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DESCRIPTION

This procedure applies only to systems with 8645/GRAM hardware. For systems with SGD Hi Slew or ACGD Cabinets, refer to *System Level Procedures: Setup and Cals: GRAM/SGA Tuning & Grafidy - SGD & ACGD 8x.*

1- OVERVIEW

This procedure tunes the entire gradient driver subsystem for systems with 8645/GRAM hardware. For GRAM tuning theory, see Table 1-1.

TABLE 1-1
GRAM TUNING THEORY

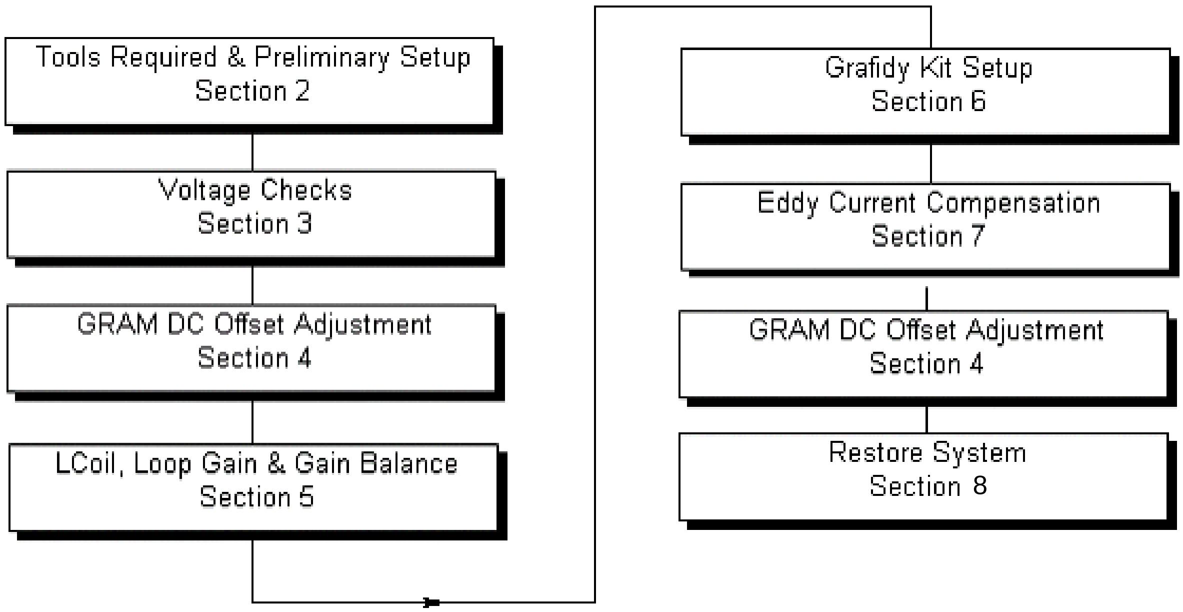
GRAM Tuning is a group of procedures assembled together in order to tune the entire Gradient Driver subsystem for systems with a GRAM. The Signa Horizon HiSpeed and the Signa Horizon EchoSpeed both have one GRAM (Gradient Ramp Accelerator Module) per axis. In addition, this procedure is specific to the digital tuning board. Those systems with a board are the **only** ones that require this GRAM Tuning procedure. Initially, all dc offsets that may be present in the Gradient Driver subsystem are adjusted to zero. Limits are set for the Pulse Width Modulation, Amp/Sec (Ampere Transitions per Second) and Bus Voltage Regulator Gain functions. The actual tuning of the GRAM is performed in the LCoil and Gain Adjustment. Eddy current compensation is done in 4 sections to compensate for for linear long time constants, cross-term time constants, B_0 time constants, and linear short time constants. The PSD for Eddy Current Compensation is called *Grafidy*. The analysis tool is found under MR Tools, and is called *Grafidy Analysis*. B_0 compensation, also referred to as FRESBECC (Frequency *S*hift B_0 Eddy Current Compensation), is an automated digital method of adjusting B_0 for all three axes. All mechanical adjustments for B_0 are no longer required with the new epoxy-filled gradient coil used with the Signa Horizon product line. **FRESBECC is performed during Grafidy for B_0 eddy current time constants portion of this procedure.**

Note

Short time constants are compensated for using default values that are in the default grafidy calibration files. If you have any of these revisions of software, you are NOT REQUIRED to run short time constant compensation (the ability to run short time constant compensation is still available in Expert Mode).

1-1 GRAM TUNING FLOWCHART

See flowchart in Illustration 1-1 for specific details on the procedure flow, and functional descriptions of each of the individual procedures performed in GRAM Tuning.



GRAM TUNING FLOWCHART
ILLUSTRATION 1-1

See Appendix A for a functional description of why that portion of the procedure is performed.

2- TOOLS REQUIRED AND PRELIMINARY SETUPS

2-1 Tools Required

- The Magnetic Shield (46-317725G10), used with the RF Measurements Kit, is required if the scope display is affected by the magnetic field.
- A 100-mHz scope and a DVM with alligator clips is required for this procedure.
- Rotary Attenuator (10db/step), 46-255838P5
- There are several Grafidy kit variations in the field. The contents of each is itemized in the tables listed below:

  Table 2-1: 46-271417G1 – 1.5T
  Table 2-2: 46-307164G1 – 1.5T
  Table 2-3: 46-307164G2 – 1.5T
  Table 2-4: 46-307164G3 – 1.0T, 1.5T
  Table 2-5: 46-307164G4 – 1.0T, 1.5T
  Table 2-6: 46-307164G6 – 1.0T

TABLE 2-1
GRAFIDY KIT 46-271417G1 – 1.5T

ITEM	DESCRIPTION	PART NUMBER	QUANTITY
1	Base Plate	46-271410G1	1
2	Coil, 1.5T	46-271411G1	1
3	Coil, 1.5T	46-271411G2	1
4	Collar	46-271456P1	1
5	Spacer	46-271457P1	2
6	Pin Diode Switch	46-271476G1	1
7	Pin Diode Drive	46-271472G1	1
8	Cable, BNC, 8 ft.	46-251920G22	1
9	Cable, BNC, 50 ft.	46-251920G23	1
10	Cable, BNC, 90 ft.	46-251920G24	1
Note: Female SMB to BNC cable, 46-301549P5 (part of TPS RF Service Kit, 46-301927G1) also required for Grafidy Kit 46-271417G1.			

TABLE 22
GRAFIDY KIT 46-307164G1 – 1.5T

ITEM	DESCRIPTION	PART NUMBER	QUANTITY
1	Coil, 1.5T	46-271411G1	1
2	Coil, 1.5T	46-271411G2	1
3	Collar	46-271456P1	1
4	Spacer	46-271457P1	2
5	Pin Diode Switch	46-288240G1	1
6	Pin Diode Drive	46-271472G1	1
7	Cable, BNC, 8 ft.	46-282803G15	1
8	Cable, BNC, 30 ft.	46-282803G14	4
9	Cable, BNC, Female SMB to BNC	46-301549P5	1
10	Adapter, BNC Coupling	46-282886P1	3
11	Quick Disconnect (Extremity/Linear Adapter), 1.5T	46-282468G3	1

TABLE 2-3
GRAFIDY KIT 46-307164G2 – 1.5T

ITEM	DESCRIPTION	PART NUMBER	QUANTITY
1	Coil, 1.5T	46-271411G1	1
2	Coil, 1.5T	46-271411G2	1
3	Collar	46-271456P1	1
4	Spacer	46-271457P1	2
5	Pin Diode Switch	46-288240G1	1
6	Pin Diode Drive	46-271472G1	1
7	Cable, BNC, 8 ft.	46-282803G15	1
8	Cable, BNC, 30 ft.	46-282803G14	4
9	Cable, BNC, Female SMB to BNC	46-301549P5	1
10	Adapter, BNC Coupling	46-282886P1	3
11	Quick Disconnect (Extremity/Linear Adapter), 1.5T	46-282468G3	1

TABLE 2-4
GRAFIDY KIT 46-307164G3 – 1.0T, 1.5T

ITEM	DESCRIPTION	PART NUMBER	QUANTITY
1	Coil, 1.5T	46-271411G1	1
2	Coil, 1.5T	46-271411G2	1
3	Collar	46-271456P1	1
4	Spacer	46-271457P1	2
5	Pin Diode Switch	46-288240G1	1
6	Pin Diode Drive	46-271472G1	1
7	Cable, BNC, 8 ft.	46-282803G15	1
8	Cable, BNC, 30 ft.	46-282803G14	4
9	Cable, BNC, Female SMB to BNC	46-301549P5	1
10	Adapter, BNC Coupling	46-282886P1	3
11	Coil, 1.0T	46-307804G2	2
12	Quick Disconnect (Extremity/Linear Adapter), 1.5T	46-282468G3	1

TABLE 2-5
GRAFIDY KIT 46-307164G4 – 1.0T, 1.5T

ITEM	DESCRIPTION	PART NUMBER	QUANTITY
1	Coil, 1.5T	46-271411G1	1
2	Coil, 1.5T	46-271411G2	1
3	Coil, 1.0T	46-307804G2	2
4	Collar	46-271456P1	1
5	Spacer	46-271457P1	2
6	Pin Diode Switch	46-288240G1	1
7	Pin Diode Drive	46-271472G1	1
8	Cable, BNC, 8 ft.	46-282803G15	1
9	Cable, BNC, 30 ft.	46-282803G14	4
10	Cable, BNC, Female SMB to BNC	46-301549P5	1
11	Adapter, BNC Coupling	46-282886P1	3
12	Quick Disconnect (Extremity/Linear Adapter), 1.5T	46-282468G3	1
13	Quick Disconnect (Extremity/Linear Adapter), 1.0T	46-317222G2	1

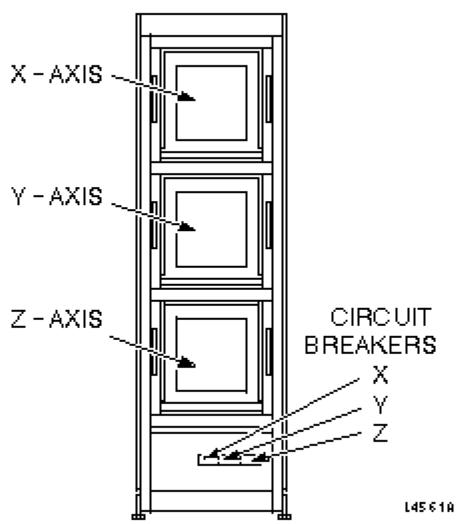
TABLE 2-6
GRAFIDY KIT 46-307164G6 – 1.0T

ITEM	DESCRIPTION	PART NUMBER	QUANTITY
1	Coil, 1.0T	46-307804G2	2
2	Collar	46-271456P1	1
3	Spacer	46-271457P1	2
4	Pin Diode Switch	46-288240G1	1
5	Pin Diode Drive	46-271472G1	1
6	Cable, BNC, 8 ft.	46-282803G15	1
7	Cable, BNC, 30 ft.	46-282803G14	4
8	Cable, Female SMB to BNC	46-301549P5	1
9	Adapter, BNC Coupling	46-282886P1	3
10	Quick Disconnect (Extremity/Linear Adapter), 1.0T	46-317222G2	1
Note: A female BNC to female BNC adapter is required on mobile systems for Grafidy Kits 46-307164G1 through G6.			

2-2 Preliminary Setup

If this is the first time you are performing this procedure, take a moment, before beginning, to read the procedure from beginning to end to become familiar with the steps required.

1. Turn off power to the GRAM cabinet using the circuit breakers located at the lower front of the GRAM cabinet for all three GRAM modules (see Illustration 2-1).



GRAM CABINET - FRONT VIEW
ILLUSTRATION 2-1

2. Remove the front cover of the GRAM cabinet.
3. Remove the cover on each GRAM module for each axis being calibrated.

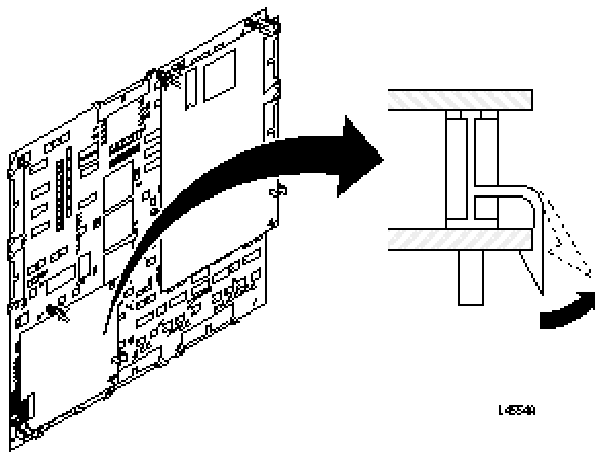
Note

There are test points and resistors, located under the GRAM Tuning Board, that are accessed during this procedure. Therefore, it is necessary to relocate the GRAM Tuning Board.

CAUTION

Equipment damage possibility. Do not pull the circuit board off. The nylon standoffs are quite brittle and will break. Push the top of the standoff away from the circuit board one by one. If they do not push off of the circuit board at first, work on the other standoffs one by one. Also use the nylon standoffs as a prop to keep the back of the Digital Tuning Board from shorting out against any components on the Control Board.

4. To get under the Digital Tuning Board, carefully push back the white nylon circuit board stand-offs, on the Digital Tuning Board, one-by-one until all stand-offs are released. See Illustration 2-2. Do not disconnect the cable from the Digital Tuning Board.



GRAM CONTROL BOARD SWITCH LOCATIONS
ILLUSTRATION 2-2

5. Use the nylon standoffs as a prop to keep the back of the Digital Tuning Board from shorting out against any of the components of GRAM's control board.

CAUTION

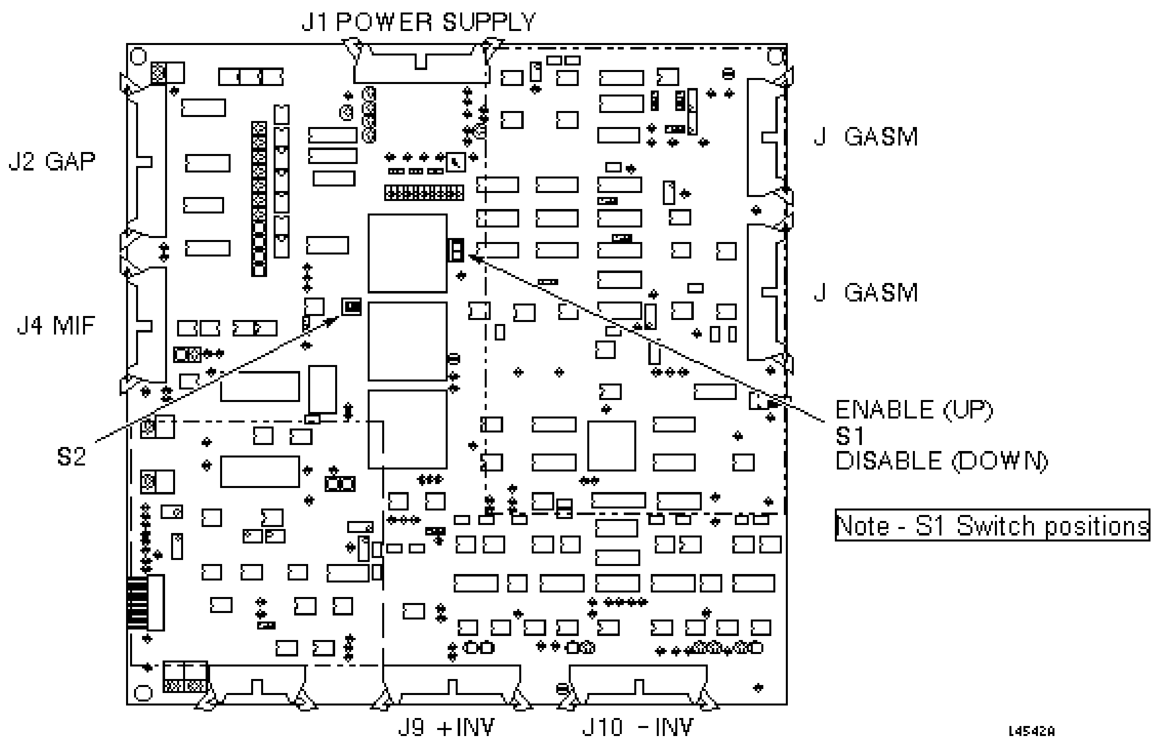
Equipment damage possibility. It is important to verify that all switches and jumpers on the GRAM Control Board and the Digital Tuning Board are set to the proper position. Failure to do so will cause adjustments to be inaccurate.

6. Verify the settings of all jumpers and switches on the GRAM Control Board and the GRAM Power Supply Board for each axis being tuned.

   a. See Table 2-7 and Illustration 2-3 for proper switch settings for the GRAM Control Board.

TABLE 2-7
GRAM CONTROL BOARD SWITCH SETTINGS

NUMBER	POSITION	SETTING	SWITCH NAME AND POSITION DEFINITION
S1	N/A	Up	GRAM Enabled – When S1 is down, the GRAM is disabled
S2	1	Down	(RES) Reserved – not used
S3	2	Down	(HV) High Voltage Enable – Under software control
S4	3	Down	(FW) Free Wheel – Enables PWM mode under software control. Up is Freewheel mode, no PWM.
S5	4	Down	(MAN) Manual Ready – This is controlled by GAP. Up is Troubleshooting, it forces the GRAM to Manual Ready. (S1 must also be up, or enabled when MAN is up.)



