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M Series Spectrometers

500M, 750M, 1000M, 1250M



SPEX Industries, Inc. 3880 Park Ave., Edison, NJ 08820
TEL: (908) 549-7144 FAX: (908) 549-5125

1 General Information

This manual contains operation and maintenance instructions for the 500M, 750M, 1000M and 1250M research-grade spectrometers. Detailed instructions for controlling devices and accessories are contained in separate manuals.

1.1 Unpacking

Note: If shipping damage is noticed at delivery, the carrier should note such evidence on the delivery receipt and sign all copies.

CAUTION: Do not use the slit housing or other protrusions for lifting.

Open the top of the shipping box and all inside braces. Carefully lift the instrument. Do not use the instrument knobs or counter, etc. The spectrometer, including the shipping base, should be placed on a sturdy table in a room with a temperature constant of $\pm 2^{\circ}$ C.

Inspect for previously hidden damages and notify carrier immediately if any are found.

Install leveling legs. Move the instrument to its permanent position; place pads under legs. Level instrument baseplate, using the two front legs and rear center leg.

1.2 Inspection for Damage

Inspect the instrument for visible evidence of any damage. Check that all readily visible mechanical and electrical components are in their proper place and intact. **If damage is evident, do not operate the instrument. Notify SPEX Industries, Inc. and the carrier at once.**

Many public carriers do not recognize claims for concealed damage if reported later than 15 days after delivery. For a shipping damage claim, the inspection by the carrier agent is required. For this reason, the original packing should be retained as evidence. While SPEX Industries, Inc. is not liable for damage in transit, the company will extend every effort to aid and advise.

1.3 Installation

Call the SPEX service department for installation of the 750m, 1000M, and 1250M spectrometers.

To install the 500M spectrometer and the ministep driver (MSD2) follow the instructions in section 3.1 through 3.2.5 of this manual and the instructions provided with the accessory.

1.3 Handling Tips

Caution: Many parts of your spectrometer are extremely delicate. Mishandling can cause serious damage.

2.0 Principles of Operation

2.1 General

The drives of the M Series of spectrometers are linear in wavelength. The ministep driver (MSD2) controls the scan motor of the spectrometer. The spectrometer is positioned through the MSD2 either locally (manually) through the MSD2 control panel or from a remote device. In remote mode, the DM3000S, the DS1000 DataScan, and the HS1000 HandScan can be used to control the stepper motor and drive the spectrometer through selected spectral regions. A personal computer in which the SPEX232 or SPEX488 interface has been isntalled can also be used as the controller. Consult the manual for these devices for information on connections and the operation of these devices.

2.2 Direction Convention

All SPEX spectrometers follow the convention that forward and high denote increasing wavelength.

2.3 Spectrometer Unit Controls

2.2.1 Slits and Mirrors

The entrance and exit slits on the front or sides of the spectrometer are controlled by a micrometer-type knob above each slit. The slits can be set from 3 µm to 3 mm are calibrated in 2 µm increments.

The optional swingaway mirrors are controlled by switches on the MSD2 or by a device such as a computer.

2.2.2 Wavelength Counter

There is a 5-digit mechanical counter on the lower side of the spectrometer which displays wavelengths in Angstroms. A needle- point at right, and white marks on the counter wheel permit reading to 0.1Å.

Note: This counter reads true **only** for 1200 gr/mm gratings. All other gratings require the counter reading be converted by an appropriate factor. This conversion is be done automatically by a SPEX controller.

2.2.3 Limit Stops

The scanning drive has limit stop switches mounted at each end of the wavelength drive within the spectrometer. Although these switches signal the SPEX drive units, the operator should avoid scanning to the ends of the drive. The normal range of operation as indicated by the mechanical counter is from 0 Angstroms to 15000 Angstroms.

2.3 Spectrometer and MSD2 Pin Assignments

See appendix A.

2.4 Backlash

To assure accurate reproducibility, scan start positions should always be approached from at least 90 units below. This is done automatically by all SPEX scan controllers.

3.0 Optical Alignment

3.1 Grating Installation

Caution: To avoid damage to the delicate scanning mechanism, do not twist the backing plate when installing the gratings. Adjust with toggle as described below. Set the grating angle so that the wavelength counter reads about 14000 Å; the greatest damage can occur when the counter is midrange.

Important: Anything, including smoke and dust, that comes in contact with the ruled surface of the grating is likely to cause damage or loss of reflectivity.

When changing gratings or working in different spectral orders, refocusing the spectrometer may be necessary to maintain optimum performance.

To change gratings, remove the hatch cover at the top of the front of the isntrument. Make sure that the toggle of the grating mount backing plate is in a vertical position.

Place the mounted grating face-up on an uncluttered clean surface. Carefully peel tape off one side of the grating and, using the tape on the other side as a hinge, swing the cover up and away from the grating. Separate the cover from the grating. Grasp the grating mount (Figure 1) by the horn-shaped handle and place it firmly onto the backing plate hook located just below the center of the grating backing plate. Check that the backs of screws A, B, and C (see Figure 2) are properly mated with the slot, cone, and flat of the backing plate. Swing toggle to horizontal position. Check again that all locating surfaces are engaged. If not, lift the toggle, correct grating position, and lock the toggle again.

