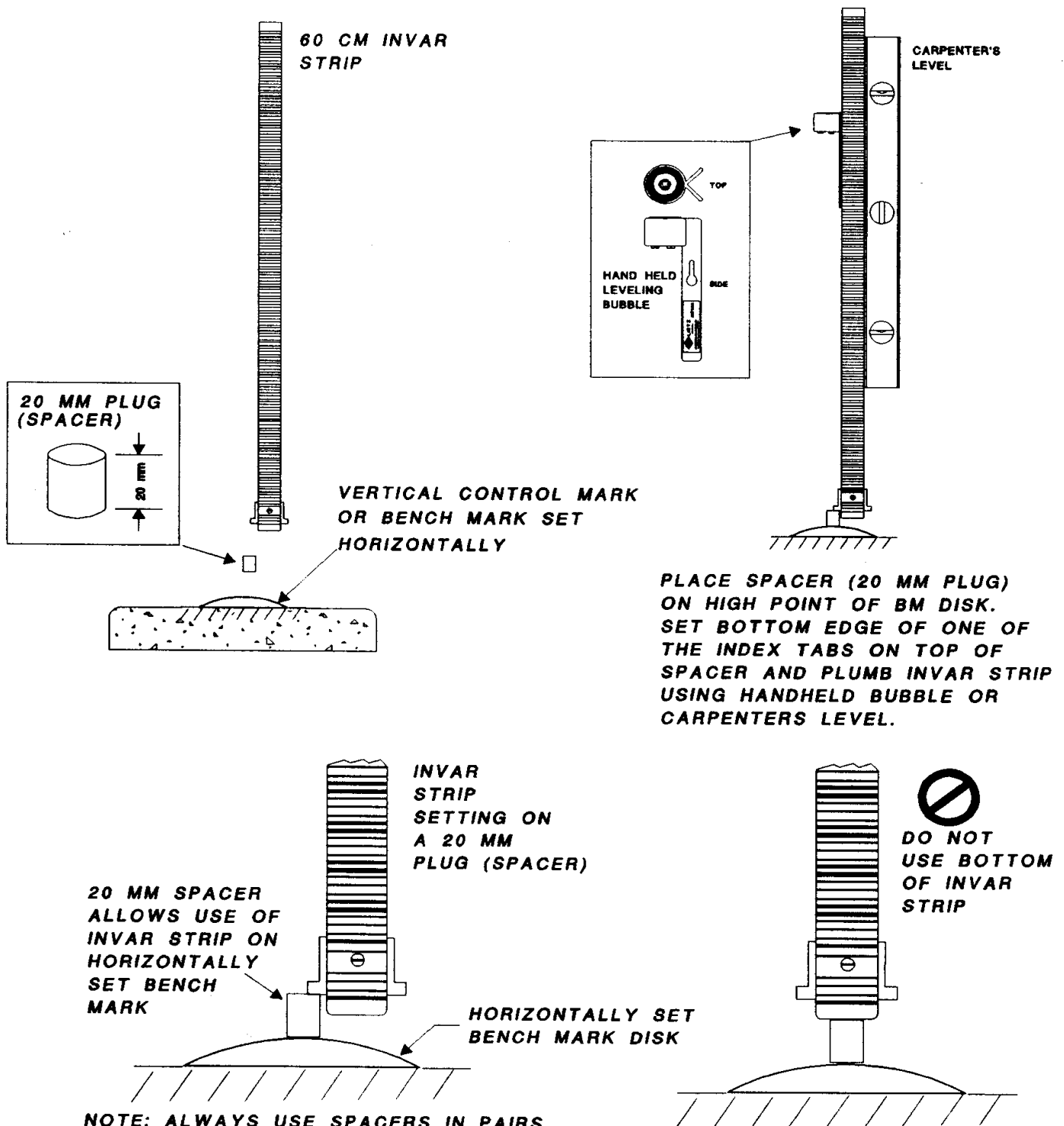


**USING LEICA'S 60 CM INVAR LEVELING STRIP  
TO LEVEL TO A VERTICALLY SET BENCH MARK**



WHILE KEEPING THE INVARI STRIP PLUMB, ADJUST IT UP AND DOWN UNTIL THE BOTTOM EDGE OF THE INDEX REFERENCE TAB IS ALIGNED WITH INTERSECTION OF THE HORIZONTAL AND VERTICAL LINES ON THE VERTICAL CONTROL MARK. USE TWO PEOPLE TO PERFORM THIS PROCEDURE. ONE CAN HOLD AND PLUMB THE INVARI STRIP, WITH THE OTHER ADJUSTS THE INDEX TO THE BENCH MARK. DO NOT USE THE BOTTOM OF THE INVARI STRIP AS THE REFERENCE POINT. USE ONLY THE BOTTOM EDGE OF EITHER OF THE TABS ON THE INVARI STRIP INDEX. (DRAWN BY ORLAND W. MURRAY, NGS)

**USING LEICA'S 60 CM INVAR LEVELING STRIP  
TO LEVEL TO A HORIZONTALLY SET BENCH MARK**



**NOTE: ALWAYS USE SPACERS IN PAIRS ONE AS SHOWN ABOVE AND ONE ON THE BACKSIGHT ROD. IF YOU ONLY HAVE ONE SPACER, PUT IT ON THE BACKSIGHT AND READ IT. THEN PUT IT ON THE FORESIGHT AND READ IT.**

**DRAWN BY ORLAND W. MURRAY, NGS I&M BR.**

**DRAWING #4**

**2. Invar scale with bar code GWCL60**

**2.1. Technical data**

<b>Dimensions (LxBxH)</b>	600mm x 25mm x 1.5mm (23.6inch x 0.98inch x 0.06inch)
<b>Division length (region)</b>	0.0cm-59.6cm (0.0-23.5inch)
<b>Weight</b>	0.175kg (0.39lb)
<b>Material</b>	Invar
<b>Divisions</b>	Bar code
<b>Line length</b>	25mm (0.98inch)
<b>Width of a single element</b>	2.025mm
<b>Manufacturing accuracy</b>	According to DIN Norm 18717
<b>Expansion coefficient for the Invar band</b>	< 1ppm/°C
<b>Usable distance</b>	1.8m-20m (5.9ft-65ft). 20m = recommended maximum distance; as when D increases the usable portion of staff decreases.
<b>Usable length Reduction</b>	Distance dependent ca. 1% of the distance
<b>At max. usable distance 20m</b>	40cm (15.7inch)
<b>Temperature range</b>	
<b>Working</b>	-20°C to +50°C
<b>Storage</b>	-40°C to +70°C

**2.2. Application**

**Application and accuracy:**

Compare with the note found in section 1.2.

**2.3. Handling**

As with industrial bar coded staffs, the usable length of the staff is dependent on the targeting distance. See also the corresponding note from section 1.3 (reduction of usable length).

The scale has two 3mm diameter holes: one each at top and bottom. You can therefore fix the scale to another object. Make sure that the scale is vertical when installing in this way.

Which end is up (down) on the scale? On the reverse side of the scale, opposite the *MADE IN GERMANY* sign, is a level mark. This mark represents the start of the divisions (0.0cm). See figures 2 to 4.