GRAM CONTROL BOARD SWITCH LOCATIONS
ILLUSTRATION 2-3

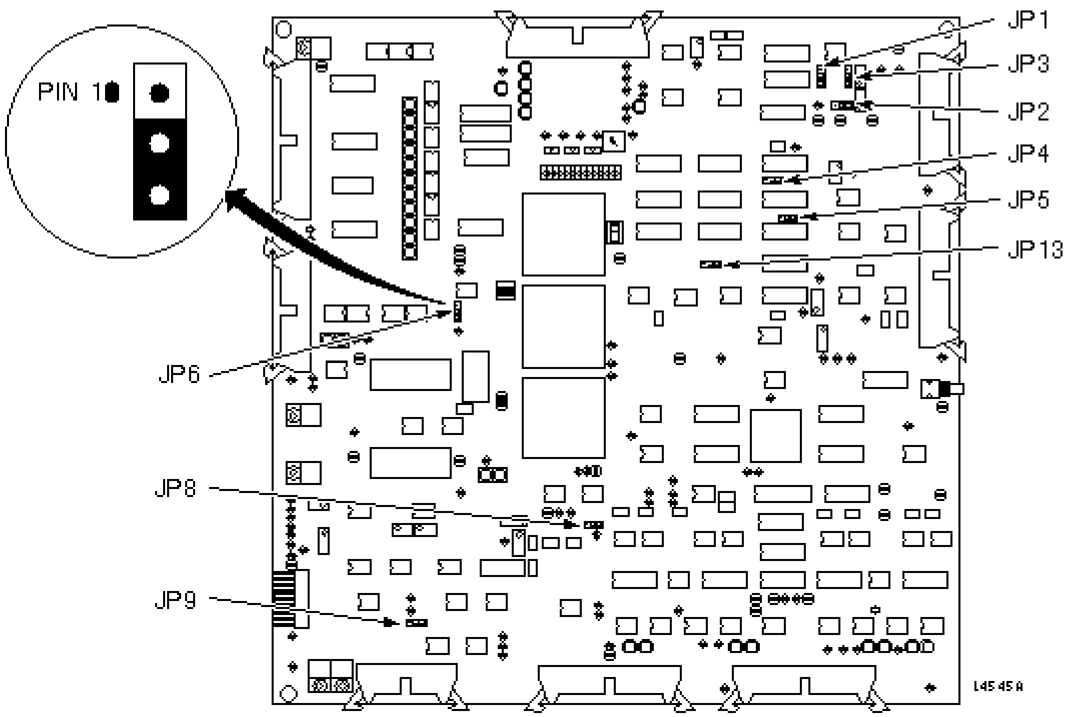
Note

The only label that is visible on this board is S1 Enable. Be sure to use the up position for enable and the down position for disable.

b. See Table 2-8 and Illustration 2-4 for proper jumper settings for the GRAM Control Board.

TABLE 2-8
GRAM CONTROL BOARD JUMPER SETTINGS

NAME	POSITION	SETTING
JP1	2&3	
JP2	2&3	
JP3	2&3	
JP4	2&3	(V/**D**) Voltage or Digital to Analog converter – DAC selected
JP5	2&3	(AN/**DIG**) Analog or Digital – Digital selected
JP6	2&3	(DIS/**EN**) Disable or Enable – Enable selected
JP13	2&3	(AN/**DIG**) Charge mode
JP8	2&3	(TST/**NRM**) Test or Normal – Normal selected
JP9	2&3	Sets up one current sensor. JP9 is located under the tuning board

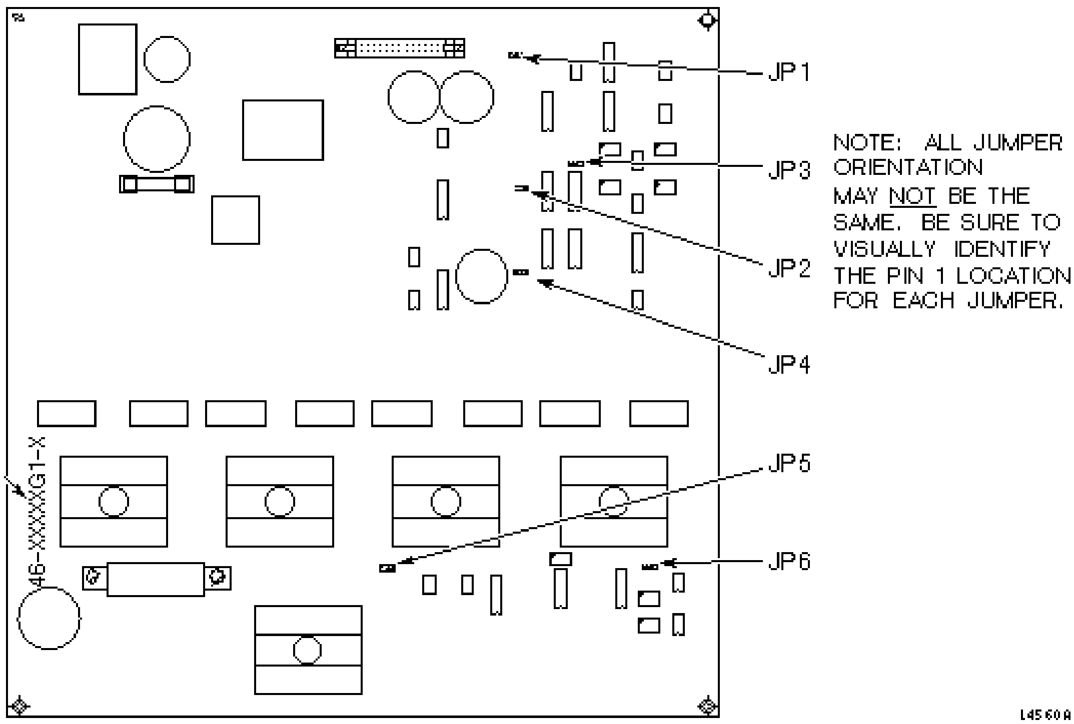


GRAM CONTROL BOARD JUMPER LOCATIONS
ILLUSTRATION 2-4

c. See Table 2-9 and Illustration 2-5 for proper jumper settings for the GRAM Power Supply Board.

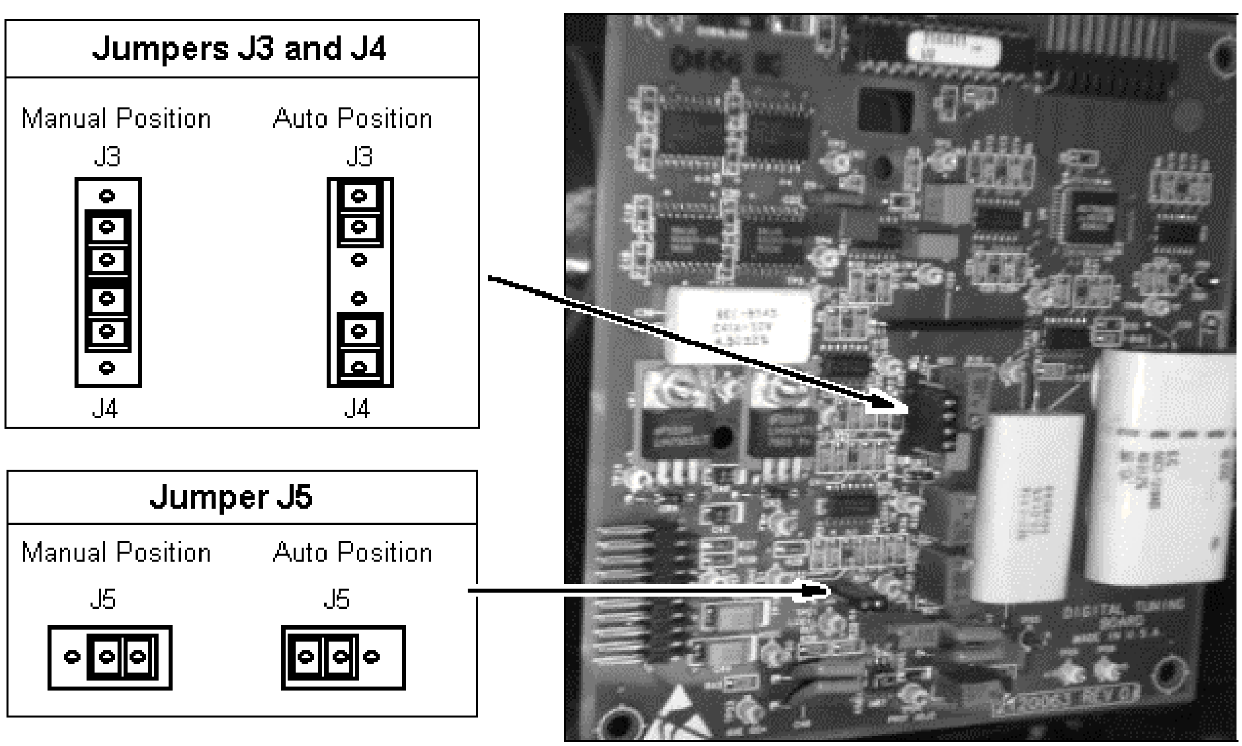
TABLE 2-9
GRAM POWER SUPPLY BOARD JUMPER SETTINGS

NAME	POSITION JP2 PRESENT	POSITION NO JP2	SETTING NOTE - PIN 1 LOCATION
JP1	2 & 3	2 & 3	Triangle Enable
JP2	1 & 2	–	Connects LGND to AGND
JP3	1 & 2	2 & 3	High Voltage Enable
JP4	2 & 3	2 & 3	Under Voltage Enable
JP5	1 & 2	2 & 3	High Voltage Enable
JP6	1 & 2	2 & 3	NORM – Normal Mode
Note: There are two versions of power supplies boards. The older version can be identified by the presence of a jumper labeled JP2. The newer revision boards do not have a JP2 jumper.			

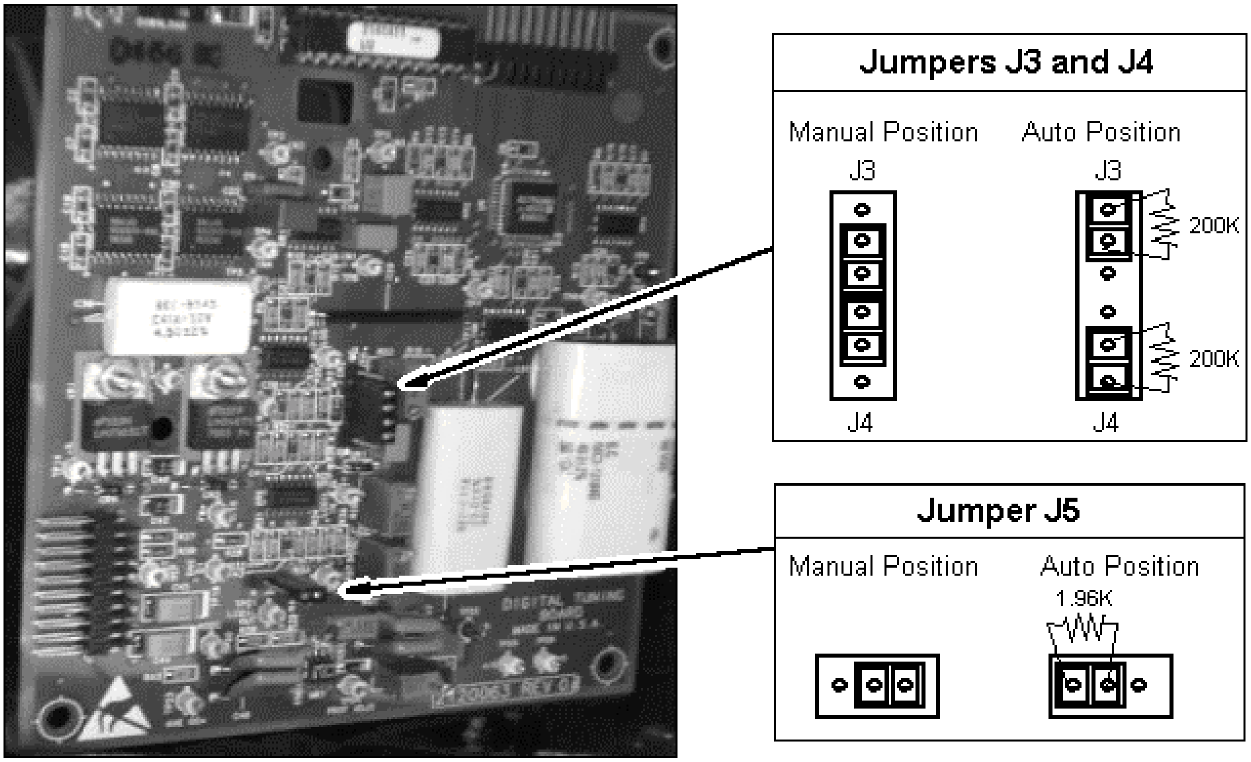


GRAM POWER SUPPLY BOARD JUMPER LOCATIONS
ILLUSTRATION 2-5

d. Set Digital Tuning Board jumpers to Manual positions:
   See Illustration 2-6A for Rev E Boards.
   See Illustration 2-6B for Rev D Boards.



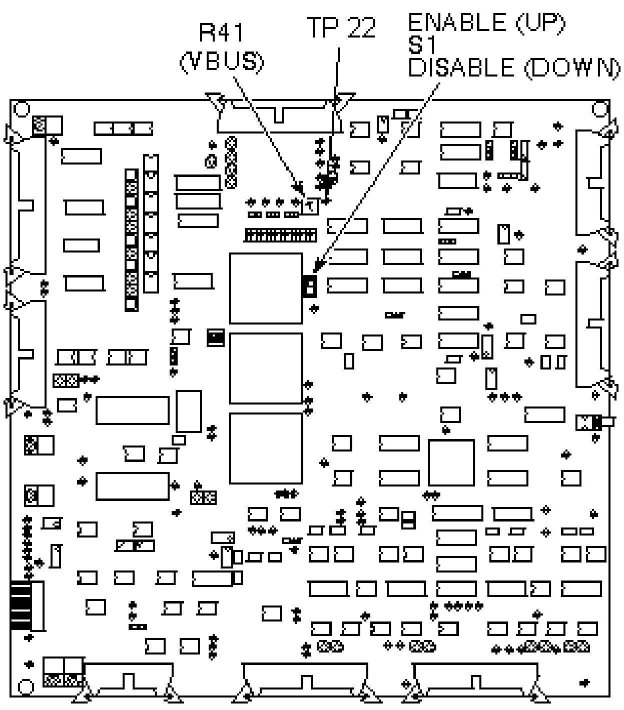
DIGITAL TUNING BOARD (REV E) JUMPER LOCATIONS / SETTINGS
ILLUSTRATION 2-6A



DIGITAL TUNING BOARD (REV D) JUMPER LOCATIONS / SETTINGS
ILLUSTRATION 2-6B

7. Verify that the revision of the IPG board is at least rev 2112565-3.

8. Locate and set R41 (VBUS) on the GRAM Control Board (see Illustration 2-7).



At TP 22 adjust R41 for:

For EchoSpeed;
Adjust to 1000 ohms ± 25 ohms.

For HiSpeed;
Adjust to 300 ohms ± 7.5 ohms.

Both settings are in respect to ground.

GRAM CONTROL BOARD: S1 & R41 LOCATIONS
ILLUSTRATION 2-7

9. If other axes are to be tuned, repeat steps 4 through 6 for each axis.

10. Turn on power to the GRAM cabinet, using the circuit breakers located at the lower-front of the GRAM cabinet for all three GRAM modules.

11. In Section 7-1, Grafidy Scan Sequence Flow, you are **strongly encouraged** to print the table which lists all the grafidy scans that must be done in the correct order. Please print this table as recommended, it will help you immensely.

12. Proceed to Section 3, Voltage Checks.

3- VOLTAGE CHECKS

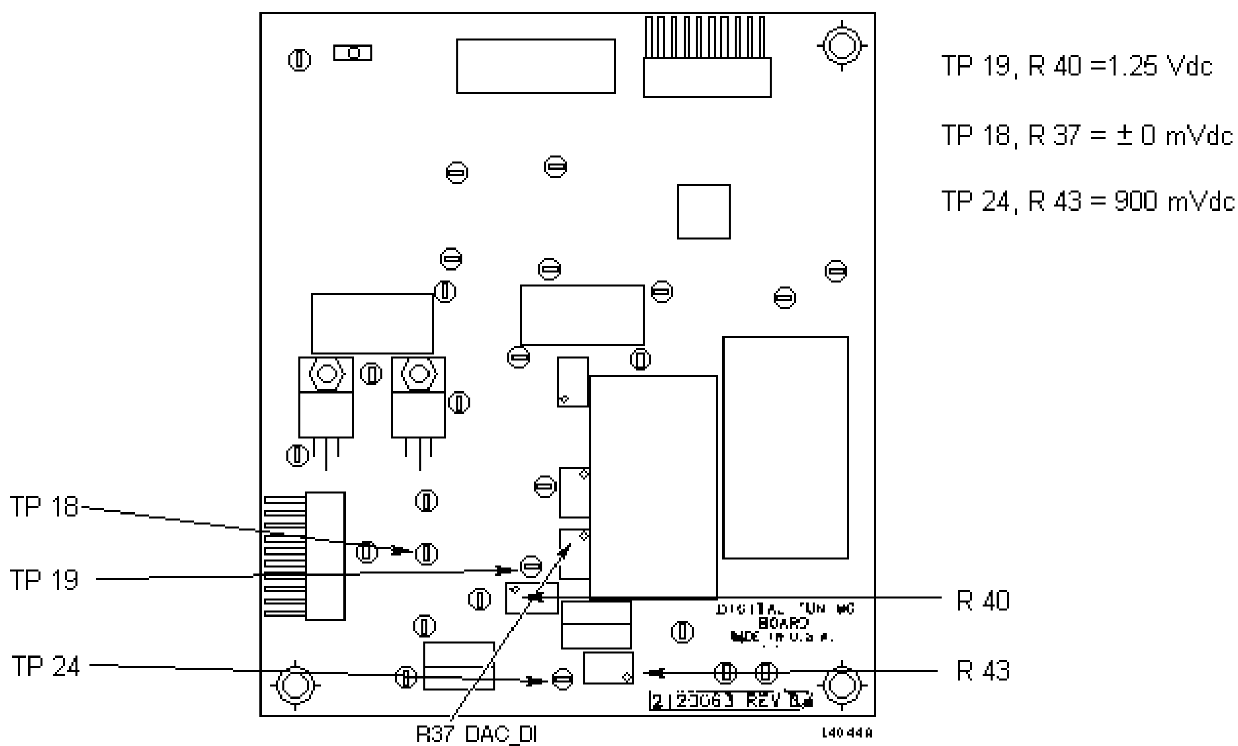
1. For all axes (if required), make the following adjustments on the Digital Tuning Board (refer to Table 3-1 and Illustration 3-1):

   - TP 18 DAC_DI Voltage Offset
   - TP 19 Pulse Width Modulation (PWM) adjustment
   - TP 24 Amp Transition per Second adjustment

Note
All test point measurements are in respect to ground.

TABLE 3-1
TOOLS REQUIRED AND PRELIMINARY SETUPS

TEST POINT	POT	SPEC	ILLUSTRATION
18	R37	0 ±3 mVdc	L4044A
19	F40	1.25 Vdc	L4044A
24	F43	900 mVdc	L4044A



DIGITAL TUNING BOARD
ILLUSTRATION 3-1

2. Proceed to Section 4, GRAM DC Offset Adjustment.

4- GRAM DC OFFSET ADJUSTMENT

Perform the GRAM DC Offset Adjustment now (or again), or the return signal may not show up, due to a magnitude offset caused by a DC offset on the output of the GRAM.