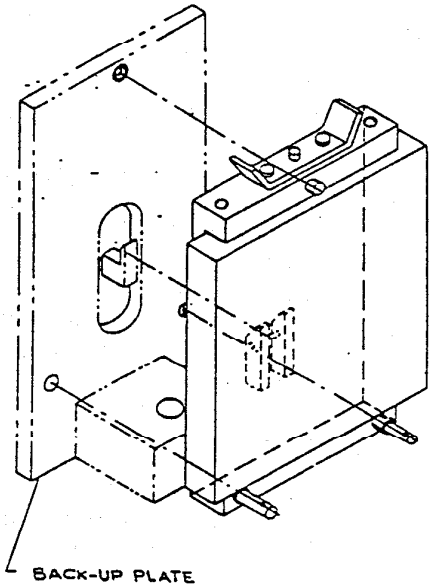


Figure 1 Grating Mount

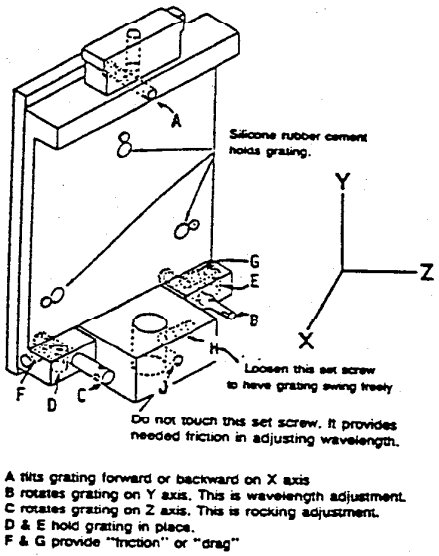


Figure 2 Grating Mount and Base Plate Assembly

3.2 Preliminary Optical Check

The instrument has been aligned at the factory. A quick optical check can be made by the customer to see if the spectrometer arrived in correct alignment.

3.2.1 Necessary Equipment

1. Low pressure Hg lamp (e.g. SPEX 1634). A fluorescent or germicidal lamp may also be suitable.

2. Eyepiece (e.g. SPEX 1529) which can be focused on the blades of the exit slit.

3. Photomultiplier tube sensitve in the appropriate wavelength region (e.g. RCA 1P28), socket and housing (1424S).

4. Appropriate photomultiplier power supply, amplifier and recorder.

3.2.2 Wavelength Calibraton

When the spectrometer is properly calibrated, the mechanical counter reading agrees with Hg spectral line (when a 1200 groove/mm grating is installed). To calibrate the spectrometer, position a Hg lamp as close to the entrance slit as possible. Set the entrance (S1) to 25 µm by 2mm high; set the exit slit (S2) at 2 mm (Figure 3). Set up the eyepiece to view S2; focus on the slit blades. Refer to the performance test record included with the manual and note the wavelength of the line with zero wavelength error nearest the blaze angle of the grating.

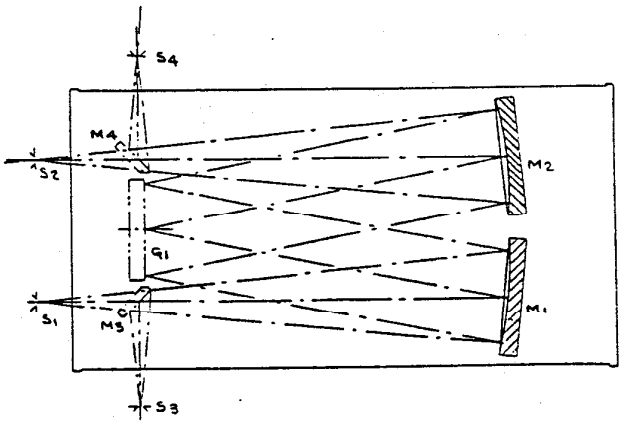


Figure 3 Optical Diagram

Scan slowly over the region of the line while looking through the eyepeice. (Note: Be sure to select a visible line.) Always scan from low to high wavelength and start at least 10Å below the line peak to remove backlash. When the line is observed through the eyepiece, close S2 to 25µm, rescan the region stopping where the line appears most intense. Observe the reading on the wavelength counter. If this value is not within 5Å from the value noted above, it may be necessary to realign the instrument. If the error is less than 5Å set the wavelength counter to the specified value, approaching it from at least 10A below the value, and adjust screw B on the grating until the intensity is at its maximum.

3.2.3 Resolution Check

Place the Hg lamp at the entrance slit and locate a peak at the wavelength noted on the sample trace (supplied by SPEX). Orient the Hg lamp until maximum intensity is obtained. Scan the region of interest, first removing backlash. The conditions under which the sample trace was run are noted on the trace and these conditions should be matched as closely as possible. If the resolution is significantly poorer, realignment of the instrument may be necessary. Contact a SPEX service represenatative for more information.

3.2.4 Improving Resolution

Reolution is affected by the paralleling of the slits and the rocking of the grating. If you are not satisfied with the resolution, sections 3.2.4a and 3.2.4b explains how to make these adjustments.