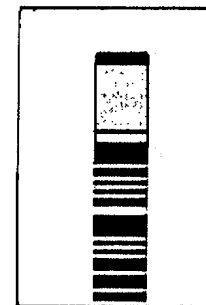


Figure 2:  
Top end

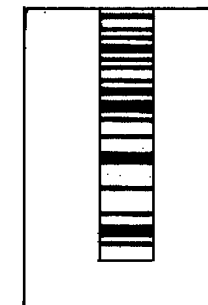


Figure 3:  
Bottom end

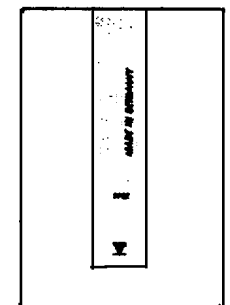


Figure 4:  
Reverse side,  
bottom end with  
zero-mark.



## **APPENDIX G**

### **EXAMPLE BACKUP RECORDING SHEET FILLED OUT AND BLANK**

**LEICA DIGITAL GEODETIC LEVELING - BACKUP RECORDING SHEET**

LINE	PROJECT	FILENAME	PAGE <i>1</i> OF 3
<i>L25391</i>	<i>Michigan Leveling</i>	<i>52599A1.RAW</i>	

SURVEY ORDER	SURVEY CLASS	TIME ZONE CODE	TEMP PROBE TOP HGT	TEMP PROBE BOTTOM HGT
<i>First</i>	<i>Two</i>	<i>R</i>	<i>1.30 m</i>	<i>0.3 m</i>

**CODE 1 - BEGINNING OF DAY OR CHANGE IN OBSERVER OR INSTRUMENT TYPE**

INFO 1 DATE (MMDDYY)	INFO 2 OBS'R #	OBS'R INIT'S	INFO 3 -INST TYPE (2000, 2002, 3000, 3003)	INFO 4 -TEMP CODE (0 for C - 1 for F)
<i>5/25/99</i>	<i>8</i>	<i>CAG</i>	<i>3003</i>	<i>1</i>

**CODE 2 - EQUIPMENT USED**

INFO 1 - INST SERIAL #	INFO 2 - INST COLLIMATION	ROD CODE	INFO 3 - ROD 1 SERIAL #	INFO 4 - ROD 2 SERIAL #
<i>282370</i>	<i>-1.3</i>	<i>396</i>	<i>26631</i>	<i>26683</i>

**CODE 11 - BEGINNING SECTION INFORMATION**

SPSN #	BM DESIG	BENCH MARK STAMPING	INFO 1 TIME (HHMM)	INFO 2 Rod On Mark #	INFO 3 TEMP	DIR F / B
<i>9146</i>	<i>U-340</i>	<i>U-340 1992</i>	<i>9:07</i>	<i>1</i>	<i>44.0</i>	<i>B</i>

**CODE 99 - ENDING SECTION INFORMATION**

SPSN #	BM DESIG	BENCH MARK STAMPING	INFO 1 TIME (HHMM)	INFO 2 Rod On Mark #	INFO 3 TEMP	INFO 4 W/ S #
<i>9212</i>	<i>67700</i>	<i>67700 1999</i>	<i>12:50</i>	<i>1</i>	<i>45.0</i>	<i>20</i>

**SECTION OBSERVATIONS INFORMATION (Recall from level using UP/DN arrows)**

TOTAL SETUPS	TOTAL DISTANCE (D)	ACCUMULATED IMB (d)	ELEV DIFFERENCE (GROUND HGT)
<i>48</i>	<i>3.681 km</i>	<i>0.6</i>	<i>0.66562</i>

CLOSURE	REMARKS
F	<i>-0.66280</i>
B	<i>0.66562</i>
DIF	<i>2.82 mm</i>
ALW'D	<i>7.65 mm</i>
	<i>Used 20 mm on first setup.</i>
	<i>Check Good!!</i>

**WIND CODE** - (0) 0-6 MPH (1) 6-15 MPH (2) >15 MPH

**SUN CODE** - (0) 25% SUNNY (1) 25-75% SUNNY (2) >75% SUNNY

**OTHER INFO CODES**

**CODE 22** - REJECT PREVIOUS BACKSIGHT AND FORSIGHT (NO INFO ENTRIES - PRESS REC)

**CODE 33** - GRADIENT TEMPERATURES (INFO 1 - LOWER PROBE - NO DECIMAL 761 FOR 76.1)  
(INFO 2 - UPPER PROBE - NO DECIMAL 761 FOR 76.1)

**CODE 9999** - END OF DAY, CHG OBS, CHG EQUIPMENT (NO INFO ENTRIES - PRESS REC)

**LEICA DIGITAL GEODETIC LEVELING - BACKUP RECORDING SHEET**

LINE	PROJECT	FILENAME	PAGE	OF

SURVEY ORDER	SURVEY CLASS	TIME ZONE CODE		TEMP PROBE TOP HGT	TEMP PROBE BOTTOM HGT

**CODE 1 - BEGINNING OF DAY OR CHANGE IN OBSERVER OR INSTRUMENT TYPE**

<b>INFO 1</b> DATE (MMDDYY)	<b>INFO 2</b> OBS'R #	OBS'R INIT'S	<b>INFO 3 -INST TYPE</b> (2000, 2002, 3000, 3003)	<b>INFO 4 -TEMP CODE</b> (0 for C - 1 for F)

**CODE 2 - EQUIPMENT USED**

<b>INFO 1 - INST SERIAL #</b>	<b>INFO 2 - INST COLLIMATION</b>	ROD CODE	<b>INFO 3 - ROD 1 SERIAL #</b>	<b>INFO 4 - ROD 2 SERIAL #</b>
		396		

**CODE 11 - BEGINNING SECTION INFORMATION**

SPSN #	BM DESIG	BENCH MARK STAMPING	<b>INFO 1</b> TIME (HHMM)	<b>INFO 2</b> Rod On Mark #	<b>INFO 3</b> TEMP	DIR F / B

**CODE 99 - ENDING SECTION INFORMATION**

SPSN #	BM DESIG	BENCH MARK STAMPING	<b>INFO 1</b> TIME (HHMM)	<b>INFO 2</b> Rod On Mark #	<b>INFO 3</b> TEMP	<b>INFO 4</b> W/ S #

**SECTION OBSERVATIONS INFORMATION (Recall from level using UP/DN arrows)**

TOTAL SETUPS	TOTAL DISTANCE (D)	ACCUMULATED IMB (d)	ELEV DIFFERENCE (GROUND HGT)

CLOSURE	REMARKS
F	
B	
DIF	
ALW'D	

**WIND CODE - (0) 0-6 MPH (1) 6-15 MPH (2) >15 MPH**

**SUN CODE - (0) 25% SUNNY (1) 25-75% SUNNY (2) >75% SUNNY**

**OTHER INFO CODES**

**CODE 22 - REJECT PREVIOUS BACKSIGHT AND FORSIGHT (NO INFO ENTRIES - PRESS REC)**

**CODE 33 - GRADIENT TEMPERATURES (INFO 1 - LOWER PROBE - NO DECIMAL 761 FOR 76.1)  
(INFO 2 - UPPER PROBE - NO DECIMAL 761 FOR 76.1)**

**CODE 9999 - END OF DAY, CHG OBS, CHG EQUIPMENT (NO INFO ENTRIES - PRESS REC)**

**LEICA DIGITAL GEODETIC LEVELING - BACKUP RECORDING SHEET**

LINE	PROJECT	FILENAME	PAGE	OF

SURVEY ORDER	SURVEY CLASS	TIME ZONE CODE	TEMP PROBE TOP HGT	TEMP PROBE BOTTOM HGT

**CODE 1 - BEGINNING OF DAY OR CHANGE IN OBSERVER OR INSTRUMENT TYPE**

INFO 1 DATE (MMDDYY)	INFO 2 OBS'R #	OBS'R INIT'S	INFO 3 -INST TYPE (2000, 2002, 3000, 3003)	INFO 4 -TEMP CODE (0 for C - 1 for F)