1. Remove the head coil and holder from the cradle. Install the Grafidy phantom holder.

2. Landmark on the center line of the Grafidy phantom holder.

3. At keypad on front magnet enclosure, press LANDMARK and MOVE TO SCAN.

4. At the operator work space, prepare the system for a Grafidy scan per scan protocol shown in the *Service Protocols* procedure located on the service methods CD-ROM, or for the alternate proprietary procedure use the following:

   Note: This alternate proprietary procedure is available for GE use, and to sites with a valid Advanced Service Package Limited License.

   a. Click on **[New Pt]**, and enter
      Id: **geservice**
      Name: **grafidy**
      Weight (Lb): **111**
      Set Patient Protocols to **Service**.
   b. In the Protocol field, type **o.5.1** (o=Other, 1=series number) to load protocol.
   c. **[Save Series]**.

5. Right click on **[Research Operations]** and select **Setup Params** from the Scan Operations list. Enter values listed in Table 4-1.

TABLE 4-1
GRAFIDY SETUP PARAMETERS

SETUP PARAMETERS
R1 = 13
R2 = 14
TG = 0 *(TG must be set to 0.)*
Number of Frames: **4 <Enter>**
WINDOW ONE
Frame: **1 <Enter>**
Frame: **0 <Enter>**
WINDOW TWO
Frame: **3 <Enter>**
Frame: **0 <Enter>**
[Done]

Note

It is necessary to set the grad shim values to zero in order to ensure that there are no additional offsets in the circuit. This ensures an accurate calibration. Remember to restore the grad shim values after this GRAM Tuning procedure is complete.

6. Go to manual prescan. Record grad shim values for *x*, *y*, and *z* axes. If values are not set to 0, set them by moving the slide bar to 0 at this time.

7. Select **[Done]** to exit manual prescan. This is important so that the scanner is ready, but not scanning.

DANGER!!

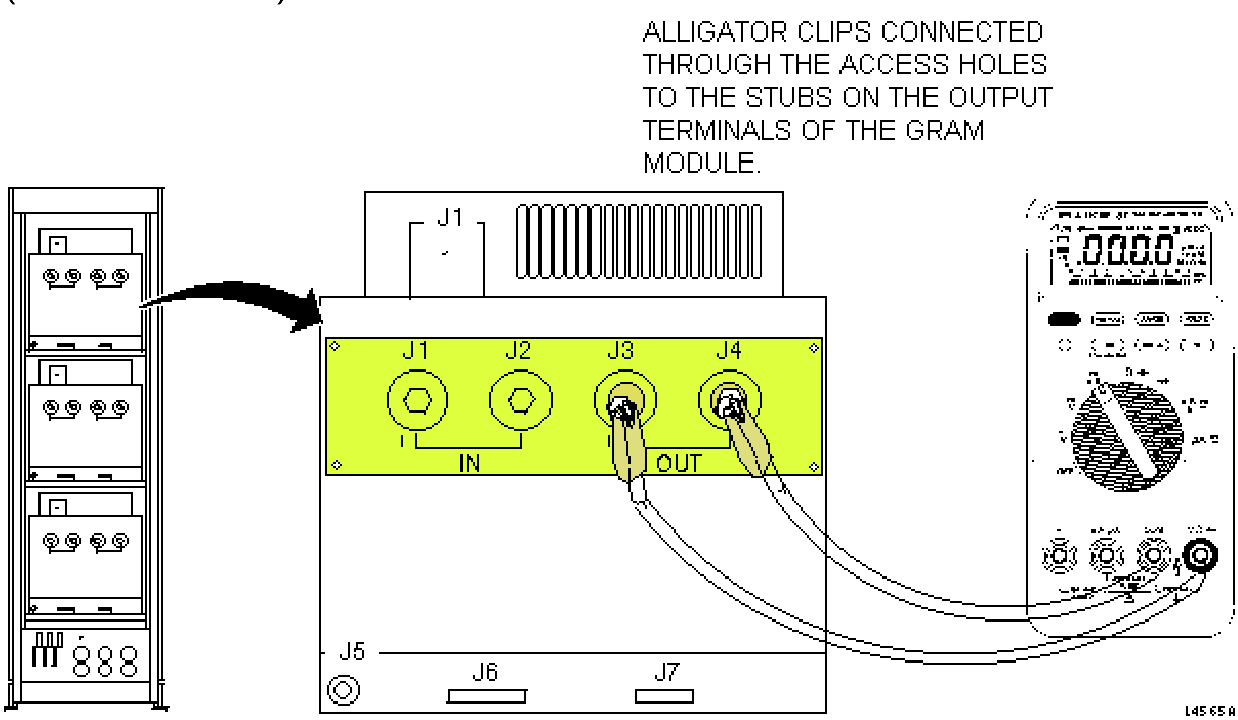
FATAL ELECTRIC SHOCK HAZARD!! GRAM MODULES GENERATE FATAL ELECTRICAL CURRENTS. SCANNING OR PRESCANNING DURING THIS MEASUREMENT MAY CAUSE A FAILURE TO THE GRAM, AND EXPLOSION OF THE VOLTMETER. DO NOT SCAN OR PRESCAN DURING THIS MEASUREMENT AND ADJUSTMENT.

8. At the GRAM Control Board, prepare to perform the GRAM DC Current Offset Adjustment to null any offset currents to zero.

Note

Always use ESD precautions when working on any of the electronic hardware for the protection of the circuit boards.

9. Using voltmeter leads with alligator clips, connect a voltmeter at the rear of the GRAM chassis across J3 (+OUT) and J4 (–OUT). The voltmeter should be set to DC millivolts (see Illustration 4-1).



GRAM CHASSIS – REAR VIEW WITH VOLTMETER ACROSS THE OUTPUT
ILLUSTRATION 4-1

Note

Using longer leads for the voltmeter allows viewing the voltmeter as the adjustment is performed because the potentiometer to be adjusted is on the front of the GRAM Module on the GRAM Control Board.

10. On the GRAM Control Board, locate and adjust R151 (Offset Null), so that the voltmeter reads 0 mVdc ±10 mVdc. R151 is accessible through a hole in the digital tuning board (located between two voltage regulators).

Note

GRAM DC Offset Adjustment must be done with the system in Ready. If the fans in the 8645 Gradient Cabinet slow down while performing the GRAM DC Offset Adjustment, GAP has put the power modules in Standby. Select **[Download]**, and GAP commands the power modules to Ready.

11. If all three axes are to be tuned, repeat steps 7 through 9 for each axis. If one or two axes are to be tuned, repeat steps 7 through 9 for the axis being tuned.

12. Proceed to Section 5, LCoil, Loop Gain, and Gain Balance if this is the first DC Offset Adjust. Proceed to Section 8, System Restoration if this is the 2nd DC Offset Adjust.

5- LCOIL, LOOP GAIN AND GAIN BALANCE

5-1 Auto LCoil Adjustment Procedure

1. Ensure that the Digital Tuning Board jumpers are in the Auto position:
    - See Illustration L9900 for Rev E Boards.
    - See Illustration L9900a for Rev D Boards.
2. Select **[Diagnostics]** from the Service Desktop Manager. -
3. Click **[Start]**.
4. Select **[Board Level Tests - IPG]**.
5. Click **[Manual]**.
6. Select **[LCoil Adjust]**. Close the *Manual* and *IPG* windows.
7. Select **[Run Diags]**.
8. Exit diags when diagnostics have completed by closing the *Results* window and clicking on **[Quit]** in the *Diagnostics* window .

    The adjustment takes about two minutes to run. It automatically updates the system configuration upon completion.

    When doing all three axes, no errors should be reported by the system and system configuration will auto update. If a problem is detected on any axis, an error message will be posted by the system and the bad axis configuration will not be updated.

    If you do not want to tune all axes, turn off power to the GRAM(s) on those axes.

Note

Error messages will be posted by the system for the GRAM(s) that are off, but configuration files will be updated for the GRAM(s) that are still on.

5-2 Prerequisite Steps (Required After Initial Release 8.2.5 Software Load)

Due to the addition of Very Long Time Constant compensation, Grafidy must be re-run after loading Release 8.2.5 software. The following steps are required **only** the **first** time Grafidy is run (after the load) to remove old Grafidy calibration files.

1. On the Service Desktop, select **[C Shell]**.

2. Type the following:
    {} **cd /usr/g/caldir <Enter>**
    {} **rm grafidy.config ecccoeff.dat <Enter>**

3. Proceed to Section 6, Grafidy Kit Setup.

6- GRAFIDY KIT SETUP

6-1 Grafidy Initialization Procedure

1. On the Service Desktop, select **[Cal/Checks]** then **[Grafidy]**.

2. **Initialize Grafidy Parameters to 0** by following these Grafidy Analysis Tool instructions:

OUTPUT/PROMPTS	INPUTS/COMMENTS
GRAFIDY - Eddy Current Analysis 1 - Read and Process Raw Data 2 - Fit 3 - Initialize Parameters 4 - System Status S or Q - Exit to Tools Menu Enter Choice: (0..4) [0] :....................	**3 <Enter>**
Enter axis to clear (0=x,1=y,2=z,3=All):(0..3) [0]:	*****<Enter>***** If all axes are being calibrated, select **3 <Enter>** to initialize all axes at once. Otherwise, select the axis currently being calibrated.
Initialize B0 parameters ? (Y,N) [N] :	**Y<Enter>**

Note

This the first and only time that B0 and Linear Long Time Constant and Linear Short Time Constant parameters are initialized—once per axis!! Initialize B0 and Linear Long Time Constant Parameters now.

OUTPUT/PROMPTS	INPUTS/COMMENTS
Initialize linear long time constants params? (Y,N):	**Y<Enter>**

Note

Short time constants are compensated for using default values that are in the default grafidy calibration files. For these revisions of software, you are NOT REQUIRED to run short time constant compensation (the ability to run short time constant compensation is still available in Expert Mode).

OUTPUT/PROMPTS	INPUTS/COMMENTS
GRAFIDY - Eddy Current Analysis 1 - Read and Process Raw Data 2 - Fit 3 - Initialize Parameters 4 - System Status S or Q - Exit to Tools Menu Enter Choice: (0..4) [0] :	(No additional entries for now.)

Note

You must invoke the Grafidy Analysis Tool now because the parameters used in the eddy current compensation may already be loaded into the Digital Tuning portion of the GIP Board. By initializing the parameters, you are setting these parameters to zero. <u>Note</u>: Exiting Grafidy restores compensation values.

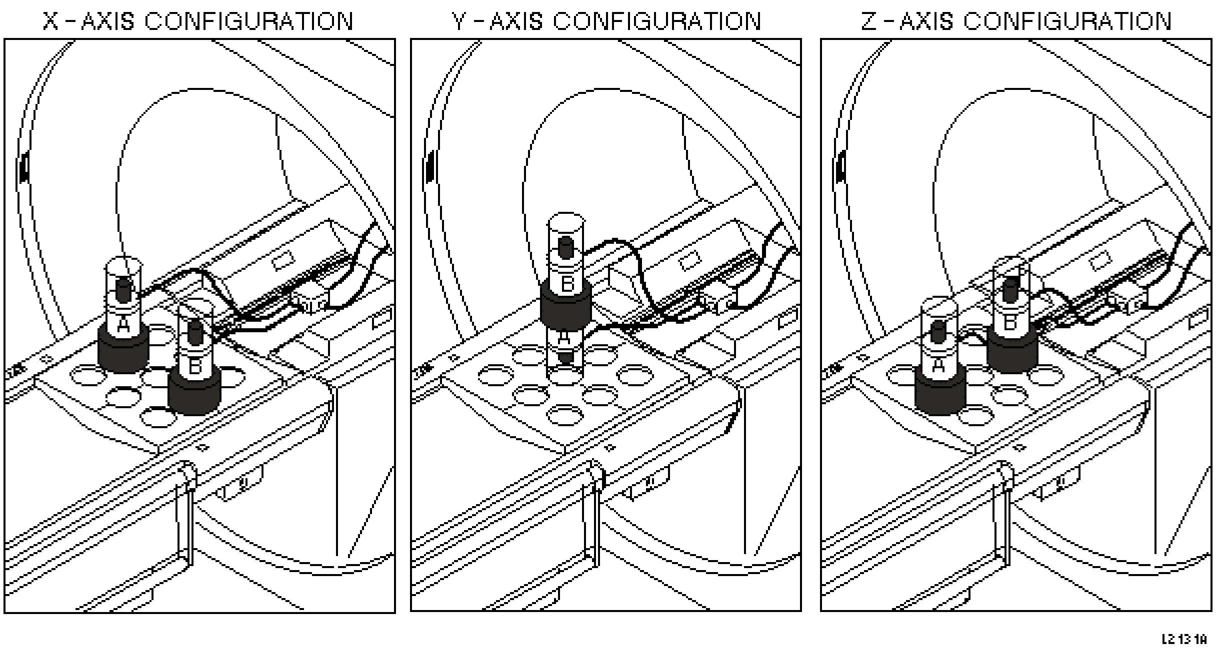
6-2 Grafidy Hardware Setup Procedure

Set up the Grafidy Kit for the first axis to be calibrated, using the following instructions.

1. Remove the head coil and holder from the cradle.

2. Select the proper coil for the system to be tested (1.5T or 1.0T).

3. Place the phantom holder on the cradle. Configure the Grafidy coil/samples and collars appropriately for the first axis on which you will perform Grafidy (see Illustration 6-1).

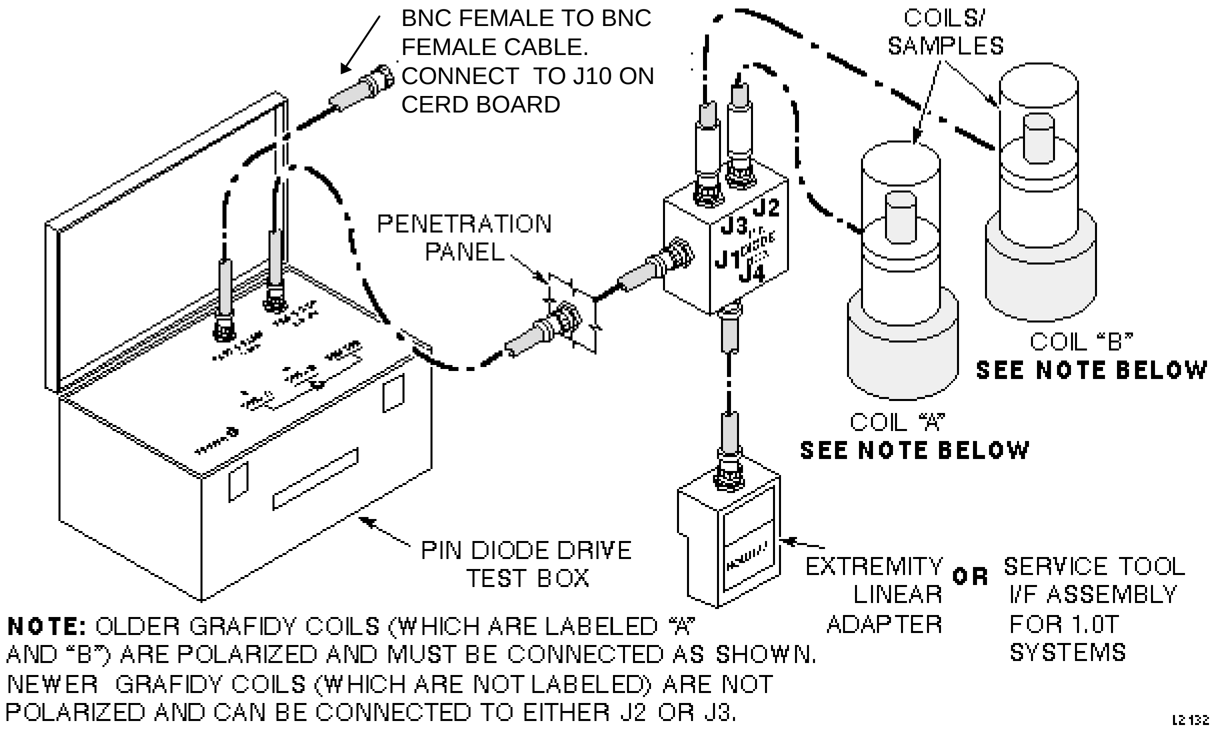


GRAFIDY PHANTOM CONFIGURATIONS
ILLUSTRATION 6-1

Note

In the x and z configurations, the coil/sample is placed with the sample at the top. In the y configuration, the top coil/sample is placed with the sample on top, while the lower coil/sample is inverted so that the sample is on the bottom. Also in the y configuration, no collars are used beneath the bottom sample.

Refer to Illustration 6-2 for steps 5 through 14.



GRAFIDY EQUIPMENT SETUP
ILLUSTRATION 6-2

4. Plug the Extremity/Linear Adapter **(for 1.0T systems, use Service Tool I/F Assm. supplied with Grafidy kit)** into Quad Head Coil Carriage Assembly. Connect 2-ft coaxial cable from Extremity/Linear Adapter BNC to J4 on pin diode box.

Note

There are multiple lengths of cables used for this portion of this procedure. The short cable is the 2-ft cable, the medium length cable is either an 8-ft or a 5-ft cable, and the long cable is any cable length that will accommodate the long cable runs, the 90-ft cable, a combination of 30-ft cables, or a custom cable that you may have created.

5. Connect cable as follows, depending on type of system:
   a. **For 1.5T systems and fixed site 1.0T systems:** Connect the long coaxial cable from J1 on pin diode box to a SERVICE coaxial feed-through on the Penetration Panel (exam room side). Cable must be routed through the bore of the magnet, exiting at the rear.

   Note

   It is not necessary to use a 90-ft cable. This length is usually supplied in some Grafidy kits. Other kits are supplied with three 30-ft cables. Use the length of cable that best suits your particular site.

   b. **For mobile systems:** Disconnect cable at J8 of Penetration Panel (this is the body receive line, which is not needed for this procedure). Connect the long coaxial cable from J1 on Pin Diode Box to J8 on Penetration Panel.

CAUTION

Equipment damage possibility. Do not run the coaxial cable under the RF door. The RF door can cut the outer cable jacket, exposing the braided shield, and grounding it to the RF door. These two grounds are not at the same potential and will adversely affect your calibration.

WARNING!