3.2.4a Paralleling the Slits

The entrance and exit slits should be parallel. To parallel the slits, set slits S1 and S2 to 15 microns and open the shutter of S1 to 10 mm. Very slowly scan past the line occurring at 5461Å, observing the manner in which the illuminated area moves up or down as you scan across the line. Loosen the allen screws of slit S2, turn the slit until it is properly paralleled and retighten. When a slit is properly paralleled, the central portion of the slit will be illuminated first, with light spreading to both ends uniformily when scanning in the direction of increasing wavelength. The line will disappear first at the center, then evenly toward both ends.

3.2.4b Rocking the Grating

An improperly rocked grating can cause poor resolution. Align the laser as in Section 3.2.2 Insert the target (part no. 31728) into exit slit S2. To rock a grating, open slits S1 and S2 to 1 mm and set shutter to 2 mm high. Scan the instrument until the counter reads approximately 12656 A. This is the second order of the 6328A line of the He-Ne laser. Scan slowly until this line is visible through the slit target and observe the vertical position of the beam on the target.

Adjust cam C (Figure 2) until the image is vertically centered on the target. Tighten the no-mar screw to prevent cam C from rotating. Scan the instrument to 0A. Check the visual centering on the exit slit target. If it is not centered, re-center with screw A on the grating and repeat the above until you are satisfied that the spectrometer is centered at high and low wavelengths. Do not adjust cam C after this adjustment has been made.

If resolution is not improved, the instrument is out of focus.

3.2.5 Focusing the Spectrometer

Note: The performance spectra included in this manual were obtained using a diamond mask. Check that this mask is installed before attempting to achieve maximum resolution. Position the Hg lamp such that it is centered on the entrance slit.

1. Loosen the two screws in the baseplate (near the mirror cups) holding the focus mirror mount in place. The focusing mirror is the mirror on your left as you face the imirrors. **Note that you should move this mirror only and not the collimating mirror.**

2. Set the slits at 6 microns by 2mm and 6 microns by .2 mm. Take a trace of the mercury doublet (3131.55 and 3131.83Å). Acquire the spectrum with the wavelength and order used to obtain the performance spectra results included in this manual.

3. Insert a screwdriver in the hole on your right (as you face the back of the instrument). Turn the screwdriver slightly in a clockwise direction to move the mirror slightly. Rescan the doublet.

4. If there is no improvement, move the mirror slightly using the procedure in step 3. Rescan the doublet.

5. If the resolution has not improved after moving the mirror several times, turn the screw counterclockwise one full turn. Then turn the screw clockwise slightly, rescan the doublet. Continue to do this until the resolution has improved sufficiently.

6. When the resolution is satisfactory, tighten down the mirror mount to the baseplate. Rescan the doublet to verify the resolution.

3.2.6 Factory Alignment

In addition to the equipment listed in section 3.2.1, the following eqipment is also required.

5. Grating target fixture (part no. 31729)

6. Exit slit target (part no. 31728).

7. Hg Pen-Ray lamp and transformer (1634 and 1635)

8. Phototube and housing (1P28 and 1424S)

9. Laser assemby

The alignment procedure described is carried out at the factory by experienced technicians. Alignment tools and familiarity with the principles and handling of optical systems are absolutely necessary to accomplish this task. It is recommended that SPEX service representatives be contacted for these services.

If it is necessary to do this procedure, sections 3..1 to 3.2.8 should be read and thoroughly understood before proceeding.

Since photomultiplier tubes can be damaged by exposure to high levels of light, power to all photomultipliers should be turned off and tubes removed from the instrument before beginning the alignment procedure.

3.2.6 Setup

Level the instrument by adjusting the length of the legs. Only the front two legs and the rear center leg should touch the table. Set both slits to 2 mm and set the height adjustment on the entrance slit to 2 mm. Position a laser so that the beam is passing through the entrance slit. Leave sufficient room to place the Hg lamp between the laser and the entrance slit. The Hg lamp will be used to check wavelength calibration and focus after the laser alignment.

Ignite the laser according to the manaufacturer's instructions, and observe the cautions noted in the laser user manual.

Warning: Do not look directly into the laser beam.

3.2.7 Alignment of the Laser Source

Position a mirror target mask on the mirror M1 over the four screws. Adjust the position of the laser side to side, up and down with respect to the slits until a spot of maximum intensity is observed on the center of the mirror target mask.

Slowly narrow the entrance slit and reposition the laser so that the bright beam goes through the narrowed slit and slit center hartman and is centered on the mirror target mask. It is possible to have the entrance slit set to 25μm and 2mm high, and the diffraction pattern will just fill the mirror mask. Opening the entrance slit to 2mm wide will leave the bright spot centered on the mirror mas.

3.2.8 Alignmnt of the Optics

Remove the grating hatch cover of the spectrometer. Remove grating. Tape on the plastic cover, and put it in a safe place. Mount the grating target fixture in position on the grating shaft making sure the alignment pin is properly seated and that the base of the target is firmly seated on the base block of the backing plate assembly.. Scan to the low wavelength (approximately 0 nm) and position the grating target fixture parallel to the end plate of the spectrometer. Aim the laser beam at the target hole in the grating target fixture by adjusting the up and down motion of M1 with hex nut A and the sideways motion with hex nut B. Remove the grating target fixture and reinstall the grating. If you do not have a grating target, be sure that the beam is centered on the grating. Scan to 6328 Å.

Warning: Do not touch the surface of the grating with anything, including your hands.