**CODE 2 - EQUIPMENT USED**

INFO 1 - INST SERIAL #	INFO 2 - INST COLLIMATION	ROD CODE	INFO 3 - ROD 1 SERIAL #	INFO 4 - ROD 2 SERIAL #
		396		

**CODE 11 - BEGINNING SECTION INFORMATION**

SPSN #	BM DESIG	BENCH MARK STAMPING	INFO 1 TIME (HHMM)	INFO 2 Rod On Mark #	INFO 3 TEMP	DIR F / B

**CODE 99 - ENDING SECTION INFORMATION**

SPSN #	BM DESIG	BENCH MARK STAMPING	INFO 1 TIME (HHMM)	INFO 2 Rod On Mark #	INFO 3 TEMP	INFO 4 W/ S #

**SECTION OBSERVATIONS INFORMATION (Recall from level using UP/DN arrows)**

TOTAL SETUPS	TOTAL DISTANCE (D)	ACCUMULATED IMB (d)	ELEV DIFFERENCE (GROUND HGT)

CLOSURE	REMARKS
F	
B	
DIF	
ALW'D	

**WIND CODE** - (0) 0-6 MPH (1) 6-15 MPH (2) >15 MPH

**SUN CODE** - (0) 25% SUNNY (1) 25-75% SUNNY (2) >75% SUNNY

**OTHER INFO CODES**

**CODE 22** - REJECT PREVIOUS BACKSIGHT AND FORSIGHT (NO INFO ENTRIES - PRESS REC)

**CODE 33** - GRADIENT TEMPERATURES (INFO 1 - LOWER PROBE - NO DECIMAL 761 FOR 76.1)  
(INFO 2 - UPPER PROBE - NO DECIMAL 761 FOR 76.1)

**CODE 9999** - END OF DAY, CHG OBS, CHG EQUIPMENT (NO INFO ENTRIES - PRESS REC)

**LEICA DIGITAL GEODETIC LEVELING - BACKUP RECORDING SHEET**

LINE	PROJECT	FILENAME	PAGE	OF

SURVEY ORDER	SURVEY CLASS	TIME ZONE CODE	TEMP PROBE TOP HGT	TEMP PROBE BOTTOM HGT

**CODE 1 - BEGINNING OF DAY OR CHANGE IN OBSERVER OR INSTRUMENT TYPE**

INFO 1 DATE (MMDDYY)	INFO 2 OBS'R #	OBS'R INIT'S	INFO 3 -INST TYPE (2000, 2002, 3000, 3003)	INFO 4 -TEMP CODE (0 for C - 1 for F)

**CODE 2 - EQUIPMENT USED**

INFO 1 - INST SERIAL #	INFO 2 - INST COLLIMATION	ROD CODE	INFO 3 - ROD 1 SERIAL #	INFO 4 - ROD 2 SERIAL #
		396		

**CODE 11 - BEGINNING SECTION INFORMATION**

SPSN #	BM DESIG	BENCH MARK STAMPING	INFO 1 TIME (HHMM)	INFO 2 Rod On Mark #	INFO 3 TEMP	DIR F / B

**CODE 99 - ENDING SECTION INFORMATION**

SPSN #	BM DESIG	BENCH MARK STAMPING	INFO 1 TIME (HHMM)	INFO 2 Rod On Mark #	INFO 3 TEMP	INFO 4 W/ S #

**SECTION OBSERVATIONS INFORMATION (Recall from level using UP/DN arrows)**

TOTAL SETUPS	TOTAL DISTANCE (D)	ACCUMULATED IMB (d)	ELEV DIFFERENCE (GROUND HGT)

CLOSURE	REMARKS
F	
B	
DIF	
ALW'D	

**WIND CODE** - (0) 0-6 MPH (1) 6-15 MPH (2) >15 MPH

**SUN CODE** - (0) 25% SUNNY (1) 25-75% SUNNY (2) >75% SUNNY

**OTHER INFO CODES**

**CODE 22** - REJECT PREVIOUS BACKSIGHT AND FORSIGHT (NO INFO ENTRIES - PRESS REC)

**CODE 33** - GRADIENT TEMPERATURES (INFO 1 - LOWER PROBE - NO DECIMAL 761 FOR 76.1)  
(INFO 2 - UPPER PROBE - NO DECIMAL 761 FOR 76.1)

**CODE 9999** - END OF DAY, CHG OBS, CHG EQUIPMENT (NO INFO ENTRIES - PRESS REC)

**APPENDIX H**  
**CODE FIELDS INPUT GUIDE**

**SEQUENCE OF DATA RECORDING CODE BLOCKS USING PROGRAM LEVELS BF ON THE LEICA NAXXXX DIGITAL LEVEL**

**START OF DAY**

**1. COLLIMATION CHECK-** Select from PROG write on Backup Sheet

**2. CLEAR RECORDING MODULE** - Press PROG key, use UP/DN arrows to select Rec Module, use UP/DN arrows to select ERASE DATA, press Run and enter password, 951, then Run

**Code 1 - Beginning of Day or Change in Observer/instrument Type**

- 1) Date (MMDDYY)
- 2) Observer's code number (1, 2, or 10, etc.)
- 3) Instrument type number (like 2000, 2002, 3000, 3003, etc.)
- 4) Temperature code ( 0 for EC or I for EF)

**Code 2 - Equipment Used**

- 1) Instrument serial number (like 90810)
- 2) Collimation error in seconds of arc (no decimal, like -58 for -5.8")
- 3) Rod 1 serial number (like 25458)
- 4) Rod 2 serial number (like 25534)

**Code 11 - Start of Leveling Section**

- 1) Time (HHMM, 24 hour local)
- 2) Rod on mark ( 1 or 2)
- 3) Temperature (no decimal, key 75 for 75.0 degrees, omit if recording temperatures for gradient)

**RUN LEV BF PROGRAM - PRESS the PROG KEY and USE UP/DN arrow keys to select P START LEV BF press RUN.**

- a. START L sure? Press RUN/YES
- b. PtNo 1 Enter Starting SPSN number like 1124
- c. INCREM. 1 Increment should be 1.
- d. GrHt ? If not already set to 0.0000, PRESS NO/CE key to enable a new height. Last digit flashes. Press enter 0.000 and then press RUN to store.
- e. BACK No= Ready to read the BACKSIGHT ROD. Display shows starting SPSN number.  
1124

**The following two codes are to be entered during observations:**

**Code 22 - Reject Previous Backsight and Foresight (No Data Entries)**

- a. An individual Backsight of Foresight can be rejected at any time by pressing the REP key.
- b. A backsight / foresight pair can also be rejected in the data by entering a CODE 22 with no info entries. At the first info prompt just press REC key.