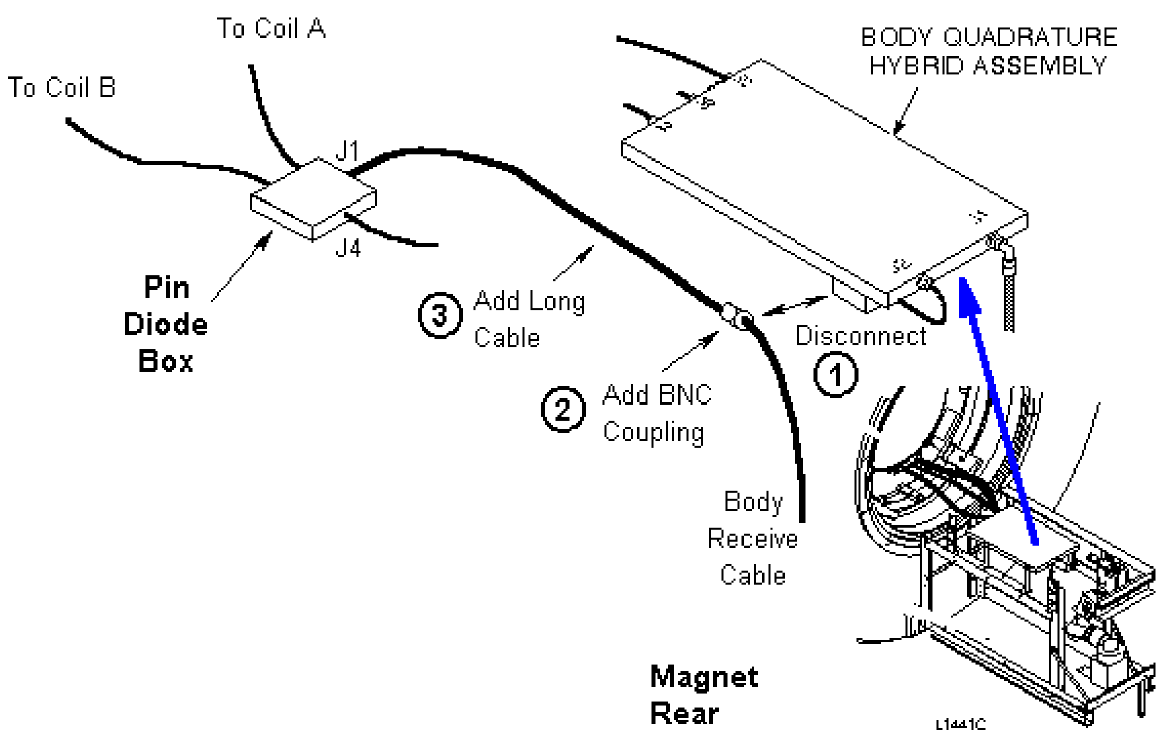
SHOCK HAZARD! THE PIN DIODE DRIVE TEST BOX SENDS 60-VOLT SIGNALS TO THE PIN DIODE BOX. VERIFY THAT THE POWER SWITCH FOR THE PIN DIODE DRIVE BOX IS OFF (DOWN POSITION) BEFORE CONNECTING CABLES.

6. Landmark on the center-line of the Grafidy coil base plate (not the coils). At the keypad on front magnet enclosure, press LANDMARK then MOVE TO SCAN.

Note

An alternate method for Steps 7 and 8 is provided here, if any difficulty is encountered with the primary method provided in the main procedure.

7. Disconnect run #262 Body Receive cable (this signal is not needed for this procedure), from the Body Hybrid Splitter at the rear of the magnet, and place a BNC coupling (not provided) on the cable end. See Illustration 6-3.



PIN DIODE DRIVE HOOKUP - MAGNET END
ILLUSTRATION 6-3

(Alternate) Connect the first long coaxial cable from J1 on Pin Diode Box to the BNC coupling on the body receive cable. This cable must be routed through the bore and out the rear of the magnet.

8. On the lower rear panel of the Systems Cabinet, disconnect the existing coaxial cable from J2 (this is the other end of the body receive line run #231T) and place a BNC coupling (not provided) on the cable end.

(Alternate) Connect a second long cable between the BNC coupling and the PIN DIODE DRIVE connector on the Pin Diode Drive Test Box.

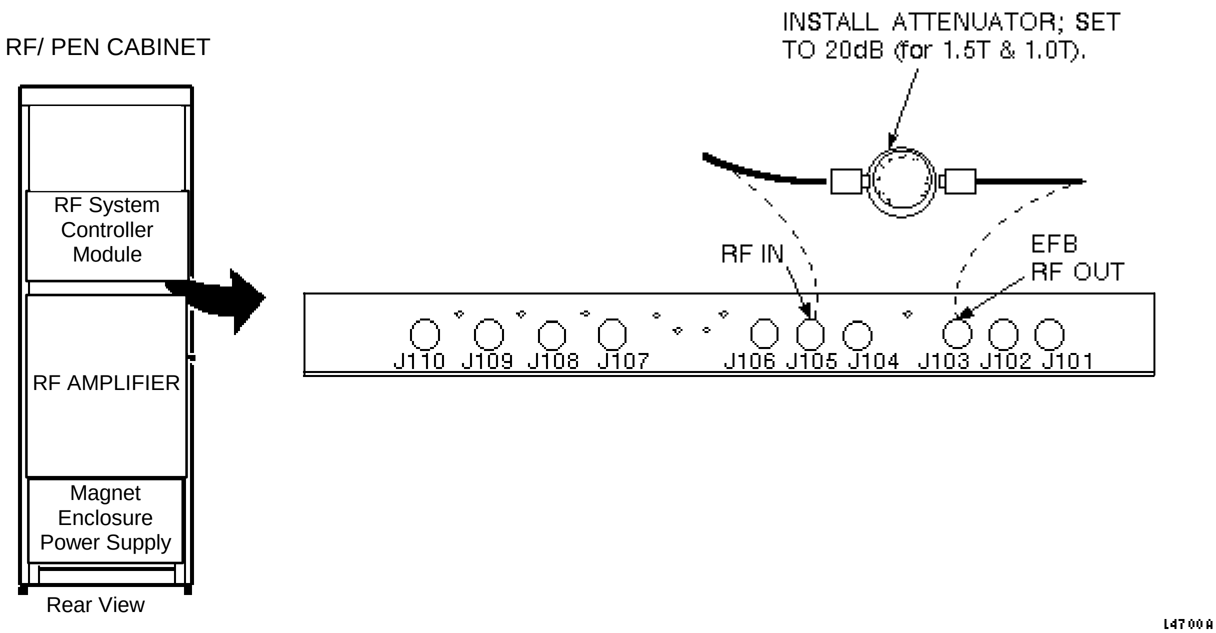
9. Verify that the switch on the Pin Diode Drive Test Box is in the Remote position.
10. Connect a BNC cable from the TRIGGER INPUT (called PATCH PANEL INPUT on some older boxes) connector on the Pin Diode Drive Test Box to J10 (DAB Out 6) on the CERD Board.
11. Plug in the power cord for the Pin Diode Drive Test Box.
12. Place the power switch for the Pin Diode Drive Test Box in the *on* position (referred to as *1* on the Pin Diode Drive Test Box).

CAUTION

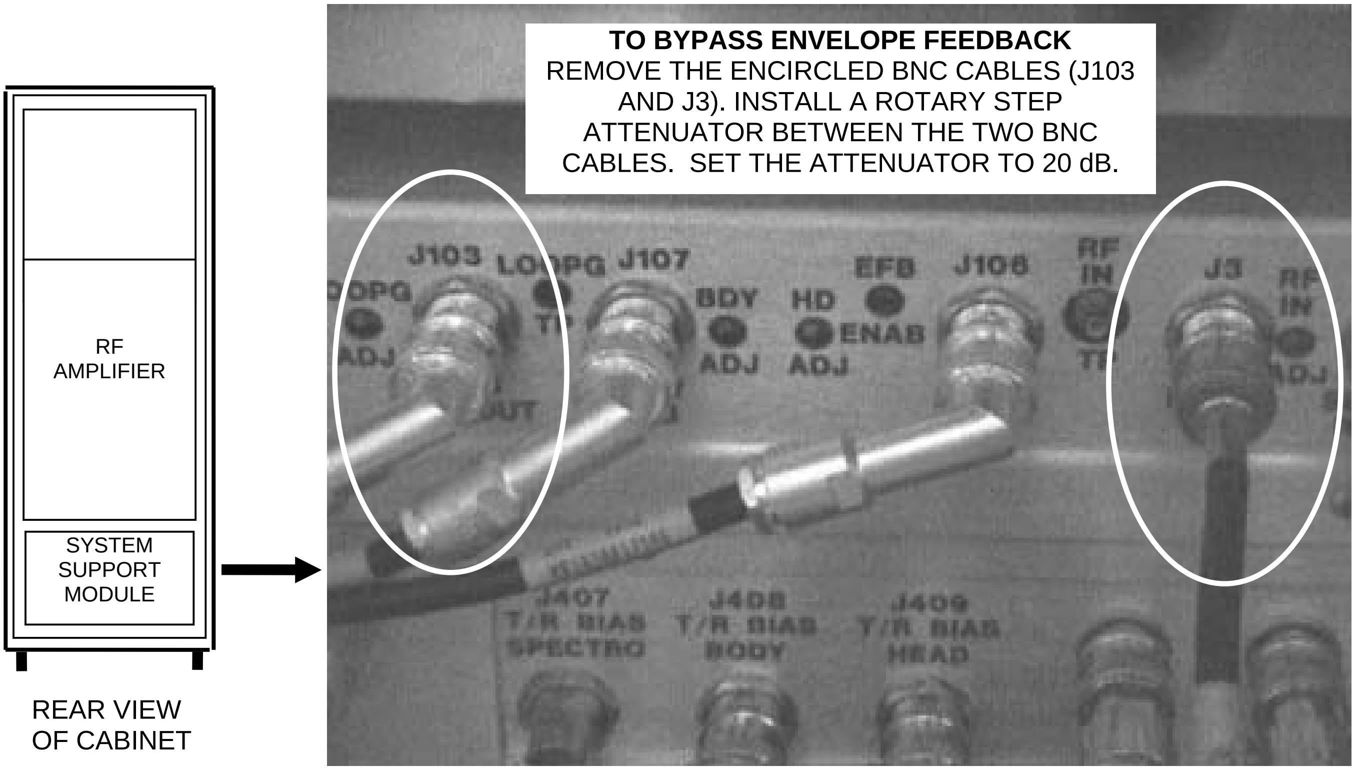
Equipment damage possibility. The coils used in the Grafidy phantoms require low RF power and can be damaged if the appropriate attenuation is not used!

13. **RF/PEN and RF/PEN II:** Install an attenuator to bypass envelope feedback circuitry at the RF amplifier. Disconnect BNC from EFB RF Out, and disconnect BNC from RF In. Add a rotary step attenuator (set to 20dB) in-line between the two BNCs, as shown for the RF PEN Cabinet in Illustration 6-4A or the RF PEN II Cabinet in Illustration 6-4B.

14. **RF/PDU (SRFD)**—Although envelope feedback is not employed on the RF/PDU cabinet, attenuation is still required. Install a rotary step attenuator set to 20dB between J1 on the rear of the System Cabinet (exciter output) and J1 on the fiber optic bracket at the rear of the RF/PDU. (J1 leads to the RFI input).



RF/PEN CABINET: RF SYSTEM CONTROL MODULE WITH EFB BYPASSED
ILLUSTRATION 6-4A

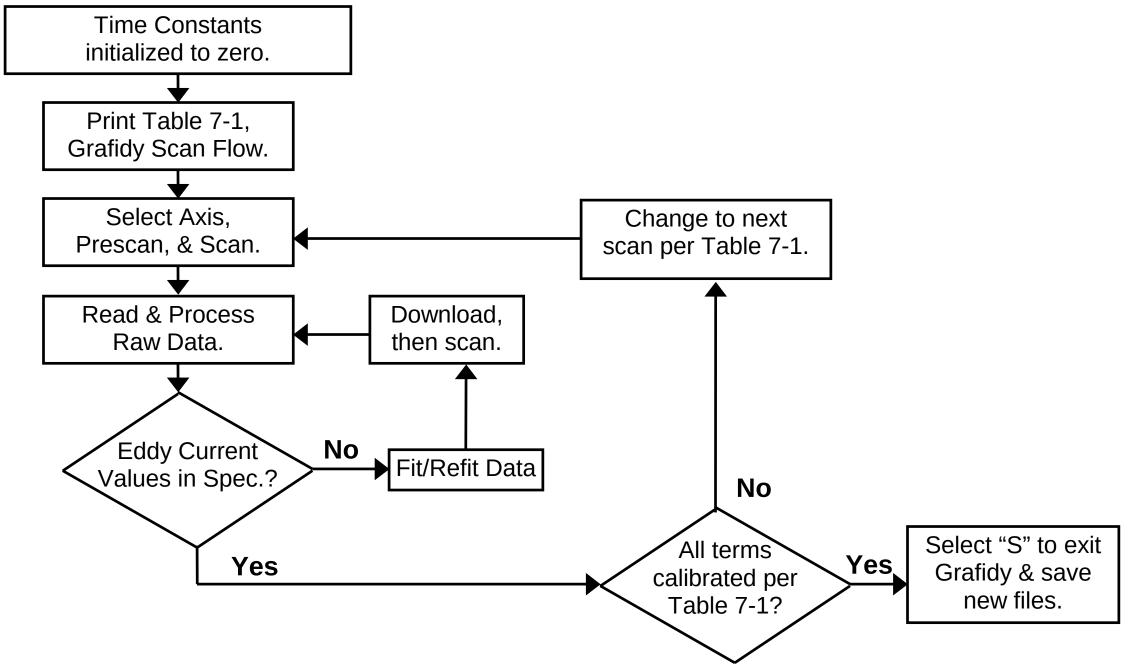


RF PEN II: SYSTEM SUPPORT MODULE--RF ATTENUATOR HOOKUPS (J3 AND J103)
ILLUSTRATION 6-4B

12. Proceed to Section 7, Grafidy Procedure.

7- GRAFIDY PROCEDURE

Grafidy is the name of the Eddy Current Compensation procedure. This is a very involved procedure, and is different from previous versions; please follow the procedure carefully. Illustration 7-1 is a general flowchart of Grafidy.



GRAFIDY FLOWCHART
ILLUSTRATION 7-1

7-1 Grafidy Scan Sequence Flow

Table 7-1 is a Grafidy scan sequence flow. It is **strongly recommended** that you print this table as a guide to ensure that you complete all calibrations required, in the proper order.

Note

VLTC FIT IS REQUIRED FOR SYSTEMS WITH SPECTROSCOPY (PROBE OR MULTI-NUCLEAR SPECTRO) and systems with a SV,SX,CX, or LCC magnet.

Hardware and Phantom Set-up ↓ Software Set-up ↓

TABLE 7-1
GRAFIDY SCAN SEQUENCE FLOW

LOCATION	**ILLUS. 7-2**	**THIS TABLE**	**THIS TABLE**	**SEC. 7-3**	**SEC. 7-4 (LIN.) SEC. 7-5 (B_0)**	**SPEC DATA (Absolute Values) Repeat Scan, Read and Process and Fit for each term/axis until in SPEC.**			
TERM	**AXIS SETUP**	**CV: MODE**	**CV: AXIS**	**READ & PROCESS**	**FIT**	**2.5-10 MSEC**	**10-100 MSEC**	**100-2000 MSEC**	**2-100 SEC**
*VLTC B_0	**X**	3 (VLONG)	0 (X)	B_0	B_0	-	-	-	≤ 0.10%
LONG	X	**0 (LONG)**	0 (X)	**LINEAR**	LINEAR	≤ 0.09%	≤ 0.030%	≤ 0.018%	-
B_0	X	0 (LONG)	0 (X)	**B_0**	B_0	≤ 0.10%	≤ 0.10%	≤ 0.10%	-
CROSS	X	0 (LONG)	**1 (Y)**	**LINEAR**	LINEAR	≤ 0.09%	≤ 0.030%	≤ 0.018%	-
CROSS	X	0 (LONG)	**2 (Z)**	LINEAR	LINEAR	≤ 0.09%	≤ 0.030%	≤ 0.018%	-
B_0 Recheck	X	0 (LONG)	**0 (X)**	**B_0**	B_0	≤ 0.10%	≤ 0.10%	≤ 0.10%	-
*VLTC B_0	**Y**	**3 (VLONG)**	**1 (Y)**	B_0	B_0	-	-	-	≤ 0.10%
LONG	Y	**0 (LONG)**	1 (Y)	**LINEAR**	LINEAR	≤ 0.09%	≤ 0.030%	≤ 0.018%	-
B_0	Y	0 (LONG)	1 (Y)	**B_0**	B_0	≤ 0.10%	≤ 0.10%	≤ 0.10%	-
CROSS	Y	0 (LONG)	**0 (X)**	**LINEAR**	LINEAR	≤ 0.09%	≤ 0.030%	≤ 0.018%	-
CROSS	Y	0 (LONG)	**2 (Z)**	LINEAR	LINEAR	≤ 0.09%	≤ 0.030%	≤ 0.018%	-
B_0 Recheck	Y	0 (LONG)	**1 (Y)**	**B_0**	B_0	≤ 0.10%	≤ 0.10%	≤ 0.10%	-
*VLTC	**Z**	**3 (VLONG)**	**2 (Z)**	**LINEAR**	LINEAR	-	-	-	≤ 0.018%
*VLTC B_0	Z	3 (VLONG)	2 (Z)	**B_0**	B_0	-	-	-	≤ 0.10%
LONG	Z	**0 (LONG)**	2 (Z)	**LINEAR**	LINEAR	≤ 0.09%	≤ 0.030%	_ 0.018%	-
B_0	Z	0 (LONG)	2 (Z)	**B_0**	B_0	≤ 0.10%	≤ 0.10%	≤ 0.10%	-
*VLTC (CROSS)	Z	**3 (VLONG)**	**0 (X)**	**LINEAR**	LINEAR	-	-	-	≤ 0.018%
CROSS	Z	**0 (LONG)**	0 (X)	LINEAR	LINEAR	≤ 0.09%	≤ 0.030%	≤ 0.018%	-
*VLTC (CROSS)	Z	**3 (VLONG)**	**1 (Y)**	LINEAR	LINEAR	-	-	-	≤ 0.018%
CROSS	Z	**0 (LONG)**	1 (Y)	LINEAR	LINEAR	≤ 0.09%	≤ 0.030%	≤ 0.018%	-
B_0 Recheck	Z	0 (LONG)	**2 (Z)**	**B_0**	B_0	≤ 0.10%	≤ 0.10%	≤ 0.10%	-

***** VLTC FIT IS REQUIRED FOR SYSTEMS WITH SPECTROSCOPY (PROBE OR MULTI-NUCLEAR SPECTRO) and systems with a SV,SX,CX, or LCC magnet.