With the mirror target mask in position on M2, adjust the position of the grating G so that the reflected laser beam is aimed at the central hole in the mirror target mask. The grating may be moved from side to side with screw B (Figure 2) and up and down with screw A. The slit target may be inserted directly into the slit asembly from the outside, placing the end wth the whole plastic disc near the slit. Aim mirror M2 at the center hole in the slit target in the same manner as M1 was aimed. **Do not look directly into the laser beam through the alignment disc.**

AFter thiis has been completed, wavelength calibration and focus should be rechecked and adjusted as required.

4.0 Specifications

	500M	750M	1000M	1250M
Focal Length, meters	0.5	0.75	1.0	1.25
Aperture	f/4[1] f/6.9[2]	f/6[1] f/10.4	f/8[1] f/13.9[2]	f/9[3] f/11[1]
Spectral Range, Å (mechanical atomosphere limited)	0-15000	0-15000	0-15000	0-15000
Dispersion, nm/mm	1.6	1.1	0.8	0.65
Resolution, nm	0.02	0.01	0.008	0.006
Multichannel Coverage, nm over 25 mm	40 nm	27.5 nm	20 nm	16.25 nm
Accuracy, nm	± 0.05	± 0.05	± 0.05	± 0.05
Repeatability, nm	± 0.005	± 0.005	± 0.005	± 0.005
Drive Step Size, nm	0.00025	0.00025	0.00025	0.00025
Dimensions inches (cm) **width** **length** **height**	 12 (30.5) 23 (58.4) 13 (33.0)	 12.25 (31.1) 33 (83.8) 13 (33.0)	 13.75 (35) 43 (109.2) 14.5 (36.8)	 17.75 (45) 53 (134.6) 14.5 (36.8)
Weight lbs. (kg)	82 (37.3)	105 (47.8)	160 (72.7)	210 (96.9)

1. with 110 x 100 mm grating
2. with 64 x 64 mm grating
3. with 120 x 140 mm grating

5.0 MSD2

The ministep driver (MSD2) controls the ministepper motor of the M Series spectrometers. The control panel of the MSD2 has several switches and indicators. The rear panel of the MSD2 has five connectors. The switches and the connectors are described in subsequent sections.

5.1 MSD2 Connectors

There are five connectors on the back panel of the MSD (See figure 4). Only four of these are presently used. Appendix A lists the pin assignments of these connectors.

The Monochromator Control Input connector (J1) controls the scanning functions of the monochromator--direction, movement, and limit-sense. It also controls the optional shutters. To control the M Series spectrometers from a remote device (DM3000, DS1000, HS1000.), plug the appropriate cable from the remote device to this connector.

The Accessory Output connector (J2) enables the MSD to control such 500M accessories as the entrance mirror assembly and the dual grating assemblies. Connect one end of the appropriate cable to the Accessory connector on the 500M. Connect the other end to this connector on the MSD.

The Monochromator Output (J3) connector enables the MSD to control the wavelength drive, the limit switch, and shutter assemblies of the M Series spectroemters. It also drives one accessory, usually the exit swingaway mirror. Connect one end of the appropriate cable to the connector labelled MONO on the spectrometer. Connect the other end to the this connector.

The Accessory Control Input connector (J4) enables you to control the spectrometer accessories such as the shutter assemblies from a remote device (Note: These devices cannot be controlled from the DS1000). It also controls the swingaway mirrors and selectable grating (dual grating). Plug the appropriate cable from the remote device to this connector.

The Filter Wheel Output connector is not used.

5.1.1 MSD2 Control Panel

The control panel has several switches that enable you to control the MSD2 either locally or from a remote device, open and close the shutter, and control the scan speed and direction (See figure 5).

Local/Remote Select Switch

The Local/Remote Select Switch is a two-position switch. In the Remote or Up position, the spectromeeter scan direction, the step and the shutter position are controlled from a remote device. The remote device must be plugged into the Monochromator Control Input connector on the back panel of the MSD2.

When the switch is in the Local or Off position, the scan direction, the step and the shutter are controlled from the MSD2 control panel. All remote control signals are locked out. Note that the switch position is indicated by the appropriate LED located to the left of the switch.

Shutter Control Switch

The Shutter Control Switch is a two-position switch that controls the shutter when the MSD2 is in the local mode (Local/Remote switch is in the down position). When the Shutter Control Switch is in the up position, the optional shutter is opened. In the down position, the shutter is closed.

The open and close indicators of the shutter show its position whether the shutter is controlled from a remote device or locally from the control panel.

5.1.2 Local Control

Direction Switch, Rate Switch, and Rate Potentiometer Knob

The wavelength drive motor may be controlled from the local control panel through the use of the Local Direction Switch, the Local Rate Switch and the Rate Potentiometer Switch. The Local Control module (500LC) is standard with the 500M and optional for all other M Series spectrometers.

Direction Switch

The Direction Switch enables you to control the step direction of the wavelength drive motor when the Local/Remote switch is in the Local (down) position. There are three swtich positions: Up for forward, Center to stop, Down for reverse.

Note: When in the Local Mode and the Direction switch is not in the Stop position (center position), the drive motor will continue to move in the direction selected.

Rate Switch

The Rate Switch controls the speed of the driver motor. There are two positions: up for fast speed (steps/second is approximately 600 Hz to 63 kHz) and down for slow speed (steps/second is approximately 20 Hz to 1.5 kHz).