**Code 33 - Temperature** (End of each setup if recording two temperatures for gradient, else omit.)

- 1) Lower probe (no decimal, key 761 for 76.1 degrees)
- 2) Upper probe (no decimal, key 750 for 75.0 degrees)

**RECORD ENDING SPSN number as point number for LAST FORESIGHT of each section. The ending SPSN number must be entered PRIOR TO READING FINAL FORESIGHT.**

- a. FORE NO= 8 Display shows ready to read foresight at setup 8. Press the NR key
- b. ind. PtNo Press the RUN key
- c. ind. No 8 Last digit of current increment number flashes. Enter ending SPSN number like 1125 and press the RUN key.
- d. FORE NO= 1125 Ready to read foresight with ending SPSN number displayed.

**Code 99 - End of Section**

- 1) Time (HHMM, 24 hour local)
- 2) Rod on mark (1 or 2)
- 3) Temperature (no decimal, key 75 for 75.0 degrees, omit if recording temperatures for gradient)
- 4) Wind & sun code, like 21

**WIND CODE:**

- 0 - If wind speed averaged less than 10 km/hr (6 miles/hour)
- 1 - If wind speed averaged 10 to 25 km/hr (6 to 15 miles/hour)
- 2 - If wind speed averaged greater than 25 km/hr (15 miles/hour)

**SUN CODE:**

- 0 - If less than 25 percent of the setups are performed in sunny conditions.
- 1 - If 25 to 75 percent of the setups are performed in sunny conditions.
- 2 - If more than 75 percent of the setups are performed in sunny conditions.

**RECALL DATA** - Use Up/Dn arrows to recall section data and record on Backup Recording Sheet

**Code 11 - To continue leveling the next section, begin again with CODE 11 above.**

**Code 9999 - End of day (no data entries) At the end of the day enter a CODE 9999. At the Info 1 prompt, press the REC key to record.**

## **APPENDIX I**

### **EXAMPLE ABSTRACT OUTPUT FROM ABSTRA PROGRAM**

-\*- FIELD ABSTRACT -\*-

990062-990603 HGZ L25391 1 4.0 MM ORDER 1 CLASS 2 PAGE 1  
 LEVEL LINE REED CITY VIA BIG RAPIDS VIA LANSING TO JACKSON  
 COLLIMATION CHECK TAKEN DAILY AND STORED INTERNALLY IN THE NA3003 AND  
 USED TO CORRECT EACH ROD READING. THE TANGENT OF THE COLLIMATION X  
 1000 IS STORED IN THE 40 RECORD COLS 65-69

FROM TO	START	F/B	DIST TOTAL (KM)	ELEV DIFF (MT)	-(F+B) TOTAL (MM)	MEAN DIFF FLD ELEV (MT)	I C
9145 T 340						330.55461	
9145 T 340	5170954	F	1.26	-18.49482	*	0.00	-18.49482 1
9146 U 340			1.26			0.00	312.05979
9146 U 340	5171310	B	3.66	-0.66280	*@	-2.86	0.66423 1
9212	5240907	F	3.68	0.66566	*@		1
	SL 1		4.92			-2.86	312.72402
9146 U 340	5181032	B	1.11	-4.57081	*	0.00	4.57081 1
9147 M 15			2.38			0.00	316.63060
9147 M 15	5181301	F	1.26	7.12043	*	0.91	7.12089 1
5301 A 341	5181433	B	1.25	-7.12134	*		1
			3.63			0.91	323.75149
5301 A 341	5190845	F	2.50	18.17463	*	2.09	18.17568 1
5302 B 341	5191333	B	2.48	-18.17672	*		1
			6.11			3.00	341.92717
5302 B 341	5200912	F	1.75	-13.13508	*	0.49	-13.13484 1
5303 C 341	5201227	B	1.76	13.13459	*		1
			7.86			3.49	328.79233
5303 C 341	5201502	F	1.61	-28.46858	*	-1.34	-28.46925 1
5304 D 341	5250938	B	1.62	28.46992	*		1
			9.48			2.15	300.32308
5304 D 341	5261009	F	2.32	-12.72924	*	0.86	-12.72881 1
5305 E 341	5261218	B	2.32	12.72838	*		1
			11.80			3.01	287.59427
5305 E 341	5271020	F	2.52	1.39076	*	-0.34	1.39059 1
5306 F 341	5271355	B	2.52	-1.39043	*		1
			14.32			2.67	288.98486
5306 F 341	6011010	F	2.08	7.71164	*	1.17	7.71222 2
5307 G 341	6011415	B	2.07	-7.71281	*		2
			16.39			3.84	296.69708
5307 G 341	0620955	F	2.05	-5.56636	*	1.61	-5.56556 2
5308 H 341	0621252	B	2.05	5.56476	*		2
			18.44			5.44	291.13152



-\*- FIELD ABSTRACT -\*-

990062-990603                    HGZ L25391 1            4.0 MM ORDER 1 CLASS 2            PAGE 2  
 LEVEL LINE REED CITY VIA BIG RAPIDS VIA LANSING TO JACKSON

FROM TO	START	F/B	DIST TOTAL (KM)	ELEV DIFF (MT)	-(F+B) TOTAL (MM)	MEAN DIFF FLD ELEV (MT)	I C
5308 H 341	6030930	F	2.46	-8.60999 *	2.35	-8.60882	2
5309 HOODPORT	6031315	B	2.45	8.60765 *			2
			20.88		7.79	282.52270	
5309 HOODPORT	6021550	B	0.46	1.12308 *	0.10	-1.12313	2
5310 HOODPORT AZ MK	6021637	F	0.47	-1.12318 *			2
			21.34		7.89	281.39957	

## ELEVATION REJECTION AND ERROR CODES

- C - section elevation difference was rejected for cause  
ie. \*43\* record rejection code set to "F"
- R - section elevation difference was rejected by Halperin rejection algorithm
- @ - section elevation difference does not include refraction correction
- \* - section elevation difference does not include rod correction

INSTRUMENT CODE	INSTRUMENT	RODS
1	243 - 282370	396 - 26631      396 - 26683
2	243 - 282370	396 - 27843      396 - 27972

LEVEL LINE SECTION RUNNING TREE

9145  
9146 (9212)  
9147  
5301  
5302  
5303  
5304  
5305  
5306  
5307  
5308  
5309  
5310

FROM	TO	N. LATITUDE	W. LONGITUDE	FIELD DISTANCE	VS. COMPUTED
	9145	435314	0853150	0.00	0.00
9145	9146	435305	0853045	1.26	1.48
9146	9212			3.66	0.00
9146	9147	435233	0853032	1.11	1.03
9147	5301	435155	0853036	1.25	1.18
5301	5302	435040	0853010	2.48	2.39
5302	5303	434946	0853013	1.75	1.67
5303	5304	434856	0853009	1.61	1.55
5304	5305	434742	0853011	2.32	2.28
5305	5306	434627	0853013	2.52	2.32
5306	5307	434523	0853007	2.07	1.98
5307	5308	434420	0853011	2.05	1.95
5308	5309	434312	0852952	2.45	2.14
5309	5310	434300	0852940	0.46	0.46

SECTION

FROM TO

E R R O R M E S S A G E S

5400 \*\*\* Bench mark description exists but mark not leveled to.  
5311 \*\*\* Bench mark description exists but mark not leveled to.  
5320 \*\*\* Bench mark description exists but mark not leveled to.  
5401 \*\*\* Bench mark description exists but mark not leveled to.  
5410 \*\*\* Bench mark description exists but mark not leveled to.  
5312 \*\*\* Bench mark description exists but mark not leveled to.  
5321 \*\*\* Bench mark description exists but mark not leveled to.  
5330 \*\*\* Bench mark description exists but mark not leveled to.  
5402 \*\*\* Bench mark description exists but mark not leveled to.