NOTE 1: SELECT **[DOWNLOAD]** BEFORE PERFORMING EACH SCAN.

NOTE 2: SHORT TIME CONSTANTS ARE COMPENSATED FOR USING DEFAULT VALUES IN THE GRAFIDY CALIBRATION FILES.

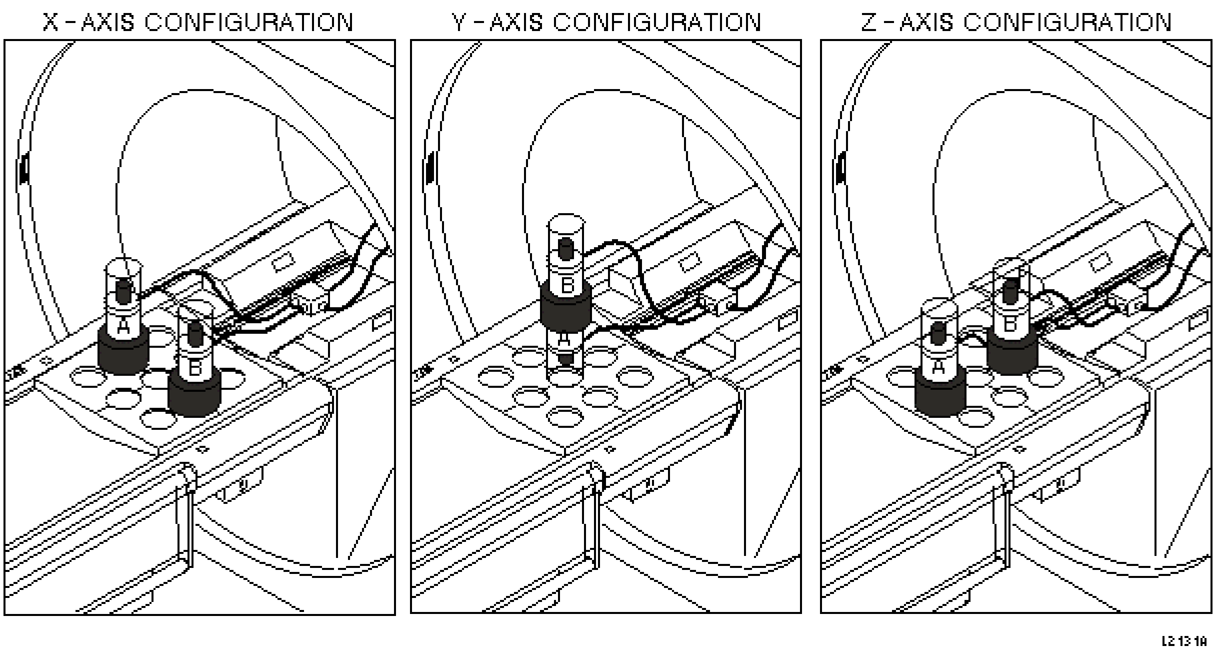
7-2 Select Axis, Prescan, Scan

This section refers to Table 7-1 (which you should have printed earlier).

1. Do the following for each term:
   - Configure the phantom for axis to be calibrated. See Illustration 7-2.
   - Set *Axis* CV per Table 7-1
   - Set *mode* CV is (**0** for long terms, cross terms, or B_0 terms (**1** for short terms)

Note

Short time constants are compensated for using default values that are in the default grafidy calibration files.



GRAFIDY PHANTOM CONFIGURATIONS
ILLUSTRATION 7-2

2. Select **[Done]**.

3. Select **[Manual Prescan]** and setup Twin Plot mode. See Table 7-2. Perform center frequency check.

4. Restore grad shims if first time. Adjust TG to peak as usual for transmit power. Record the TG value for next pass reuse.

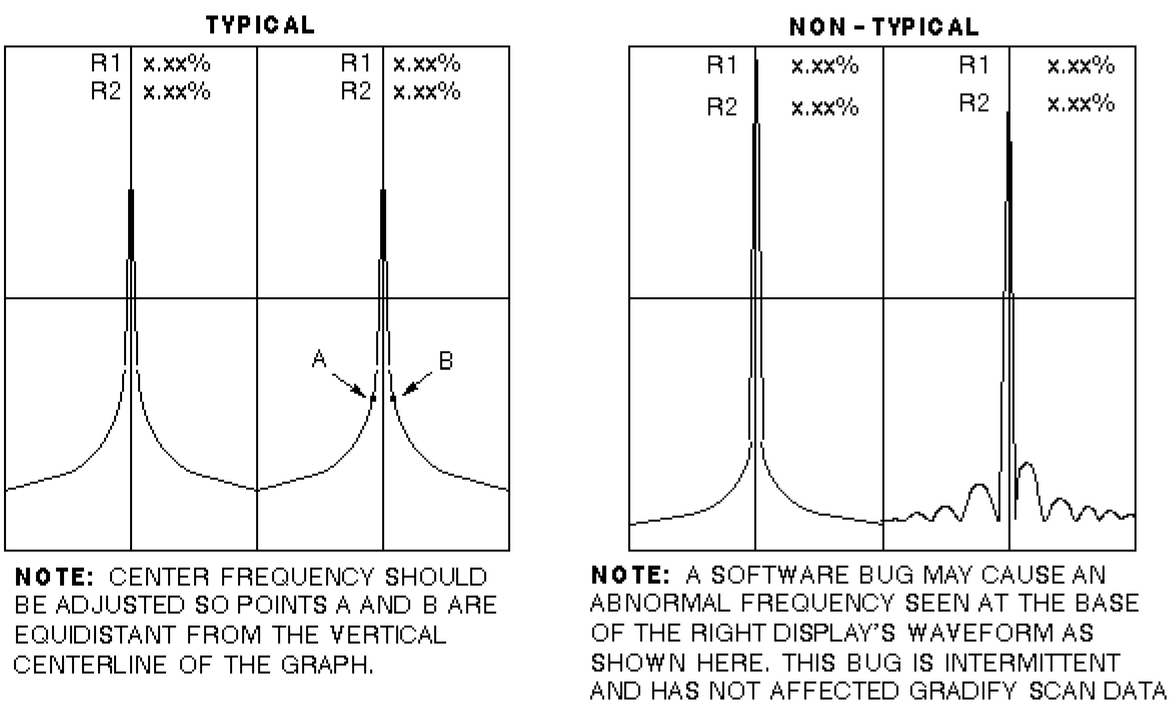
TABLE 7-2
MANUAL PRESCAN

PULL DOWN MENU	**[Windows]**
Select:	**Two Windows**
WINDOW ONE	
Type:	**P. Spect**
Plot Gain:	**1**
WINDOW TWO	
Type:	**P. Spect**
Plot Gain:	**1**

Note

The first time running grafidy on a system, you may need to restore the grad shim values that were set to zero during the DC offset portion of GRAM tuning. Otherwise the signal may not be large enough to peak the TG.

An example of a typical and an atypical prescan display are shown in Illustration 7-3. Examine the typical example and verify that your display is somewhat similar. Peaks of two waveforms need not be exactly equal.



GRAFIDY PRESCAN
ILLUSTRATION 7-3

Note

When the system is scanning, the LEDs (marked A and B) on the Pin Diode Drive Box flicker, indicating alternating coil selection. If you doubt whether the Grafidy test tools are working correctly, perform the procedure in section 2-16, Functional Check of Grafidy Hardware.

Note

If the IP screen goes blank, select **[Back Up]** and reenter **[Manual Prescan]**.

4. Select **[Done]**.

5. Select **[Scan]**

6. When the scan is finished, continue at Section 7-3 Read and Process Raw Data.

7-3 Read and Process Raw Data

See Screen 7-1.

SCREEN 7-1
READ AND PROCESS RAW DATA

OUTPUT/PROMPTS	INPUTS/COMMENTS
`GRAFIDY - Eddy Current Analysis`	Note - Grafidy has two modes; Normal and Expert

`1 - Read and Process Raw Data`
`2 - Fit`
`3 - Initialize Parameters`
`4 - System Status`	

`S or Q - Exit to Tools Menu`	
`Enter Choice: (0..5) [1] : ............`	**1 <Enter>**
`Please enter runfile number : 1024 ...............`	**<Enter>** (Read/process data from most recent scan.)

`Coils Along ()axis`
`Coil A Position: a.aaaaa cm`
`Coil B Position: a.aaaaa cm`	

See Illustration 7-4. for an example of an uncompensated Linear Long Time Constant Eddy Current response that is displayed at this point.	

`Linear Eddy Current Performance:`
`Max Deviation:`
`2.50ms to 10.00ms/ 10.00 ms to 100.00ms/ 100.00 ms to 2000.00ms/`	

`1.278 1.002 0.449 <--`	Record Linear eddy current values on Data Sheet (Appendix D). If values *are* in spec then continue at next term in Section 7-2 Select Axis, Prescan, Scan. If Linear eddy current values *are not* in spec, continue at Section 7-4 Fit/Refit Linear Terms, for Long or Cross terms
*See Illustration 7-5 for an example of the B_0 Eddy Current response that is displayed at this point. There is no need to save the B_0 display to a postscript file; Select **[Exit]** and continue.*	

`B0 Eddy Current Performance:`
`Max Deviation:`
`2.50ms to 10.00ms/ 10.00 ms to 100.00ms/ 100.00 ms to 2000.00ms/`	

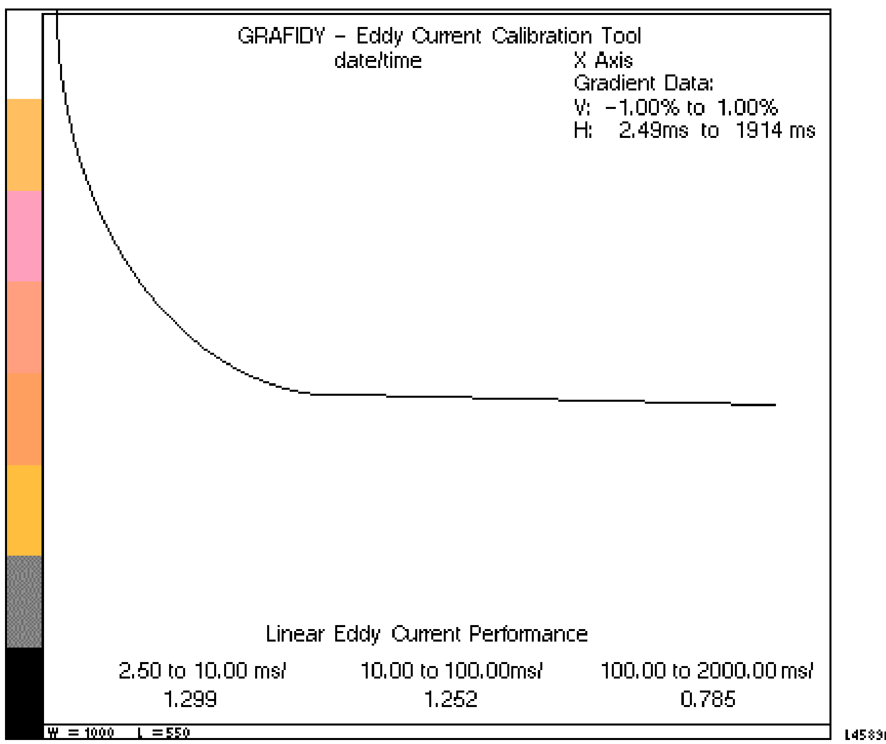
`-0.170 -0.057 0.015 <--`	Record B_0 values on Data Sheet (Appendix D). if doing B_0 terms. If values *are* in spec then continue at next term in Section 7-2 Select Axis, Prescan, Scan

OUTPUT/PROMPTS	INPUTS/COMMENTS
	If you are doing B_0 terms and the values *are not* in spec, continue at Section 7-5 Fit/Refit B_0 Terms

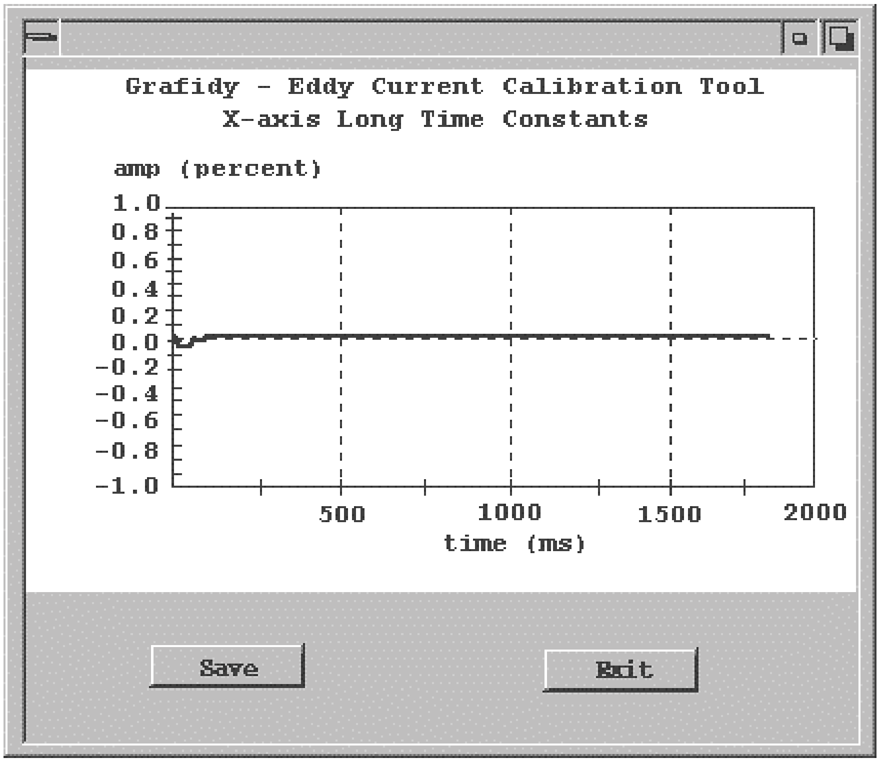
Note

This section documents the Normal Mode which is designed to provide you with all the necessary information you normally need to perform eddy current adjustment. The Expert Mode provides additional information about gradient and B_0 statistics, additional plotting capability that allows you to plot raw channels 1 and 2, B_0 graphs, and also capability to enter starting compensation values. There is a section named How to Enter Grafidy Expert Mode that documents how to get in/out of this mode, but it is not typically used.

NOTE: AXIS REFERENCE WILL REFLECT THE AXIS BEING TUNED.



UNCOMPENSATED LINEAR LONG TIME CONSTANT EDDY CURRENT RESPONSE PLOT
ILLUSTRATION 7-4



L4589B

B_0 EDDY CURRENT RESPONSE PLOT
ILLUSTRATION 7-5

7-4 Fit/Refit Linear Terms

See Screen 7-2.

SCREEN 7-2
FIT/REFIT LINEAR TIME CONSTANTS (LONG, CROSS, & SHORT TERMS)

OUTPUT/PROMPTS	INPUTS/COMMENTS
`GRAFIDY - Eddy Current Analysis`	
`1 - Read and Process Raw Data`	
`2 - Fit`	
`3 - Initialize Parameters`	
`4 - System Status`	
`S or Q - Exit to Tools Menu`	
`Enter Choice: (0..4) [1] : ...........`	**2<Enter>** (Select Fit.)
`GRAFIDY - Fit Menu`	Note: "Fit B0 Data" choice is not present during cross terms.
`1 - Fit Linear Data`	
`2 - Fit B0 Data`	
`S or Q - Exit Fit Menu`	
`Enter Choice: (1..2) [1] : ...........`	**1<Enter>** (Select Linear)
`Initial fit (or Refit): Hit enter to continue, s or q`	

OUTPUT/PROMPTS	INPUTS/COMMENTS

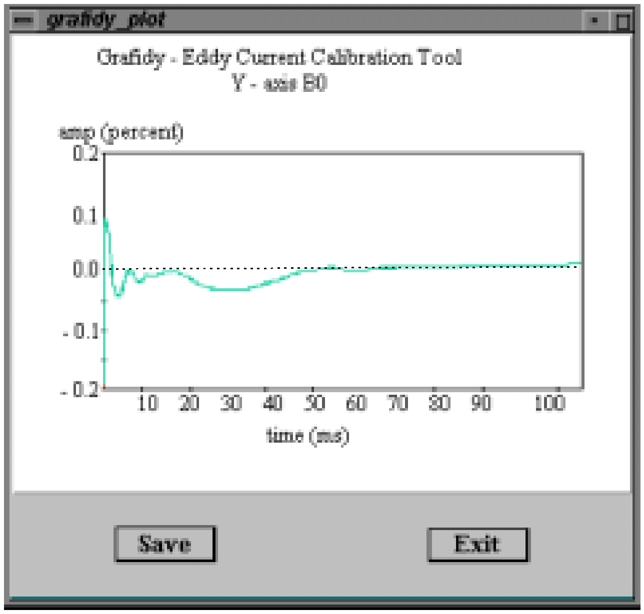
`to return to main menu: ..`
`Initial fit (or Refit)in progress..`
`*****************`
`Long TC Linear Fit Results:`
`tau[1]=  18.98 ms alpha[1]=0.01 percent`
`tau[2]=  40.96 ms alpha[2]=0.00 percent`
`tau[3]= 212.28 ms alpha[3]=0.00 percent`
`tau[4]= 463.84 ms alpha[4]=0.00 percent`	

`Do you want to plot linear data? (Y,N) [N] : .....`	**Y<Enter>** (Plot the data and view it on the image display. Accept all default parameters for the plots.)
`Do you want to accept new fit parameters?(Y,N)[N]:.`	**Y <Enter>** to save the new parameters to a file. Then from **Research Operations** select **[Download]** to write these parameters to the IPG. Then select **[Scan]** to collect raw data using the new parameters. (Select **N** only if the plot looks unexpectedly bad)
`WARP Coefficients Updated From working Parameter Set.`	
	Return to Section 7-3 Read and Process Raw Data to process the new raw data after the scan completes to get the linear eddy current response.

7-5 Fit/Refit B_0 Terms

Note

X and Y B_0 axes calibrations may fail to meet spec for magnet types: Oxford, S-V, Cx, and LCC. If failure is being caused from the steep slope in the beginning of the graph shown in Illustration 7-6, ignore failure, image quality will not be affected. If failure is a result of something else, calibrate axes as close to spec as possible.



Y-AXIS B_0 PLOT
ILLUSTRATION 7-6

See Screen 7-3 (Use for B_0 terms only).