Rate Potentiometer Knob

The Rate Potentiometer knob provides fine control of the driver motor in either the fast or slow mode.

Joystick Connector

The joystick connector enables you to use an optional joystick (SPEX part no. 1799) to operate the wavelength drive motor. This is done in the Local Mode with the control panel Direction switch in the Stop position.

To operate the joystick, position the joystick such that the cable is facing away from you. Slowly push the joystick away from you to move the wavelength drive motor forward. To move the motor in reverse, pull the control towards you. To stop the motor, return the joystick to the center position.

6.0 Operation

To operate the 500M through the MSD in the remote mode, place the Local/Remote switch in the up position. To operate the 500M in the local mode through the MSD control panel, place the Local/Remote switch in the down position.

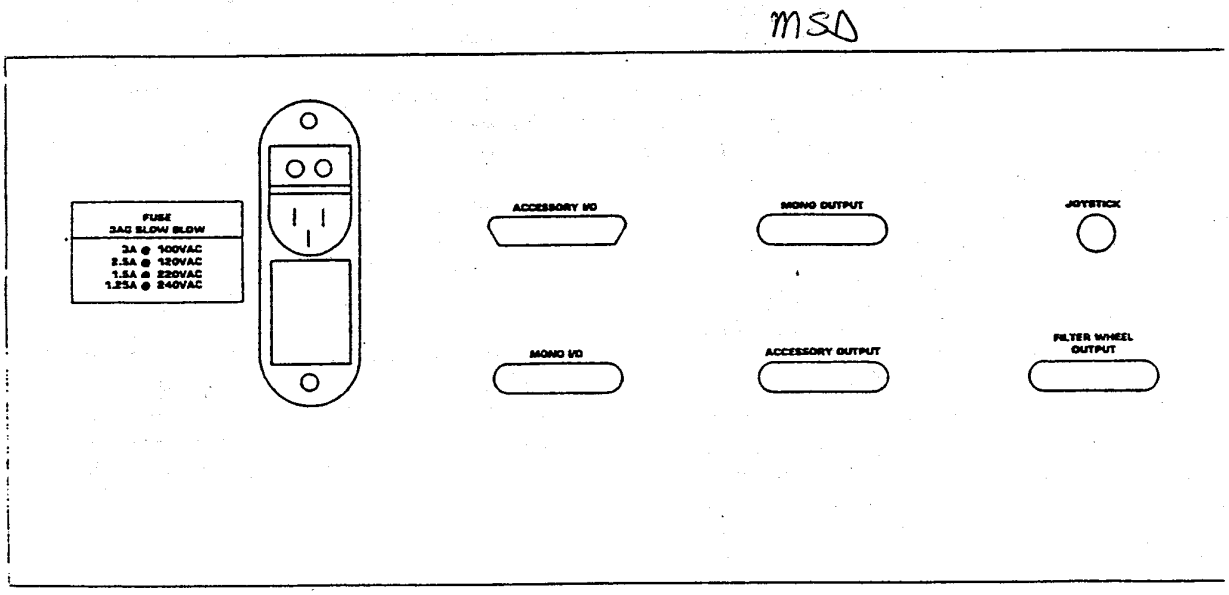
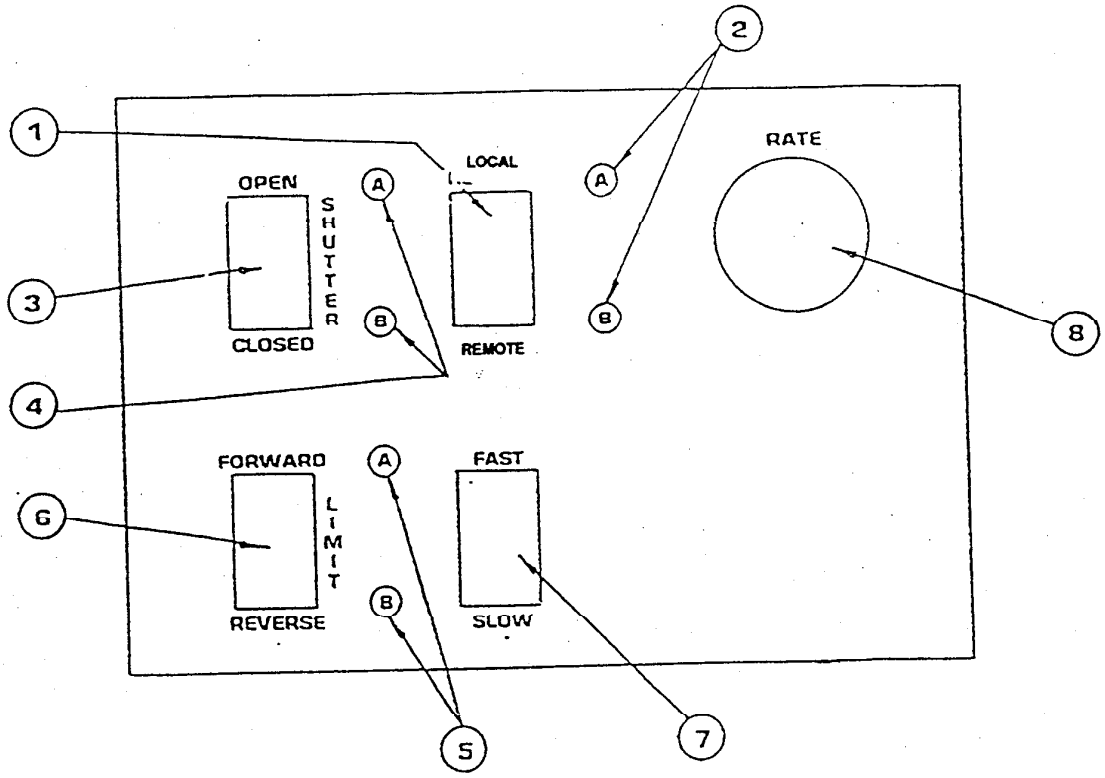