## **APPENDIX J**

**POLICY OF THE NATIONAL OCEAN SERVICE  
REGARDING INCORPORATION OF GEODETIC DATA  
OF OTHER ORGANIZATIONS INTO THE  
NATIONAL GEODETIC SURVEY DATA BASE**

**ANNEX K  
PROJECT REPORT INSTRUCTIONS  
OUTLINE FOR A VERTICAL CONTROL PROJECT  
AND EXAMPLE NGS PROJECT REPORT**

**POLICY OF THE NATIONAL OCEAN SERVICE REGARDING THE  
INCORPORATION OF GEODETIC DATA OF OTHER ORGANIZATIONS INTO  
THE NATIONAL GEODETIC SURVEY DATA BASE**

The National Ocean Service (NOS), Coast and Geodetic Survey, National Geodetic Survey (NGS), has determined that the value to the National Spatial Reference System (NSRS) of geodetic observations obtained by other Federal, state, and local organizations compensates for the costs incurred by the Federal Government to provide quality assurance, archiving, and distribution functions for surveys contributing to the public good. Agencies submitting data must adhere to the following requirements. The final decision whether to accept data will be the responsibility of the Chief, NGS.

**FORMAT** The survey data must be submitted in the automated formats specified in the Federal Geographic Data Committee (FGDC), Federal Geodetic Control Subcommittee (FGCS), publication Input Formats and Specifications of the National Geodetic Survey: Data Base (September 1994), which describes the formats and procedures of submitting data for adjustment and assimilation into the NGS data base. Separate volumes of this publication refer to horizontal control data (volume I), vertical control data (volume II), and gravity control data (volume III). Guidelines for submitting three-dimensional Global Positioning System (GPS) relative positioning data are contained in Annex L of volume I.

**ACCURACY** Standards of accuracy are given in Standards and Specifications for Geodetic Control Networks (1984) and Geometric Geodetic Accuracy Standards and Specifications for Using GPS Relative Positioning- Techniques (May 1988).

The survey data must be properly formatted as set forth by FGCS and meet the minimum accuracy requirements of:

First-order horizontal accuracy standards for GPS or conventional horizontal surveys.

Second-order, class II vertical accuracy standards for conventional geodetic leveling.

Third-order gravity accuracy standards for gravity surveys.

In addition, these data standards and accuracies must be verified, using currently available NGS software, by the provider prior to submitting the survey project to NGS.



Please note: Effective September 1, 1995, survey project data must meet the above minimum accuracy standards to be accepted for inclusion in the NGS data base. Surveys that are of lower order than given above will be accepted only in exceptional cases approved by the Chief, NGS.

- MONUMENTATION** Monumentation must be uniquely identified and conform to minimum prescribed standards. Guidelines for control monuments are given in NOAA Manual NOS NGS 1 (1978), Coast and Geodetic Survey Special Publication 247 (1950), and in Geometric Geodetic Accuracy Standards and Specifications for Using GPS Relative Positioning Techniques, appendix H (May 1988). Monument descriptions must be submitted in the automated format specified in Input Formats and Specifications of the National Geodetic Survey Data Base (September 1994).
- FIELD RECORDS** Original field records (or acceptable copies) are requested with data submission. NGS will retain these records in the National Archives and Records Administration. This is necessary in the event that questions arise concerning the surveys upon which the adjusted data are based. Where digital records are required, e.g., GPS projects, such records will be submitted to NGS in a format specified by NGS at the time of submission. If field records are not submitted with the data, NGS reserves the right to inspect these records upon request. If field records are not submitted on request, NGS reserves the right to not accept and/or not publish the data, and if published, a disclaimer may be attached to the published data.
- PROJECT REPORT** A project report, including sketches, is required for geodetic control projects. It should be submitted with the data and adhere to the form outlined in annexes K and L (GPS) of Input Formats and Specifications of the National Geodetic Survey Data Base (September 1994).
- REVIEW** Reconnaissance reports describing proposed connections to the NSRS, along with the planned instrumentation and field procedures, must be submitted prior to beginning a project. This will enable NGS to comment on the proposed connections, using information available in the NGS data base concerning the accuracy and condition of these points, and to assure conformance with minimum accuracy standards and criteria. The project review could save the submitting agency the expense of placing data in computer- readable form that will fail accuracy or monumentation criteria. NGS work schedules and computer requirements can also be developed from this information. Upon receipt of the reconnaissance reports, NGS will respond within 10 working days.

**RETURNED  
SUBMISSIONS**

With verbal concurrence of the submitting organization, a limited number of errors in the submitted data will be corrected by NGS. Beyond a reasonable limit of about 1 percent, the entire project will be returned to the sender.

**SUBMITTED  
PROJECTS**

Projects must be submitted such that the unit of field work will compute independently of other projects. They must be connected to points already in the NGS data base. All data pertaining to a project (observations, descriptions, adjustments, reports, etc.) must be simultaneously received by NGS. Due to a limited capability to review, analyze, and edit survey data before they are loaded into the NGS data base, data contributed for inclusion into the data base should be processed and adjusted by the provider, using currently available NGS software, prior to submittal to NGS.

**COST**

There is no cost to submitters for NGS quality review, archiving, and distribution functions for survey data submitted according to the requirements discussed above. When NGS is requested to provide on-site instruction with respect to data formatting and/or data processing, the requesting organization will be charged for travel and per diem costs.

**PUBLICATIONS**

All the publications referenced in this statement are available from the National Geodetic Information Branch, N/CG174, NOAA, 1315 East-West Highway, Silver Spring, MD 20910-3282.

Telephone (301) 713-3242 Fax (301) 713-4172

## **ANNEX K**

### **PROJECT REPORT INSTRUCTIONS**

Information concerning data preparation and transmittal to NGS is found in Chapter 1, HORIZONTAL CONTROL (HZTL) DATA, in Chapter 5, VERTICAL CONTROL (VERT) DATA, and in Chapter 9, GRAVITY CONTROL (GRAV) DATA. The section titled 'Media for Submitting Data' describes procedures for packaging of the data as well as information required in the letter of transmittal pertaining to the floppy disks or magnetic tape. The transmittal letter should inventory the total contents of the shipment. In addition, special instructions for submitting CPS relative positioning data to the NGS are provided in ANNEX L.

The most important supporting document that should be included with the shipment is the project report. The project report is the permanent hardcopy record that summarizes project accomplishments. It describes the general project goals and the equipment and procedures employed to meet specific conditions and requirements.- The report provides information useful for verification and adjustment, including detailed explanation of unusual or special features of the project. The recommended content of a project report follows. The project sketch is an attachment to the report. For projects totally or partially supported by NGS, a different report may be required.

NOTE: Report Outline for a Horizontal Control Project not included herein. Only the report outline for a Vertical Control project is included.

## Report Outline for a Vertical Control Project

- I. Title page. List the type of report (Vertical Control), order and class of survey, project title including the state, any appropriate identifying number (for projects that have been assigned HGZ accession numbers by NGS, the numbers should be listed on the title page), beginning and ending dates of both mark setting and leveling, agency name, and the name of the project director (supervisor). The project title should include the locality of the project.
  
- II. The report should address the following topics:
  - A. Location. Briefly describe the project area, including state or states in which it is located. Note the number of lines, their general configuration, and their-total distance.
  