SCREEN 7-3
FIT/REFIT B_0 TIME CONSTANTS

OUTPUT/PROMPTS	INPUTS/COMMENTS
GRAFIDY - Eddy Current Analysis 1 - Read and Process Raw Data 2 - Fit 3 - Initialize Parameters 4 - System Status S or Q - Exit to Tools Menu	
Enter Choice: (0..4) [1] :	**2<Enter>** (select Fit)
GRAFIDY - Fit Menu 1 - Fit Linear Data 2 - Fit B0 Data S or Q - Exit Fit Menu	
Enter Choice: (1..2) [1] :	**2<Enter>** (Select B_0.)
Initial fit (or Refit): Hit enter to continue, s or q to return to main menu: ..	**<Enter>** (to continue)
Initial fit (or Refit) in progress.. ******** Long Time-Constant B0 Fit Results: tau[1] = 6.38 ms alpha[1] = 0.08 percent tau[2] = 26.62 ms alpha[2] = -0.02 percent tau[3] = 234.67 ms alpha[3] = 0.00 percent tau[4] = 1.00 ms alpha[4] = -1.46 percent	("Refit" is shown for second and additional iterations)
Do you want to plot B0 data? (Y,N) [N] :	**Y<Enter>** (Plot the data and view it on the image display. Accept the default parameters for the plot.)
Do you want to accept new fit parameters?(Y,N)[N]:..	**Y<Enter>** to save the new parameters to a file. Then from **Research Operations,** select **[Download]** to write these parameters to the IPG. Then select **[Scan]** to collect raw data using the new parameters. (Select **N** only if the plot looks unexpectedly bad)
WARP Coefficients Updated From Working Parameter Set	**Note: Review Linear eddy current values when**

OUTPUT/PROMPTS	INPUTS/COMMENTS
	processing B0 Raw Data to verify linear data does not become out of spec. Else you will have start over on that axis. Return to Section 7-3 Read and Process Raw Data to process the new raw data after the scan completes to get the B_0 eddy current response.

7-6 Select *S* to Exit Grafidy

Select ***S*** to exit Grafidy and save the new files created during this procedure. If you select ***Q*** to exit Grafidy, you will lose the files created since the last save.

7-7 GRAM DC Offsets Re-Check

Readjust GRAM DC Offsets per Section 4, GRAM DC Offset Adjustment, then finish with Section 8, System Restoration.

8- SYSTEM RESTORATION

1. Remove the in-line attenuator (which bypasses Envelope Feedback) in the RF cabinet, added at the start of this procedure, and reconnect the BNC connectors to the original locations.

2. Remove the Grafidy Kit from the system.

3. Replace Patient Comfort Module at rear of body coil, if necessary.

4. Using proper ESD precautions, reposition the GRAM Tuning Boards on each axis.

CAUTION

Equipment damage possibility. Do not push the circuit board on. The nylon standoffs are quite brittle and will break. Push the top of the standoff away from the circuit board one by one. If they do not push off of the circuit board at first, work on the other standoffs one by one.

5. Replace the cover on each GRAM module.

CAUTION

Equipment damage possibility. EMI interference will cause the GRAMs to function incorrectly. It is important that all screws are in place on the GRAM module cover to control EMI emissions in or out of the module.

6. Replace GRAM cabinet front cover.

7. Restore the grad shim values if they were changed at the beginning of this procedure.

9- QUICK REFERENCE FOR GRAM TUNING

9-1 How to Use This Quick Reference Section

This section provides the necessary steps to complete GRAM tuning, but without the detailed step-by-step instructions and supporting illustrations. Obviously this section is intended for the very experienced "tuners." This quick reference can also be used to verify all the major sections have been completed.

9-2 Preliminary Steps

1. Power off
2. Check jumpers. All GRAM control board jumpers are set to pins 2 and 3.
3. All jumpers on the Digital Tuning Board should be in the Manual position.
4. Set R41 (VBUS) to 1000 ±25 ohms (for EchoSpeed), or 300 ±7.5 ohms (for HiSpeed).
5. Adjust Bus Voltage Regulator Gain (on GRAM control board. This is the only time that R41 is adjusted during this procedure.).
6. Power On.

9-3 Voltage Offset Adjustment

1. Measure TP18 (DAC_DI on the Digital Tuning Board) to ground with DVM.
2. Adjust R37 (DAC_DI Offset on the Digital Tuning Board) until TP18 reads 0 mVdc ±3 mVdc.

9-4 PWM Limit

1. Measure TP19 (PWM Limit on Digital Tuning Board) to ground using DVM.
2. Adjust R40 (on Digital Tuning Board), until TP19 equals 1.25 Vdc.

9-5 Amp Transitions per Sec Limit

1. Use DVM to measure TP24 (Amp/Sec limit at bottom of Digital Tuning Board) to ground.
2. Adjust R43 until TP24 equals 900 mVdc: (C48 & C49 are marked *475*)

9-6 GRAM DC Offset

1. At the operator work space, prepare the system for a Grafidy scan per scan protocol shown in the *Service Protocols* procedure located on the service methods CD-ROM, or for the alternate proprietary procedure use the following:

   Note: This alternate proprietary procedure is available for GE use, and to sites with a valid Advanced Service Package Limited License.

   a. Click on **[New Pt]**, and enter
      Id: **geservice**
      Name: **grafidy**
      Weight (Lb): **111**
      Set Patient Protocols to **Service**.
   b. In the Protocol field, type **o.5.1** (o=Other, 1=series number) to load protocol.
   c. **[Save Series]**.

2. Be sure that CVs axis=**0**, mode=**2**, R1=**7**, R2=**14**.

3. Use **[Manual Prescan]** to set all grad shim values to 0; save, and then **[Done]** to stop pulsing.
4. Measure GRAM out J3 (+ out) to J4 (– out) with a DVM (digital volt meter).
5. Adjust R151 (offset null under Digital Tuning Board, through a hole) for 0 mVdc, ±10 mv dc.
6. Repeat steps 2 & 3 for each axis being tuned.

9-7 LCoil Adjustments

1. Select **[Diagnostics]**, **[Start]**, **[IPG]**, **[Manual]**, **[LCoil Adjust]**. Then select **[Run Diags]**.

9-8 Grafidy Procedure

1. Install the Grafidy phantoms for axis to be calibrated.
2. Refer to Table 7-1 for sequence to perform Grafidy.

In the next step, you will change the CV values as indicated.

3. Set CVs for the axis and term being calibrated:
   axis=**0** (for *x*), 1 (for *y*), 2 (for *z*),
   mode=**0** (for long, cross, & B_0 terms), 1 for (short terms)
   TG=**0**, R1=**13**, R2=**14**, 4 frames, 1,0; 3,0
   Two Windows; One: P.Spect,1 Window Two: P.Spect,1
4. **[Manual Prescan]**, peak TG as usual
5. **[Scan].**
6. Read and process raw data, use defaults, record max dev values.
7. If performing grafidy for linear long, cross term, or short term time constants do a Linear Fit of the data. For B_0 terms, do a B0 Fit of the data; use defaults, accept suggested values.
8. Accept the new parameters and then **[Download]** them to the IPG.
9. **[Scan]** with the new parameters, then repeat Read and Process to see the results. Continue doing Refits until the parameters are in spec. Then record on data sheet.
10. Set up the phantoms and CVs for the next axis or term. **[Manual Prescan],** adjust TG and **[Scan].**
11. Continue calibrations in the following order: Long Time Constants, Cross Term Time Constants, B_0 Time Constants and lastlly Short Time Constants. All axes must be done for each set of time constants.
12. Select **S** to exit Grafidy and save the new files created during this procedure.

9-9 GRAM DC Offset

1. Adjust R151 (offset null under digital tuning board, through a hole) for 0 mVdc, ±10 mVdc.

The Grafidy process causes a dc voltage to be applied, so this must now be removed. Check and set Offset after performing Grafidy on each axis. The dc offset introduced from one axis may cause the sample position of the next axis to be less than desired.

9-10 Put everything back

1. Restore the system.
2. Remove the Grafidy kit including the 30 dB attenuator.
3. Restore Grad Shim values if they were changed.

10- SAVING/RESTORING COEFFICIENT FILES

This section details how to back up the ecccoeff.dat, and the gram_tune.dat files before a pass of Grafidy is performed. This is useful if you are in troubleshooting mode, and want to restore the system to its original calibration.

10-1 Gradient Configuration

The ecccoeff.dat file is also used to store the B_0 (zeroeth order) coefficients for systems **with** a GRAM and works in conjunction with the gram_tune.dat file. The gram_tune.dat file is downloaded everytime the GAP board is reset, i.e., on a TPS reset, a power cycle to the GAP chassis, or every time the Grafidy analysis tool is run. This file contains the eddy current (first order) coefficients for systems **with** a GRAM.

10-2 Backing up the Files

It is possible to back up these files in either of two ways: from the Service desktop, and from a C-shell on the Service desktop.

10-2-1 From the Service Desktop

1. Click on **[Install]**.
2. Place an MOD in the appropriate drive.
3. Click on **[Save Info]**.
4. When you want to restore the files, ensure that the MOD is inserted in its drive.
5. Ensure that you are on the Service desktop.
6. Click on **[Install]**.
7. Click on **[Restore Info]**, and answer the appropriate questions.

10-2-2 From a C-Shell on the Service Desktop

1. At the prompt, type
   cd /usr/g/caldir<Enter>
2. For <u>all</u> systems, type
   cp ecccoeff.dat ecccoeff.bak<Enter>
3. For systems with a GRAM, type
   cp gram_tune.dat gram_tune.bak<Enter>

10-3 Restore the Files

1. Ensure that you are in the /usr/g/caldir directory.
2. For <u>all</u> systems, type
   cp ecccoeff.bak ecccoeff.dat<Enter>
3. For systems with a GRAM, type
   cp gram_tune.bak gram_tune.dat<Enter>

10-4 System Restoration

Always perform a goodbye scan to ensure system functionality.

APPENDIX A - GRAM ADJUSTMENT DESCRIPTIONS

A-1 Preliminary Set Up Functional Description

The Preliminary Setup for GRAM Tuning is designed to ensure the state of the gradient driver subsystem. For example, if the switches and or jumpers on the GRAM control board are in the wrong location, unpredictable results will occur during this calibration.

VBUS (Bus Voltage Regulator Gain), an adjustment on the GRAM control board must be set to a preset gain. If this potentiometer cannot be adjusted, the GRAM must be replaced.
The Grafidy Coil and Grafidy Hardware are installed in this section to save time.

A-2 Voltage Checks

A-2-1 DAC Adjustments

This adjustment uses a DAC whose dc offset is unpredictable, and is neither controlled nor specified; therefore, there is no guarantee which value dc offset each DAC component will have. This dc offset must be eliminated so that the VControl signal receives no offset from this device. If VControl cannot be adjusted, it is probably due to a dc offset from this DAC.

VControl (VC) is = IR (drop across the coil) + Ldi/dt (drop across the coil)
DAC_I is the current command DAC, and DAC_DI is the Ldi/dt command from the GRAM.

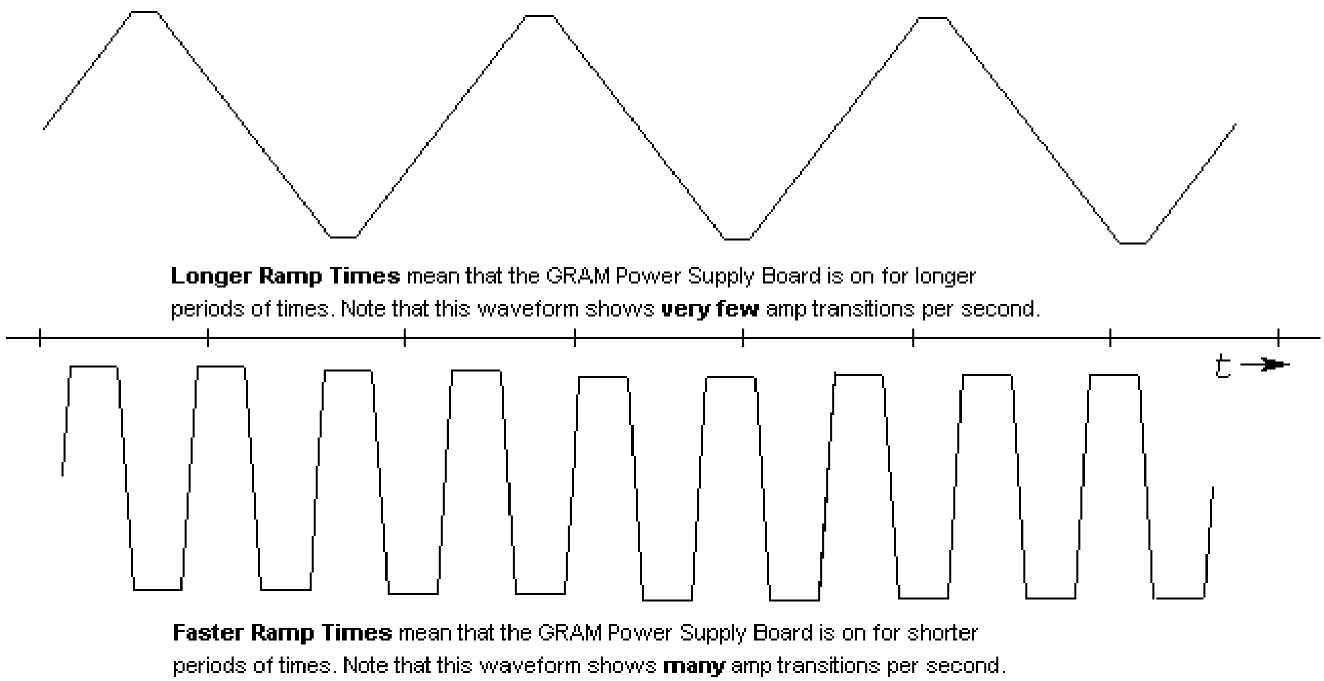
A-2-2 Pulse Width Modulation Adjustments

The value *%PWM* is simply the amount of time in a ramp without looking at current. Since the GRAMs are active only during the ramps, %PWM is also the amount of time that the GRAMs are PWM-ing. This adjustment sets the %PWM to 25%. If the ramp times are greater than 25%, this parameter starts to limit. The acceptable parameter is 25% PWM for approximately five seconds. This signal is filtered, so instantaneous ramp times can exceed 25%, but sustained ramps are limited. This adjustment allows for protection for snubber circuitry. Snubber function reduces switch loss on the IGBTs.

A-2-3 Amp Transitions per Second Adjustment

This adjustment prevents overloading of the power supply board in the GRAM. Since switching loads down the power supply board, it is important to be sure that there are acceptable number of transitions per second so that the power supply board does not overload.

If the average EPI waveform is displayed, the number of times the waveform transitions from one polarity to another for a given amount of time is measured. If there are long ramps, the number of transitions is lower; however, the time that the power supply board is active is longer (Remember that the GRAM is active during the ramps). If there are fast ramps, the number of transitions is much higher, and the time that the power supply board is active is shorter (see Illustration A-1).



AMP TRANSITIONS PER SECOND WAVEFORMS
ILLUSTRATION A-1

The optimum number of transitions must be set to protect this circuitry; therefore, we manually limit these transitions with the Amp Transitions per Second Adjustment.

A-3 GRAM DC Offset Adjustment Description

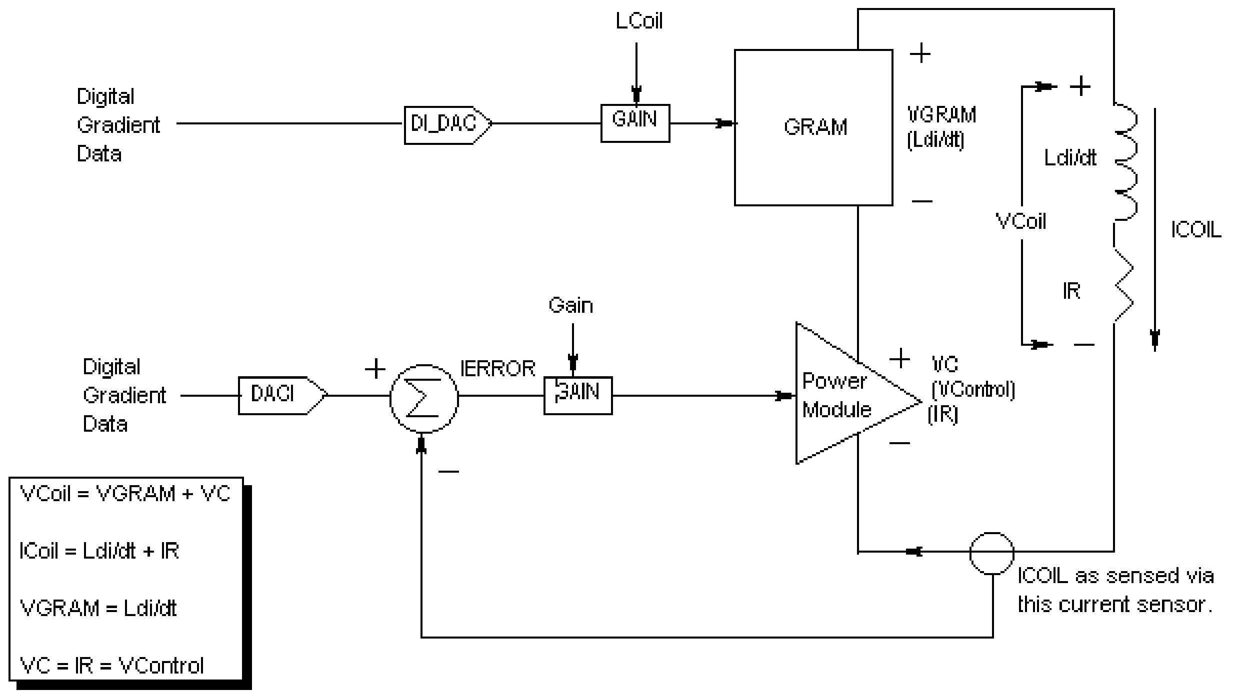
GRAM DC Offset Adjustment must be performed first, or the return signal may not show up. This is due to a magnitude offset caused by a dc offset on the output of the GRAM. A helpful tip is to make sure that the DVM that is used to measure the GRAM dc offset has long leads. This ensures that the connection at the rear of the GRAM can be made while the DVM display is near the GRAM Control Board. The potentiometer that is used for this adjustment is located on the GRAM Control Board. If this adjustment cannot be made, **make sure the grad shim values are set to zero**. If not zero, they provide a dc offset that you cannot adjust around.