Figure 4 MSD2 Back Panel



1. Local/Remote Select Switch
2. Local/Remote Indicators (A-Local, B-Remote)
3. Local Shutter Control Switch
4. Shutter Indicators (A-Open, B-Closed)
5. Limit Indicators (A-Upper Limit, B-Lower Limit)
6. Local Scan Direction/Control Switch
7. Local Scan Coarse Rate Switch
8. Local Scan Rate Potentiometer

Figure 5 Local/Remote Panel

500M, 750M, 1000M, 1250M Spectrometers

Monochromator Input

Pin#	Signal	Notes
11	Phase '	scan motor drive
15	Phase 2'	"
14	Phase 1'	"
2	Phase 2	"
3	Phase 3	"
17	Phase 4'	"
16	Phase 3'	"
4	Phase 4	"
24	LOLIM	lower limit sense switch
12	LIMRTN	limit switch common
25	HILIM	upper llimit sense switch
13	chassis GND	chassis ground
5	motor B1	current limited to 24 volt power and phase drive signals for the exit mirror acessory
18	PH1B	
6	PH2B	
19	Motor B2	
7	PH2B	
20	PH4B	
6	SENSECOM	exit mirror posiiton sense switch
21	B SIDE	exit mirror sense switch
9	B FRONT	exit mirror front sense switch
10	SHUT	shutter drive and return lines
22	SRTN	
11	SHUT	
23	SRTN	

500M, 750M, 1000, 1250M Spectrometer

Accessory Input

Pin #	Signal	Notes
1	MOTOR D1	Current limited 24-volt power and phase driver signals for dual grating accessory
14	PHD1	
2	PHD2	
15	MOTOR D2	
3	PHD3	
16	PHD4	
4	DSENSE COM	dual grating position sense switch common
17	D POS B	dual grating position "b" sense switch
5	D POS A	dual grating position "A" sense switch
23	not used	
11	"	
24	"	
12	"	
13	GROUND	
25	not used	
18	"	
6	MOTORA1	Current limited 24-volt power and phase driver signals for the entrance mirror accessory
19	PH1A	
7	PH2A	
20	MOTORA2	
8	PH3A	
21	PH4A	
9	ASENSECOM	Entrance mirror position sense switch common
22	A SIDE	Entrance mirror side sense switch
19	A FRONT	Entrance mirror front sense switch

MSD Jumper Options

The 54950 Monochromator Controller Card has three jumper options--J1, J2, and J3. Their functions are as follows:

J1 (SHUTSENSE) -- Controls the state of the shutter current driver output.

Not Installed - Shutter output driver will supply current to OPEN shutter.

Installed - Shutter ouptut driver will supply current to CLOSE shutter.

Installed in systems using shutter assemblies such as the 1425 or 500SH type used in the M Series spectrometers.

J2 (DIREV) -- Controls the clockwise or counterclockwise rotation of the <scan> drive motor specified by the direction signal from either the control panel or the remote device.

Not installed for M series spectroemters.

J3 (LIMIT DISABLE) - Diables LIMIT SENSE capabilaities; not nornallly installed; primarly used for maintenace purposes.

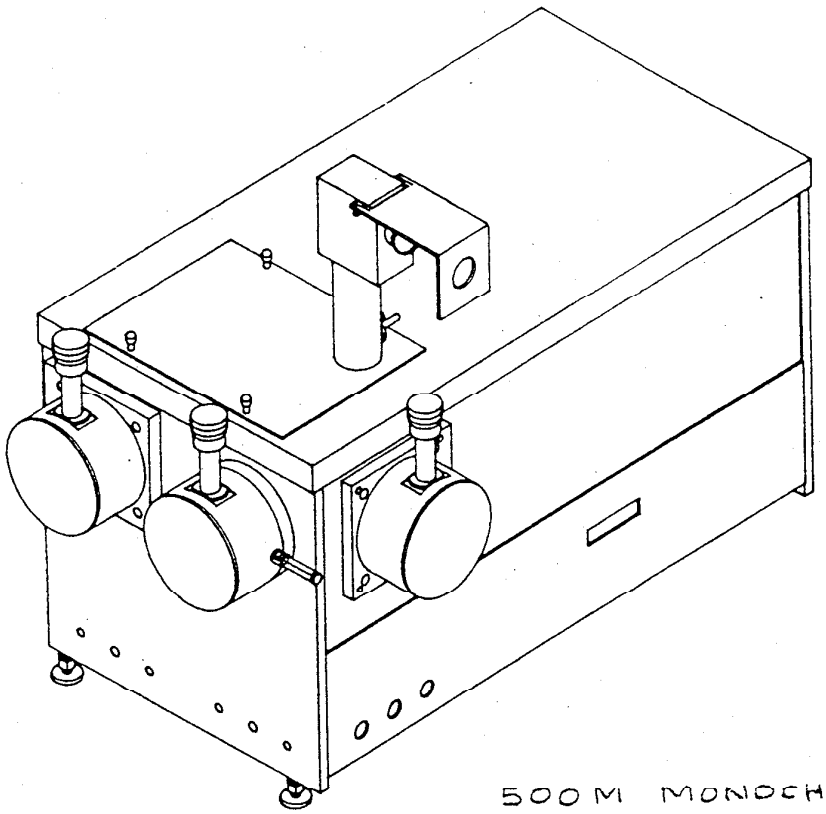
Not normally installed.