  - B. Scope
    1. Purpose. State the purpose of the survey and the extent to which the requirements were satisfied.
    2. Specifications. State the specifications which were followed and the methods used.
    3. Monumentation. Describe the monumentation that was established and recovered.
    4. Instrumentation. Describe the equipment, including a list of instruments, rods (including calibration information), and recording equipment. Include model and serial numbers of all equipment and the dates they were in use. Note the reasons for return of equipment for repairs or adjustment. For rod calibrations, cite which previously submitted calibration data are to be used to process the project. If none were submitted previously, include such calibration data with the leveling data submitted with this report.
  
  - C. Comments (THIS IS THE MOST IMPORTANT SECTION OF THE REPORT!)
    1. Reconnaissance. If a reconnaissance plan was submitted and approved by NGS prior to beginning the field measurements, describe any changes from the original reconnaissance and the reasons for the changes.
    2. Specifications. Describe any deviations from the specifications used and the reason for such deviations.
    3. Routes. Briefly describe each line, including line number or other identification, topography and climate, features of the routing such as control point spacing and frequency of connections, unusual points leveled, unusual procedures, river or valley crossings, and ties established.

4. Problems. Describe all problems encountered, such as: moved or "suspect" marks, systematic new-minus-old comparisons, poor ground or atmospheric conditions, etc.
  5. Recommendations. Mention specific sections that required additional work as a result of preliminary analysis. Describe areas which may require additional leveling in the future.
- D. 1. Closures. List loop closures for all loops of concurrent surveys. State the-accumulated forward-backward difference for each line.
2. Check-measurements. Compute and list new-minus-old tabulations for all releveling of previously leveled lines. Also, list the average and maximum disagreements.
  3. Progress. (Needed only if submitting organization is supported by NGS funding and/or equipment). Total progress along lines, double-run progress, single-run progress, total distance leveled, distance leveled as reruns, and number of sections.
  4. Reruns. For all sections that were relevelled for any reason other than those exceeding the tolerance limit, list the sections and the reasons for releveling.

E. Status

1. Records. Describe the current status and future disposition of the station and observation records. If submitted to NGS, they will be archived in a Federal records center.
  2. Contact. Provide the name and telephone number of a person to contact regarding questions which may arise during NGS processing of the data.
- III. Attachments to the report. Include as an attachment to the report a simple sketch of the project area showing completed lines, junctions, and loops. A section of the State Index Map of Control Leveling is sufficient with progress marked and lines clearly labeled. Also, attach copies of sketches showing loop closure computations.

**"EXAMPLE NGS PROJECT REPORT - NOT ALL ITEMS  
MAY BE APPLICABLE TO YOUR PROJECT"**

U.S. DEPARTMENT OF COMMERCE  
NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION

NATIONAL OCEAN SERVICE

NATIONAL GEODETIC SURVEY  
**Charles W. Challstrom**  
Acting Director

**PROJECT REPORT**  
First Order Class II Levels  
Leveling and Mark Setting  
**TASK NUMBER 8K6D4000**

April 22, 1999 - April 30, 1999

**XXXX NAME XXXXXX**  
Project Director - NL4130  
Survey Section C

Project Title

**PROJECT TITLES ARE SAME AS LINE TITLES**

HGZ No.	Line Title
L26012	CHICO USCG CORS SITE SURVEY 1999 NEAR BIGGS, CALIFORNIA
	JOB CODE <u>T5</u>

**CONTENTS**

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B. Purpose -----	1
<i>II. PROJECT AREA</i>	
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B. Terrain -----	1
<i>III. CONDITIONS AFFECTING PROGRESS</i>	
A. Climate and Terrain -----	1
<i>IV. DEVIATION FROM INSTRUCTIONS -----</i>	<i>1</i>
<i>V. ORGANIZATION</i>	
A. Personnel -----	2
B. Liaison -----	2
C. Equipment -----	2-3
<i>VI. FIELD WORK</i>	
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(2) Bench mark setting and recovery --	3
(3) Leveling procedures -----	3
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**PROJECT STATISTICS**  
**Survey Unit C**

*I. INTRODUCTION*

**A. Authority**

Bench Mark Setting and Leveling to CORS Site near Biggs, California. Authorized by Charles W. Challstrom, Acting Director, National Geodetic Survey.

**B. Purpose**

The purpose of this leveling project is to establish precise NAVD 88 heights for the bench marks located near the CORS Site.

*II. PROJECT AREA*

**A. Locality**

The CORS site is located about 70 miles north of Sacramento, 25 miles Southeast of Chico, about 10 miles Southwest of Oroville and about 3 miles East of Biggs in north central California.

**B. Terrain**

The terrain is flat.

*III. CONDITIONS AFFECTING PROGRESS*

**A. Climate and Terrain**

The climate was mild. The Terrain is flat.

*IV. DEVIATION FROM INSTRUCTIONS*

The line title was changed to read: CHICO USCG CORS SITE SURVEY 1999 NEAR BIGGS, CALIFORNIA

*V. ORGANIZATION*

**A. Personnel**

<b>Permanent Employees</b>	<b>Title</b>
NAME .....	Project Director
NAME .....	Mark setter/Rod Person
NAME .....	Computer
NAME .....	Mark



Setter/Recorder/Observer

NAME ..... Recorder/Rod  
Person/Observer

NAME ..... Assistant Computer/Utility

**Schedule A. Employees                      Title**

NAME ..... Rod Person      EOD 04/19/99

NAME ..... Rod Person      EOD 04/12/99

**B. Liaison**

Liaison was maintained with the Field Operations Branch, Spatial Reference System Division. (**See Contact Sheet**)

**C. Equipment**

**(1) Instruments and serial numbers**

Ni002

456583

**(2) Rod pairs, Unmatched Kern, Invar ½ CM GRAD**

**Serial Numbers**

352134/368781

**(3) Vehicles**

1 - 1 ton Chevrolet/utility bed for mark setting.

1 - 3/4 ton Chevrolet suburban equipped for conventional and Phase II leveling procedures.

2 - Honda CT-110 motorbikes for Phase II leveling.

**(4) Field Equipment**

2 - Data collector, programmable CMT MC-V

2 - Thermometer, Digital Doric MDL-450

2 - Computers, Micro Computers, TI TM4000E

2 - Printers - 1 Cannon BJ 200EX ADP1 ADP, 1 Cannon BJC-240,- various hand tools, mallets, turning plates and pins for leveling and mark setting.

V. ORGANIZATION (continued)

C. Equipment (continued)

(5) Office Equipment

2 - Computers, 2 - Dell Latitude LM intel inside pentium. 3 - Printers, 1 HP Deskjet Portable, 1 HP Deskjet 694C, and 1 Cannon BJC-620, 1 - XC540 Xerox Copying Machine.

VI. FIELD WORK

A. Chronology

(1) Project & Line Titles

Project Title

PROJECT TITLES ARE SAME AS LINE TITLES

HGZ No. Line Title

L26012 CHICO USCG CORS SITE SURVEY 1999 NEAR BIGGS,  
CALIFORNIA

JOB CODE T5

(2) Bench Mark Setting and Recovery

Mark setting and recovery were performed according to project instructions, established procedures, and mark setting manuals and memorandum.

(3) Leveling Procedures

Motorized leveling is with the use of 1-suburban for transporting the instrument man and recorder, and 2-Honda CT110 motorcycles for transporting the rod person, and leveling rods between setups.

Conventional leveling is with all personnel being afoot.