A-4 LCoil, Loop Gain, and Gain Balance Adjustment Descriptions

The Auto Lcoil adjustment automatically calibrates Lcoil, Loop Gain, and Gain Balance.

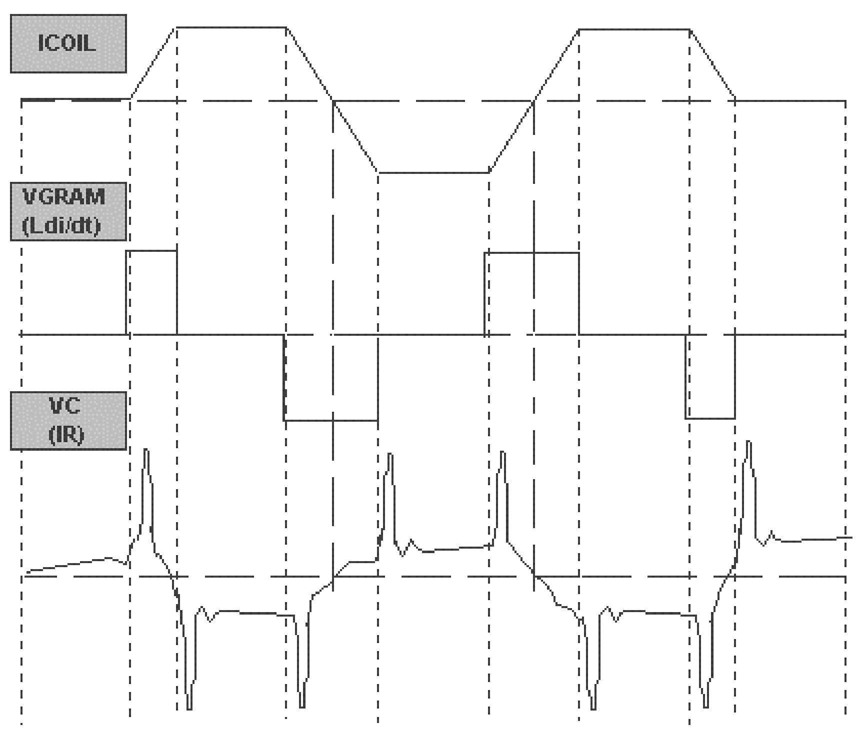
A-4-1 LCoil Adjustment

VCoil is equal to the IR potential from the power modules, **plus** the Ldi/dt potential from the GRAM. (V = IR + Ldi/dt). For our system, the L is the gradient coil, and this parameter is frequency dependent. Since the coil is not an ideal inductor, its frequency varies from coil to coil. Illustration A-2 shows a simplified gradient driver schematic. Illustration A-3 shows some important gradient driver waveshapes (ICoil, VGRAM, and VC). It is important to note that VC is VControl, and is simply equal to the voltage from the Techron power modules. Illustration A-4 shows VC if the inductance of the coil is greater than VC in Illustration A-3. Note that if LCoil is adjusted, this waveform looks more like the one in Illustration A-3.



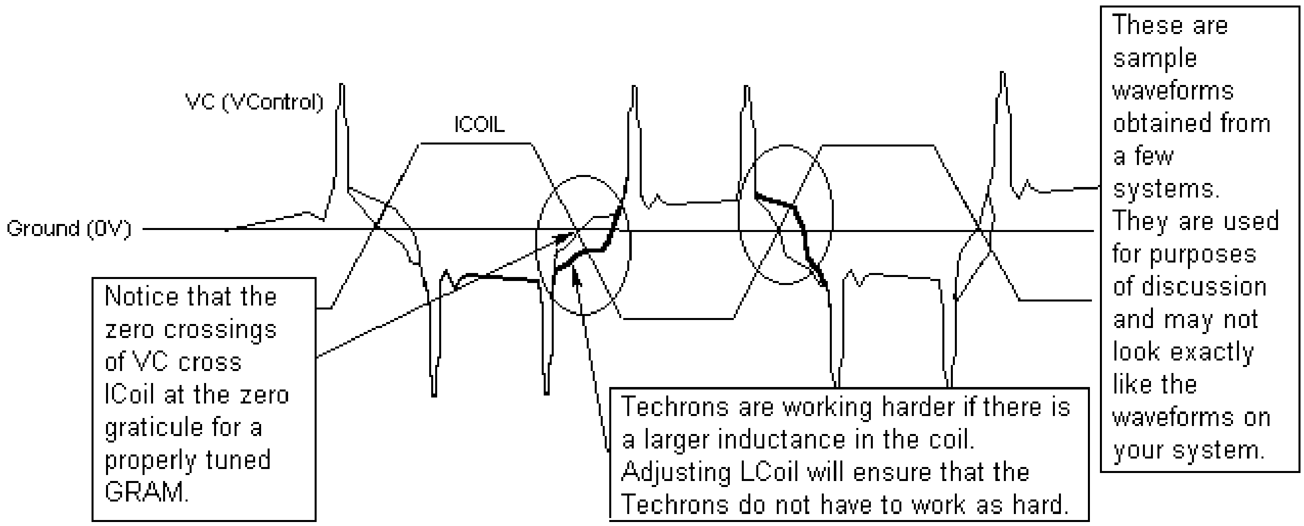
GRADIENT DRIVER SIMPLE SCHEMATIC
ILLUSTRATION A-2

In order to produce the trapezoidal current, ICOIL, the combination of Ldi/dt plus IR must be present. LCoil is the gain adjustment for VGRAM. DI_DAC is the GRAM command current. Gain is the Loop Gain applied to IERROR. IERROR is the error between the requested Techron command current (DACI), and the actual current (ICOIL). The Techron power modules try to compensate for losses or instantaneous differences between the current requested and the actual current. During a ramp, the GRAMs put out a constant voltage. (Note that this voltage actually occurs BEFORE the ramp by design so that the Techrons do not have to compensate as much.) When the Techrons see the requested current does not match the actual current they play out more VC. These are the "ears" that are present in the VC waveform. When the Techrons see that the GRAM is playing out adequate voltage to produce the required current, they begin to go back to zero. Since the Inductance of the coil is different from coil to coil, an adjustment must be made to essentially match the gain of the circuit with the inductance of the coil. This adjustment is *LCoil*.



GRADIENT DRIVER WAVESHAPES
ILLUSTRATION A-3

If the inductance of the coil increases, then the Techron power modules produce more voltage. This illustration shows the change in VC when the inductance of the coil increases. By adjusting LCoil, the GRAM will be producing the correct voltage, and the Techrons will not have to compensate by producing more voltage or current. Notice that if LCoil is adjusted, the zero crossings of VC and ICOIL move. The section of the waveform that is bold represents the additional voltage produced by the Techron power modules (VC) for a coil with higher inductance.



GRADIENT DRIVER WAVESHAPES
ILLUSTRATION A-4

If LCoil does not seem to be able to be adjusted, there may be a coil problem. An eddy current structure could be disturbed. One such disturbance could be extra metal in the imaging area. Another problem could be because the gain is set wrong. Since LCoil and gain are interactive, if one won't come in, it could be because the other is misadjusted.

A-4-2 Loop Gain Adjustment

Gain, or Loop Gain, is the amount of gain necessary to amplify the error signal (IERROR) so that the output of the Techron power module(s) is correct. This parameter compensates for the differences in gain between systems with one power module per axis (Signa Horizon HiSpeed), and systems with two power modules per axis (Signa Horizon EchoSpeed). Signa Horizon base model with two power modules per axis, do not have GRAMs, and, therefore, are not adjusted for gain.

If VC is overdamped, there will not be enough gain for the Techron power modules to assist the GRAM during ramps. If VC is underdamped, the Techron power modules are too sensitive to changes in the GRAM Voltage, thus making the circuit rather unstable during the ramps.
In order to produce the correct damping, VC must be adjusted such that there is a small amount of characteristic "bump" so that the correct gain is produced by the Techrons when needed. If the gain is not adjusted correctly, eddy current compensation for long and short time constants will not be able to converge correctly.

APPENDIX B - EDDY CURRENT COMPENSATION THEORY

B-1 Introduction

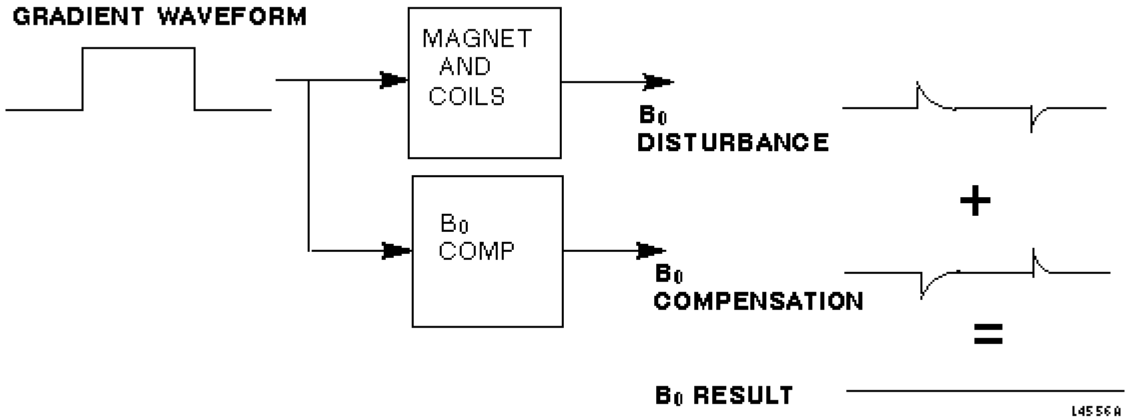
Eddy currents degrade image quality. The faster the scan, the more important eddy currents become. Eddy currents must be measured at shorter time intervals than before, due to the faster capability of the Signa Horizon product line. Eddy currents come in three categories: linear long time constant eddy currents, linear short time constant eddy currents, and B_0 eddy currents (FRESBECC, Frequency Shift B_0 Eddy Current Compensation) (see Table B-1 for all three). There are different implementations for each of the different types of eddy currents.

TABLE B-1
EDDY CURRENTS - LINEAR ECC

	ANALOG	ANALOG / DIGITAL	DIGITAL
Parameter	• Long time constants	• Long time constants • Short time constants	• Long time constants
Where ECC Occurs	Done with Tuning (Grafidy) Board on 8607 Master Gradient Amplifier	Done on GRAM with Digital Tuning Board or on GIP for SGD	Done on IPG-WARP
How to Perform Grafidy	VT and VA adjusted by potentiometers on the Grafidy Board	Digital potentiometers on the Digital Tuning Board controlled by software High Pass filters on the GIP for SGD that are controlled by software	VT and VA adjusted by software on IPG-WARP
Hardware & Systems Affected	• Signa Advantage Release 5.5 with 8607s • All Signa Advantage Release 5.4 Systems	• Signa Horizon Hi & Echo Speed (8645s & GRAM) • Signa Horizon Hi & Echo with SGD hardware	• Signa Horizon (8645s)

B-2 B_0 Eddy Currents: Zeroth-order Eddy Current Compensation

Gradient pulses induce eddy currents. Some of these eddy currents cause time-varying magnet field errors with zeroth-order, or B_0, geometry. Zeroth-order eddy current compensation, also called *B_0 eddy current compensation*, prevents image quality degradations caused by eddy currents. In prior systems, the mechanical alignment of the inner gradient coil with respect to the outer gradient coil was adjusted to minimize B_0 eddy currents. At this time, compensation is done as shown in Illustration B-2.



B_0 EDDY CURRENT RESPONSE AND COMPENSATION FOR EPOXY-FILLED GRADIENT COIL
ILLUSTRATION B-1

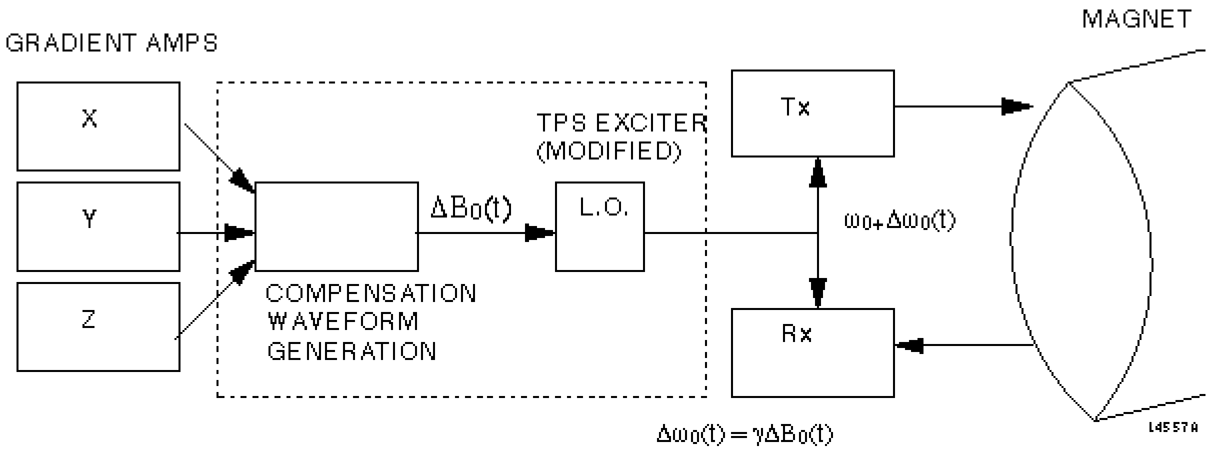
The commanded gradient waveforms are fed into a block which realizes the transfer function from gradients to B_0 field disturbance. The negative of the predicted waveform is used to null the B_0 disturbance. Past experience indicates that the transfer function from a gradient axis to the B_0 disturbance can be adequately approximated as shown in the formula in Illustration B-2, where *N* is equal to 4. The amplitudes *Ai* and time constants *Ti* are determined when the Grafidy procedure is used. A unique set of amplitudes and time constants are needed for each gradient axis. The total B_0 disturbance derived from multiple gradient axes is the sum of the individual B_0 disturbances.

$$h_{axis}(t) = \sum_{i=1}^{N} A_i e^{-t/T_i}$$

L4576A

FORMULA
ILLUSTRATION B-2

The B_0 disturbance caused by eddy currents can be cancelled by pulsing a special B_0 winding; however, the equivalent effect can be achieved by shifting the transceiver reference frequency to track the disturbance. Since the errors are due to the difference between the magnet frequency and the system reference frequency, the effect is the same as cancelling the field disturbance. This method is called *Frequency Shift B_0 Eddy Current Compensation* (FRESBECC). See Illustration B-3.



B_0 EDDY CURRENT BY FREQUENCY SHIFTING
ILLUSTRATION B-3

B-3 B_0 Hardware Changes

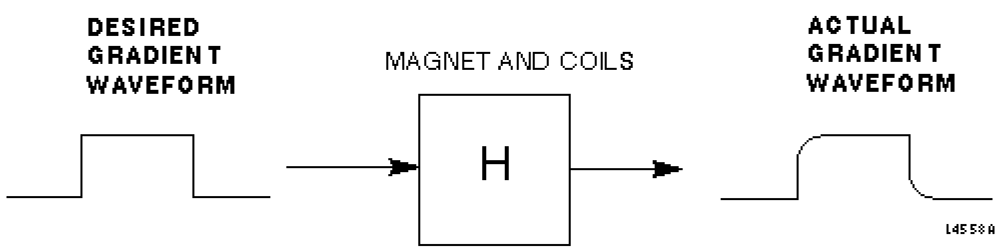
IPG can generate frequency shift waveforms appropriate for zeroth order eddy current compensation. This requires the addition of a bit serial interface from the WARP processor to the backplane. The inputs to the WARP processor function, which generates the Frequency Shift Waveform, are:

- The digital gradient commands for physical *X*, *Y*, and *Z* gradients.
- A set of calibration values.

The calibration values include four amplitudes and time constants for each axis, plus a scale factor. The output from the IPG is digital frequency shift waveform values in 16-bit C30 bit serial format. The signals are available on the chassis backplane for transfer to the CERD.

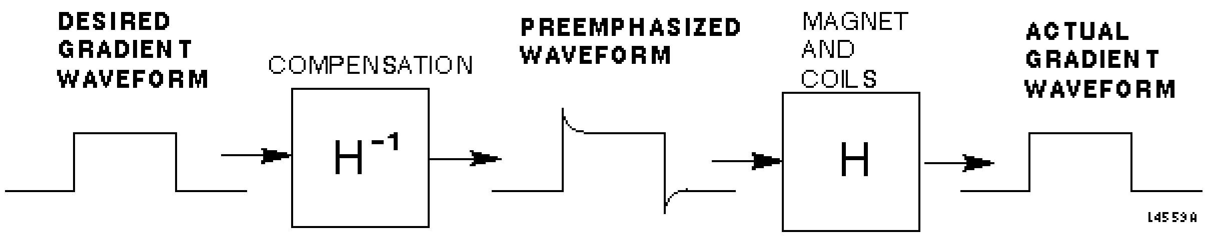
B-4 Linear Eddy Currents: First-order Eddy Current Compensation

Gradient pulses induce eddy currents. Some of these eddy currents cause time varying magnet field errors with the same geometry as the applied pulse. The effect is a distortion of the desired gradient pulse, as shown in Illustration B-4. First-order eddy current compensation prevents these distortions.



EFFECT OF FIRST-ORDER EDDY CURRENTS
ILLUSTRATION B-4

The method used to compensate gradient waveforms for distortion is to apply the inverse of the transfer function, which causes the distortion, prior to playing out the pulse. When the resultant pre-emphasized pulse is played, the final output is the desired gradient pulse, as shown in Illustration B-5. Past experience indicates that the transfer function from gradient command input to actual gradient output axis can be adequately approximated as the formula in Illustration B-6 shows, where *N* is equal to 4. The amplitudes *Ai* and time constants *Ti* are determined when the Grafidy procedure is used. A unique set of amplitudes and time constants are needed for each gradient axis.



FIRST-ORDER EDDY CURRENT COMPENSATION
ILLUSTRATION B-5

$$h_{axis}(t) = 1 - \sum_{i=1}^{N} A_i e^{-t/T_i}$$

FORMULA
ILLUSTRATION B-6

In previous products, pre-emphasis was applied by means of analog circuitry on each gradient amplifier (the Grafidy boards). Currently, pre-emphasis is applied either by using similar circuitry on the Gradient Ramp Accelerator Module (GRAM) Tuning Board in system configurations using GRAMs, or by using digital pre-emphasis in the systems cabinet in system configurations with 8645 gradient amplifiers, and without GRAMs.