MSD2 External Connector
Monochromator I/O and Accessory I/O

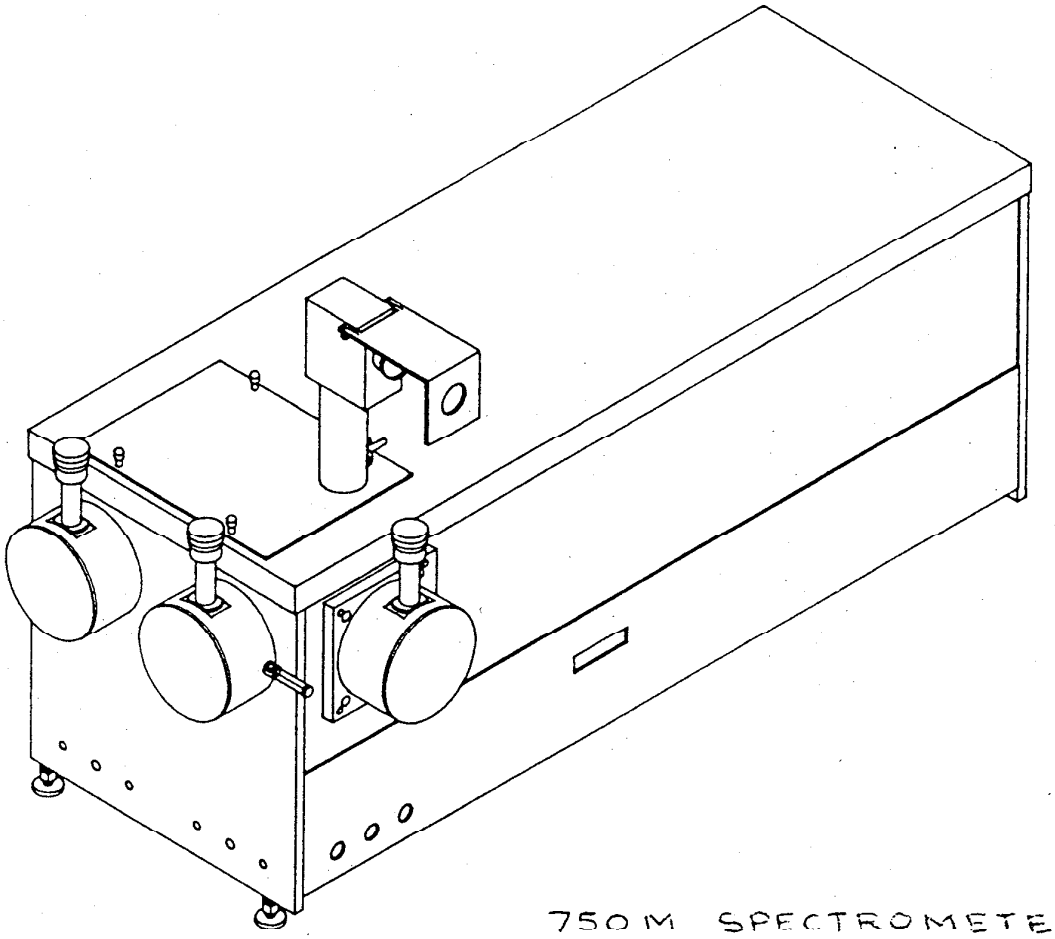
:Pin #	Signal	Notes
1	MIR A PORT	MSD2 Input Data to Select MIrror Position
14	RETURN	Ground
2	MIR B PORT	MSSD2 Input Data to Select MOtor Position
15	RETURN	Ground
3	GRATING POS A	MSD2 Input Data to Select Grating Position
16	RETURN	Ground
4	REMOTE SELECT	An AND of Remote Computer and Control Panel REMOTE SELECT
17	RETURN	Ground
5	LSTAT OK	Signals Remote Device all Accessories in VALID Position
18	RETURN	Ground
6	FBIT A	MSD2 Data Inoput for Filter selection
19	RETURN	Ground
7	FBIT B MSD2	Data Input for Filter Selection
20	RETURN	Grouind
8	FBIT C	MSD2 Data Input for Filter slection
21	RETURN	Ground
9	SHUT-N	MSD2 Data Input for Filter selection
22	RETURN	Ground
10	FWD	MSSD2 Data Input for WAVLEENGTH MOTOR direction
23	RETURN	Ground
11	STEP-N MSD2	Input for WAVELENGTH MOTOR Stepping sense switch
24	RETURN	Ground
12	LOLIM_N	MSD2 LOW Limit Sense Output
25	RETURN	Ground
13	HLIM_N	MSD2 HIGH Limit Sense Output