VI. *FIELD WORK* (continued)

A. **Chronology** (continued)

(4) **Leveling Progress**

**L26012 CHICO USCG CORS SITE SURVEY 1999 NEAR BIGGS,  
CALIFORNIA**

6.495 km double run  
2.370 km single run  
15.360 km total linear distance

8.865 km forward progress

Setups=196

Leveling date: 04/28/99 - 04/30/99

Bench mark recovery: (13-rec., 1 NR) Marks set  
6: 2 3D Stainless Steel Rod Class B Marks in  
sleeve, 4 structure class B marks. The 2-3D  
marks are Reference Marks **CHICO A and CHICO B**

Mark recovery and setting began (04/26/99)  
Completed (04/28/99)

B. **Specifications**

Leveling was performed according to First Order  
Class II Standards. In accordance with Project  
instructions, and as outlined in the NOAA NGS  
Operations Manual, and the Geodetic Leveling Manual.

C. **Data Formats and Handling**

All data was recorded and processed as outlined by  
Project Instructions, the NOAA NGS Operations  
Manual, and the Geodetic Leveling Manual.

VI. **FIELD WORK** (continued)

D. **Statistics**

The computer printout of the "**Vertical Bench Mark and Field Statistics**" for each line are attached.

**Personnel Days**

5.0	----	Project Director
3.0	----	Computer
3.0	----	Mark setting/recovery
2.5	----	Observer
2.5	----	Recorder
5.0	----	Rod person
10.0	----	Travel
<u>6.0</u>	----	Training
37.0	----	Total

Level and Bench Mark Setting/Recovery "**UNIT**" Down  
time

<u>3.0</u>	----	due to move travel
3.0	----	total Unit Days

**New marks established**

0	----	Class A
<u>6</u>	----	Class B
6	----	Total

**Marks recovered**

3	----	Class A
4	----	Class B
5	----	Class C
<u>1</u>	----	Class D
13	----	total

E. **Logistics**

The field computations and project support was managed from the National Geodetic Survey field office in Oroville, California.

**VI. FIELD WORK** (continued)

**F. Summary**

Both leveling procedures were used as dictated by traffic, road shoulders, and other terrain features. (see Item 3 Page 3)

Leveling was performed using First Order Class II standard of accuracy. The CMT MC-V system was used for field data recording and data processing. Data for the project will be released under separate cover.

**G. Attachments**

Project Instructions (1-set)  
Letters Transmitting Data "LTD" (1-sheet)  
Bench Mark Statistics (1-sheet)  
Field Statistics (1-sheet)  
Memo from BM Setters (1 sheet)  
List of Contacts (1-sheet)  
Bench Mark Designations (1-sheet)

Respectfully Submitted,

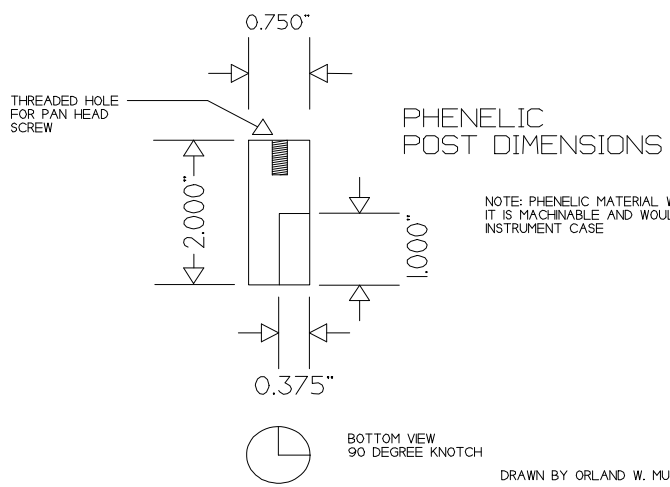
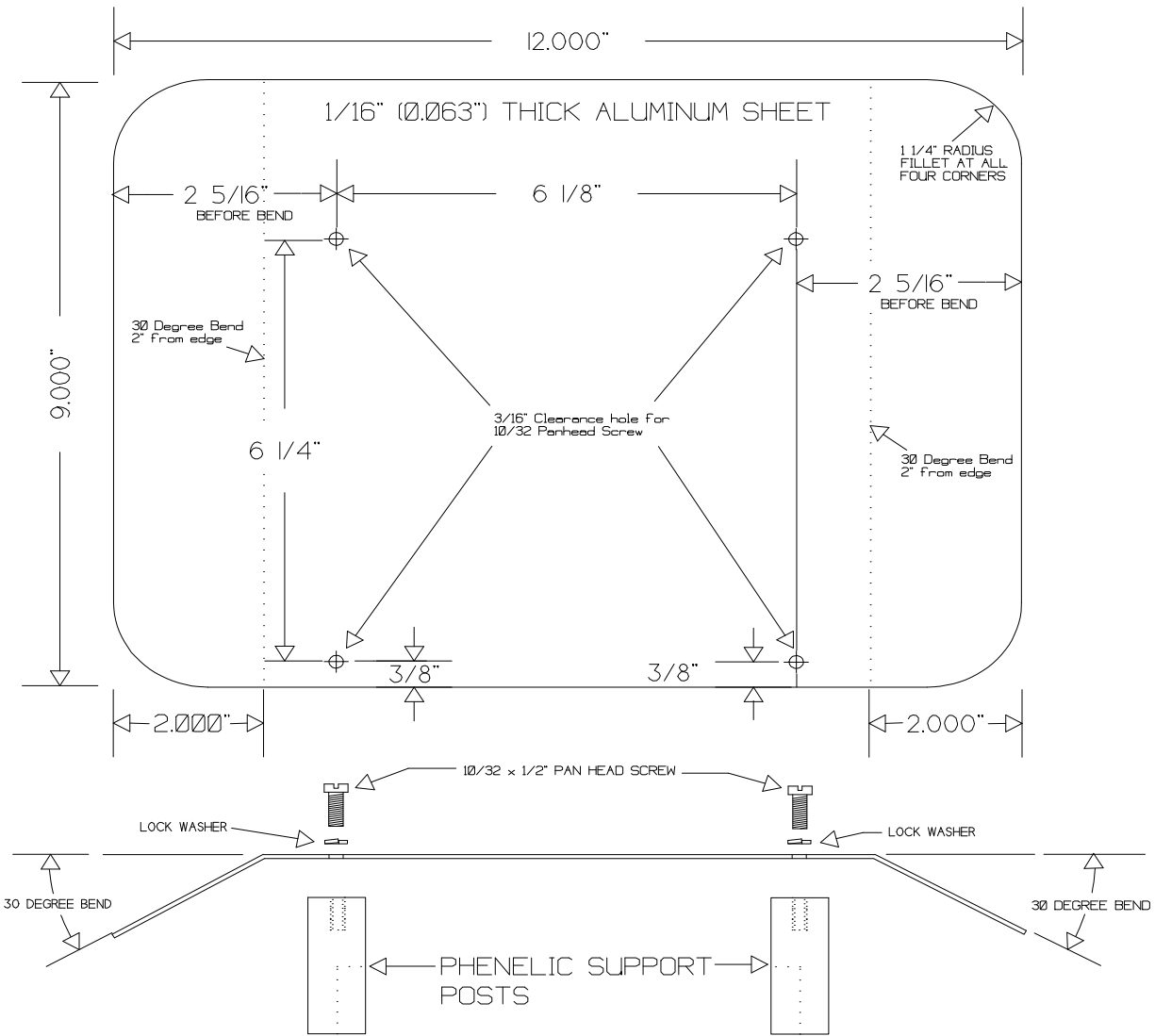
NAME OF PROJECT DIRECTOR  
Project Director, NL4130  
Survey Section C  
National Geodetic Survey