B-5 Linear Eddy Current Hardware Changes

IPG hardware and software have been changed so that IPG can add pre-emphasis to the generated physical gradient waveforms before they are sent to the gradient amplifiers. The inputs to the WARP processor function, which generates the pre-emphasis, are:

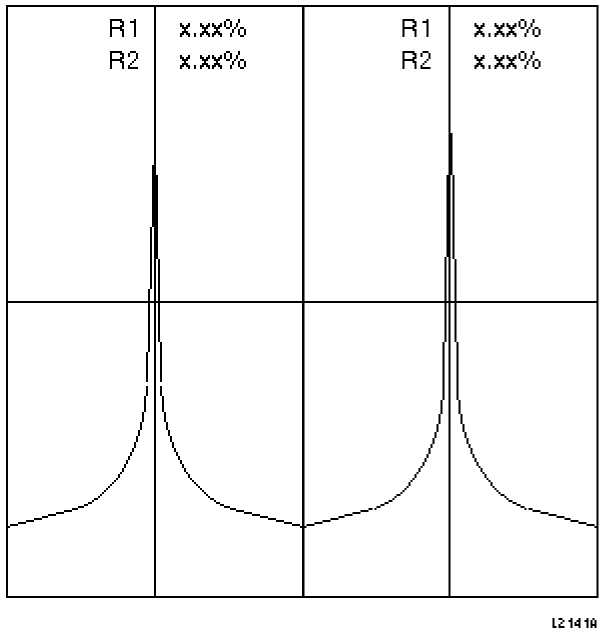
- The digital gradient commands for physical *X*, *Y* and *Z* gradients
- A set of calibration values

The calibration values include four amplitudes and time constants for each axis. The amplitudes are expressed as a percentage of the desired gradient command. The time constants are in milliseconds. The output from IPG is digital gradient command waveforms with pre-emphasis added, if required for the present system configuration.

APPENDIX C

C-1 Functional Check of Grafidy Hardware

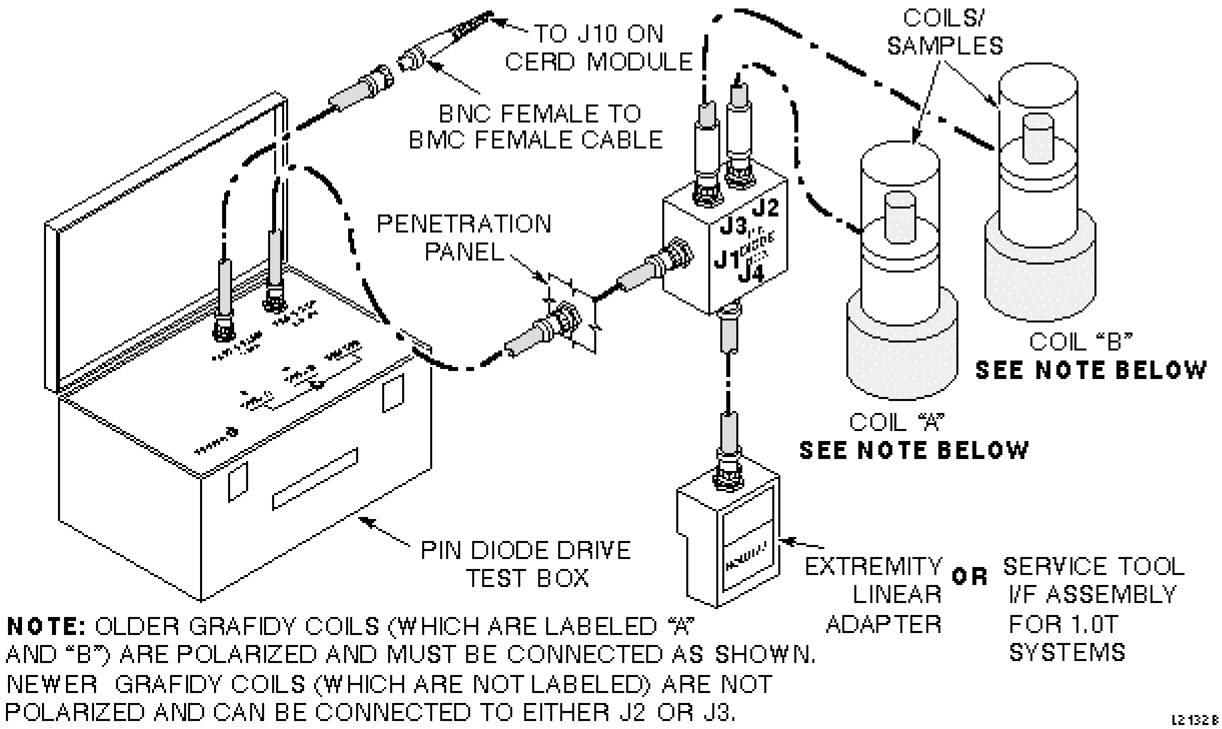
1. Start manual prescan using the Grafidy hardware. Verify that the display is similar to the display in Illustration C-1.



TYPICAL GRAFIDY PRESCAN
ILLUSTRATION C-1

If it is not, some things to check include:

- Are all cables, including the coil/samples, connected per Illustration C-2?
- Is the Pin Diode Drive Test Box plugged into a good power source with the switch in the *1* position?
- Is a signal present at J10 on the DAB module (alternating from 0 volts to 2.5–4.0 volts)?



GRAFIDY EQUIPMENT SETUP
ILLUSTRATION C-2

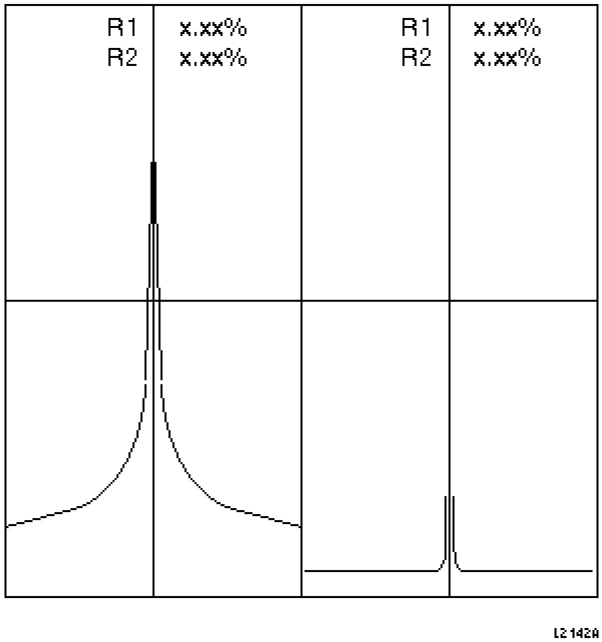
2. Select **[Done]**.

3. Turn off the Pin Diode Drive Test Box.

4. Disconnect one of the coil/samples from the hardware by removing cable from J3 of the pin diode box.

5. Place the power switch for the Pin Diode Drive Test Box in the *1* position.

6. Select **[Manual Prescan]** again, and verify that one of the signals has been eliminated (see Illustration C-3). At this point, you can be fairly sure that the Grafidy hardware works. It is important that only one waveform be eliminated when a coil is disconnected; which one is not important.



PRESCAN MINUS ONE COIL/SAMPLE
ILLUSTRATION C-3

C-2 Functional Check/Maintenance of Grafidy Coil

C-2-1 1.5T Coil Impedance Check

1. To verify the functionality of the 1.5T Grafidy coil, measure the impedance. To do this, the pin diode must be forward biased. Use a BNC tee adapter to inject a 10-mA dc current at the point where the impedance meter probe mates with the quarter wavelength cable. A 1000-ohm resistor, driven by a 10-volt power supply, produces the necessary current with only a small additional load on the desired input impedance. Forward bias the pin diode as described above.

2. Set the vector impedance meter at 63.86 mHz, and measure the input impedance of the coil.

3. Fine tune the variable trim capacitor, P10, to get nearly 50 ohms at 0º phase. Acceptance values are:
    Magnitude: 38 to 65 ohms
    Phase Angle: –15º to 15º

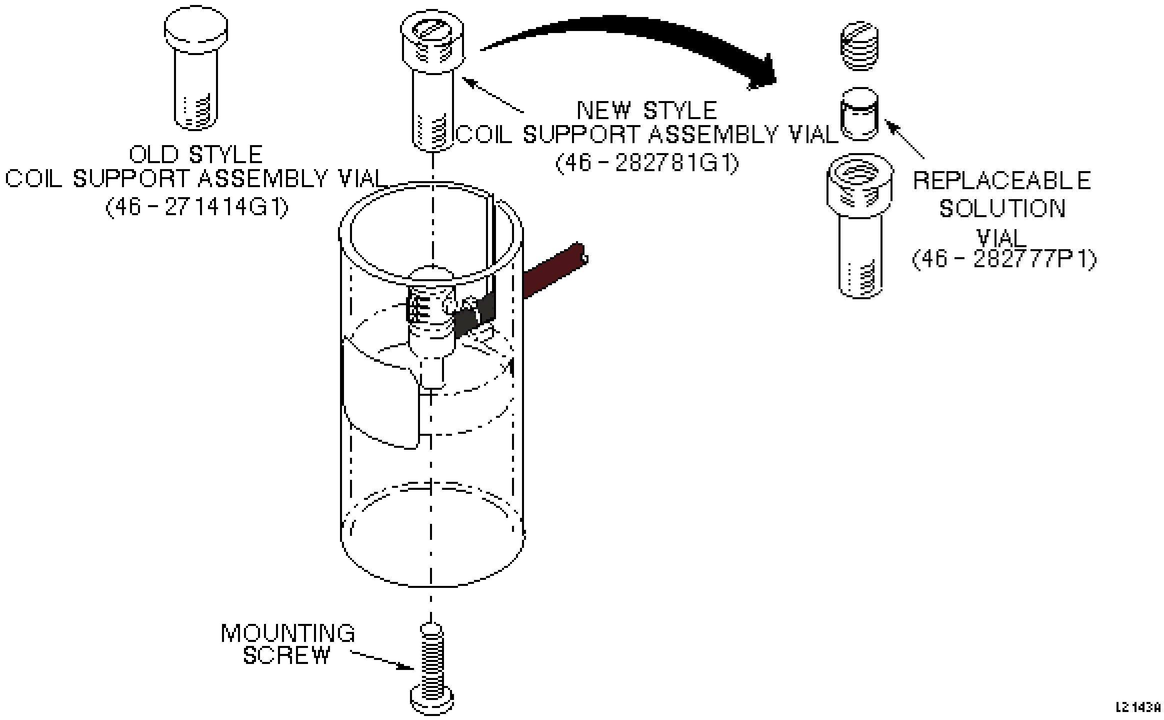
C-2-2 1.0T Coil Impedance Check

Place Grafidy coil assembly on a non-conductive stand at least three feet from any conducting surfaces. Set vector impedance meter at 42.68 mHz, and measure the input impedance of the coil. Acceptance values are:

Magnitude: 38 to 65 ohms
Phase Angle: –15º to 15º

C-3 Solution Vial Replacement

The Grafidy coils have replaceable solution vials; see Illustration C-4 for assembly and part number information.



GRAFIDY COIL/SAMPLE REPLACEMENT
ILLUSTRATION C-4

APPENDIX D - GRAFIDY DATA SHEETS

VERY LONG TIME CONSTANTS (Cross-term, Linear, Bo)					
Axis	**Time Interval (M Sec)**	**Run # _______ Max. Deviation**	**Run # _______ Max. Deviation**	**Run # _______ Max. Deviation**	**Specifications**
X (Coil) Bo axis = 0 (X)	2000-200,000				≤ 0.10% (B0)
Y (Coil) Bo axis = 1 (Y)	2000-200,000				≤ 0.10% (B0)
Z (Coil) Bo axis = 2 (Z)	2000-200,000				≤ 0.10% (B0)
Z (Coil) Linear axis = 2 (Z)	2000-200,000				≤ 0.018% (Linear)
Z(Coil) Cross-term axis = 0 (X)	2000-200000				≤ 0.018% (Cross-Term)
Z(Coil) Cross-term axis = 1(y)	2000-200000				≤ 0.018% (Cross-Term)

LINEAR LONG TIME CONSTANTS					
X-axis	**Time Interval (msec)**	**Run# _______ Max. Deviation**	**Run# _______ Max. Deviation**	**Run# _______ Max. Deviation**	**Specifications**
	2.5 - 10.00				≤ 0.09%
	10.00 - 100.00				≤ 0.03%
	100.00 - 2000.00				≤ 0.018%
Y-axis	**Time Interval (msec)**	**Run# _______ Max. Deviation**	**Run# _______ Max. Deviation**	**Run# _______ Max. Deviation**	**Specifications**
	2.5 - 10.00				≤ 0.09%
	10.00 - 100.00				≤ 0.03%
	100.00 - 2000.00				≤ 0.018%
Z-axis	**Time Interval (msec)**	**Run# _______ Max. Deviation**	**Run# _______ Max. Deviation**	**Run# _______ Max. Deviation**	**Specifications**
	2.5 - 10.00				≤ 0.09%
	10.00 - 100.00				≤ 0.03%
	100.00 - 2000.00				≤ 0.018%

LINEAR CROSS-TERM TIME CONSTANTS					
X-axis axis = 1(y)	**Time Interval (msec)**	**Run# ______ Max. Deviation**	**Run# ______ Max. Deviation**	**Run# ______ Max. Deviation**	**Specifications**
	2.5 – 10.00				≤ 0.09%
	10.00 – 100.00				≤ 0.03%
	100.00 – 2000.00				≤ 0.018%
X-axis axis = 2(z)	**Time Interval (msec)**	**Run# ______ Max. Deviation**	**Run# ______ Max. Deviation**	**Run# ______ Max. Deviation**	**Specifications**
	2.5 – 10.00				≤ 0.09%
	10.00 – 100.00				≤ 0.03%
	100.00 – 2000.00				≤ 0.018%
Y-axis axis = 0(x)	**Time Interval (msec)**	**Run# ______ Max. Deviation**	**Run# ______ Max. Deviation**	**Run# ______ Max. Deviation**	**Specifications**
	2.5 – 10.00				≤ 0.09%
	10.00 – 100.00				≤ 0.03%
	100.00 – 2000.00				≤ 0.018%
Y-axis axis = 2(z)	**Time Interval (msec)**	**Run# ______ Max. Deviation**	**Run# ______ Max. Deviation**	**Run# ______ Max. Deviation**	**Specifications**
	2.5 – 10.00				≤ 0.09%
	10.00 – 100.00				≤ 0.03%
	100.00 – 2000.00				≤ 0.018%
Z-axis axis = 0(x)	**Time Interval (msec)**	**Run# ______ Max. Deviation**	**Run# ______ Max. Deviation**	**Run# ______ Max. Deviation**	**Specifications**
	2.5 – 10.00				≤ 0.09%
	10.00 – 100.00				≤ 0.03%
	100.00 – 2000.00				≤ 0.018%
Z-axis axis = 1(y)	**Time Interval (msec)**	**Run# ______ Max. Deviation**	**Run# ______ Max. Deviation**	**Run# ______ Max. Deviation**	**Specifications**
	2.5 – 10.00				≤ 0.09%
	10.00 – 100.00				≤ 0.03%
	100.00 – 2000.00				≤ 0.018%

B0 TIME CONSTANTS					
X-axis	Time Interval (msec)	Run# ________ Max. Deviation	Run# ________ Max. Deviation	Run# ________ Max. Deviation	Specifications
	2.5 – 10.00				≤ 0.10%
	10.00 – 100.00				≤ 0.10%
	100.00 – 2000.00				≤ 0.10%
Y-axis	Time Interval (msec)	Run# ________ Max. Deviation	Run# ________ Max. Deviation	Run# ________ Max. Deviation	Specifications
	2.5 – 10.00				≤ 0.10%
	10.00 – 100.00				≤ 0.10%
	100.00 – 2000.00				≤ 0.10%
Z-axis	Time Interval (msec)	Run# ________ Max. Deviation	Run# ________ Max. Deviation	Run# ________ Max. Deviation	Specifications
	2.5 – 10.00				≤ 0.10%
	10.00 – 100.00				≤ 0.10%
	100.00 – 2000.00				≤ 0.10%

Note: Short time constants are compensated for using values in the default Grafidy calibration file.

LINEAR SHORT TIME CONSTANTS					
X-axis	Time Interval (msec)	Run# ________ Max. Deviation	Run# ________ Max. Deviation	Run# ________ Max. Deviation	Specifications
	–0.95 to –0.80				≤ 1.50%
	–0.80 to –0.50				≤ 0.75%
	–0.50 to –0.01				≤ 0.75%
Y-axis	Time Interval (msec)	Run# ________ Max. Deviation	Run# ________ Max. Deviation	Run# ________ Max. Deviation	Specifications
	–0.95 to –0.80				≤ 1.50%
	–0.80 to –0.50				≤ 0.75%
	–0.50 to –0.01				≤ 0.75%
Z-axis	Time Interval (msec)	Run# ________ Max. Deviation	Run# ________ Max. Deviation	Run# ________ Max. Deviation	Specifications
	–0.95 to –0.80				≤ 1.50%
	–0.80 to –0.50				≤ 0.75%
	–0.50 to –0.01				≤ 0.75%

REVISION HISTORY

REV	DATE	AUTHOR	PRIMARY REASONS FOR CHANGE
0	Oct 5, 1998	M. Keber, F. Fiore	Initial Release CV1 version.
1	Oct 19, 1998	M. Keber	Updated for program change from Release "CV1" to "8.2.5"; corrected VLTC Bo spec on data sheet.
2	Nov 11, 1998	M. Keber	Corrected Sec 5-2 file names to remove. Noted that VLTC is required for Spectro but optional for non-spectro systems.
3	Dec. 21, 1998	J. Wolak	Added clarification to a note regarding saving plots
4	May 20, 1999	SM Atladottir	Updated Procedure References for New GUI
5	June 18, 1999	K. Keshena	Add note to section 7-5 for X & Y B0 axes test failures per SPR #53070.
6	October 23, 2000	K. Keshena	Changed software release to 8.x
7	Jan. 31, 2002	K. Keshena	Changed note in section 7-1 & Table 7-1, VLTC FIT IS REQUIRED FOR SYSTEMS WITH SPECTROSCOPY (PROBE OR MULTI-NUCLEAR SPECTRO) and systems with a SV,SX,CX, or LCC magnet.
8	July 11, 2002	K. Keshena	Removed reference to Section 8, Voltage Clamp Checks in flowchart and DC Offsets section. Confirmed with Tom Mcfarland that procedure was not necessary and had not been part of the document.