## **APPENDIX K**

**SUNSHADE DIAGRAM FOR LEICA NA SERIES DIGITAL LEVELS**

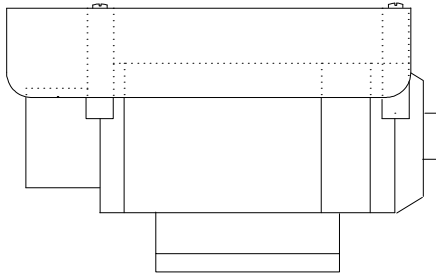
**DIAGRAM FOR MOUNTING SUNSHADE**

# NA3003 DIGITAL LEVEL SUNSHADE

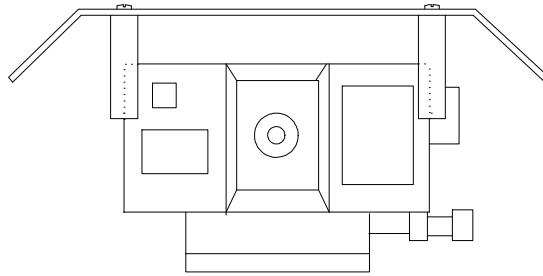


DRAWN BY ORLAND W. MURRAY, NGS, I&M BRANCH

# NA3003 SUNSHADE



LEFT SIDE



BACK

DRAWN BY ORLAND W. MURRAY, NGS, IBM BRANCH

PLACE 90 DEGREE NOTCHES IN SUNSHADE POSTS AT CORNERS OF LEVEL CASE AND PRESS SUNSHADE INTO PLACE. IF TENSION IS NOT TIGHT ENOUGH, LOOSEN SCREWS AND ADJUST POSTS OR BOW SHADE INWARD SLIGHTLY.



## Digital Leveling Data Processing Notes

1. In NABOOK folder create four folders: RAW, BLU, BOK, AFILES
2. Transfer daily observations files from level instrument to NABOOK\RAW folder using the day's date, a letter code A, B for each separate file and end with the extension \*.RAW.  
Examples: 51900a.raw and 51900b.raw.
3. Copy the RAW files to two backup floppy disks.
4. Copy one of the RAW files to the NABOOK folder from the RAW folder.
5. Run the NABOOK program. If sequence errors are indicated, edit the A edit file. Working with the files at the NABOOK level, delete the copy of the original RAW file and rename the A edit file to the original RAW file name. Example: rename 51900AA.RAW to 51900A.RAW.
6. Run NABOOK again using the edited RAW file. If all of the sequence errors have been resolved, the program will generate the following:
  - a. A new A edit file, i.e. 51900AA.RAW
  - b. A fieldbook file with the extension \*.bok, i.e. 51900A.BOK
  - c. A bluebook record file with the extension \*.blu, i.e. 51900A.BLU
7. Use an editor or word processing program to VIEW the fieldbook file, 51900A.BOK. Check for error codes in the rightmost column. Also, check the equipment info, starting and ending section information for correct info especially the temperatures, and the difference of elevation total which is the Sum on the last line of the BS/FS lines. Compare this info against the BACKUP SHEETS from the field. It may be necessary to return to the A edit file to make corrections and rerun the file with NABOOK. Also, note the last line: "Mean height of instrument for day...". The mean height will be determined by the height of the observer, i.e. 149 cm. Edit the NA.DO file and replace the height entered when the CONSTANT program was run with the height from the fieldbook. It is easier to just edit NA.DO rather than rerun the CONSTANT program.
8. After all errors have been resolved, copy the A edit file to the A edit folder, copy the \*.BLU file to the \*.BLU folder, and copy the fieldbook file to the \*.BOK folder.
9. Delete the working files just copied from the NABOOK level folder and then copy the next RAW file to the NABOOK level and process it.
10. To BUILD a preliminary BLUEBOOK file, copy the HEADER.BLU file to a new file named, L25391P2.TXT.
11. Next copy or cut and paste each of the processed data \*.BLU from the BLU folder and in chronological order to the \*.TXT file.

12. After all \*.BLU files have been appended to the \*.TXT, enter an ending job code to the last line of the file. The ending job code will be \*MI\* for Michigan. Save and close this file.

13. Copy the preliminary bluebook file the folder, VERTPGM. VERTPGM contains the NGS programs necessary to finish the data processing.

14. Before the preliminary bluebook file can be processed using the ABSTRA program, it must be converted to binary format from the text format. This is accomplished using a program called MAKEFILE. Run MAKEFILE and select the preliminary bluebook file, L25391P2.TXT, as the input \*.HGZ file and then enter the output file name as L25391P2.HGZ. The output file will be used as input to the ABSTRA program.

15. Now run the ABSTRA program. At the prompt, select the L25391P2.HGZ for the \*.HGZ file. Stored in the VERTPGM folder is a description file called L25391.HA. This file contains descriptive information about all the benchmarks on the line. Although ABSTRA can be run without it, benchmark designations will not be displayed in the output file nor will SPSN number checking occur. Always run ABSTRA with the \*.HA file included. SEE the VFPROC manual for more information on running ABSTRA. NOTE: there are other files in the VERTPGM folder needed by ABSTRA. These are the rod calibrations files and another called the INST.DAT.

16. ABSTRA will out put several files that need to be reviewed. See VFPROC manual for output files. In the end a FINAL BLUEBOOK \*.HGZ file will be generated the leveling project. There are more notes in the User's guide and VFPROC manual about submitting the project report and data to NGS. To view the final bluebook \*.HGZ file, it has to be converted from binary to text. Use the program READFILE to do this. Select the \*.HGZ file and name the output file like L25391P1.OUT.

## Digital Leveling Observation Notes - Reobserving a Setup

**WARNING: If the backsight rod should be moved during either of the follow conditions, it will be necessary to start the section over. Reobserving a setup requires that the backsight rod is still holding the elevation to that point.**

There are two conditions when reobserving a setup:

### 1. Backsight (BS) Read

The first condition is having already read only the backsight (BS) rod. If only the BS rod has been read, press the REP key on the level instrument. It should prompt “rep BK?” and show the backsight number. Press the Run/Yes key. The “BACK No=” and point number of the BS should now be displayed and program is ready for the BS rod measurement. Although a previous BS was read and stored on the REC module, it will be rejected by the NABOOK program when the file is processed.

### 2. Both Backsight (BS) and the Foresight (FS) have been read.

The second condition is having read both the BS and FS rods. Before doing anything else, enter a CODE 22 and store it to the REC module. The CODE 22 is a flag to tell the NABOOK program to reject the previous BS and FS records.

After the CODE 22 is stored, press the REP key on the instrument. The display should show the prompt “rep FR?”. Press the Run/Yes key. The display should show “FORE No=” and point number for the foresight rod.

Press the REP key again and the prompt should show “rep BK?”. Press the Run/Yes key again and the display should show the prompt “BACK No=” and the point number of the BS rod.

The program is now ready for new BS and FS measurements. In the RAW file there will be two sets of BS/FS readings separated by a CODE 22 record. The NABOOK program will now reject the first BS and FS and use only the second pair. The fieldbook file will list the both pairs, but indicate the two rejected ones in the right most column.