MSD2 External Connectors
Accessory Output Connector

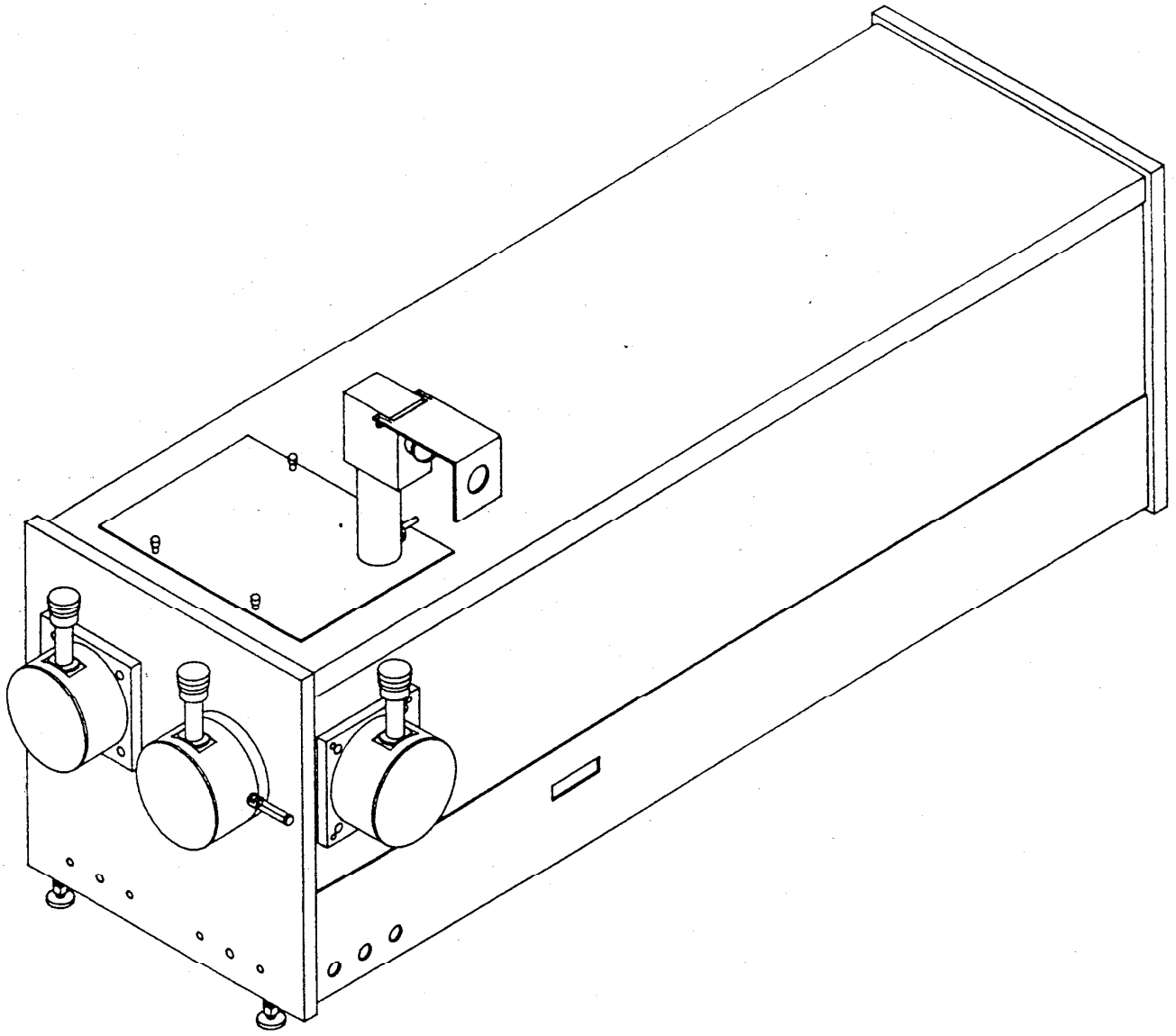
Pin #	Signal Name	Description
1	MOTOR_D1	Power for Grating Turret Accessory Motor
14	PH1D	Grating Turet Motor drive signal
2	PH2D	Grating Turret Motor drive signal
15	MOTOR_D2	Power for Grating Turret Accessory Motor
3	PH3D	Grating Turret Motor drive signal
16	PH4D	Grating Turret Motor drive signal
4	RTN	Ground
17	D_SIDE	Position Sense Switch
5	D_FRONT	Position Sense Switch
6	MOTOR_A1	Power for Entrance Mirror Accessory Motor
19	PH1A	Entrance Mirror Motor drive signal
7	PH2A	Entrance Mirror Motor drive signal
20	MOTOR_A2	Power for Entrance Mirror Accessory Motor
8	PH3A	Entrance Mirror Motor drive signal
21	PH4A	Entrance Mirror Motor drive signal
9	RTN	GROUND
22	A_SIDE	Position Sense Switch
10	A_FRONT	Position Sense Switch
13	CH_SND	Chassis Ground



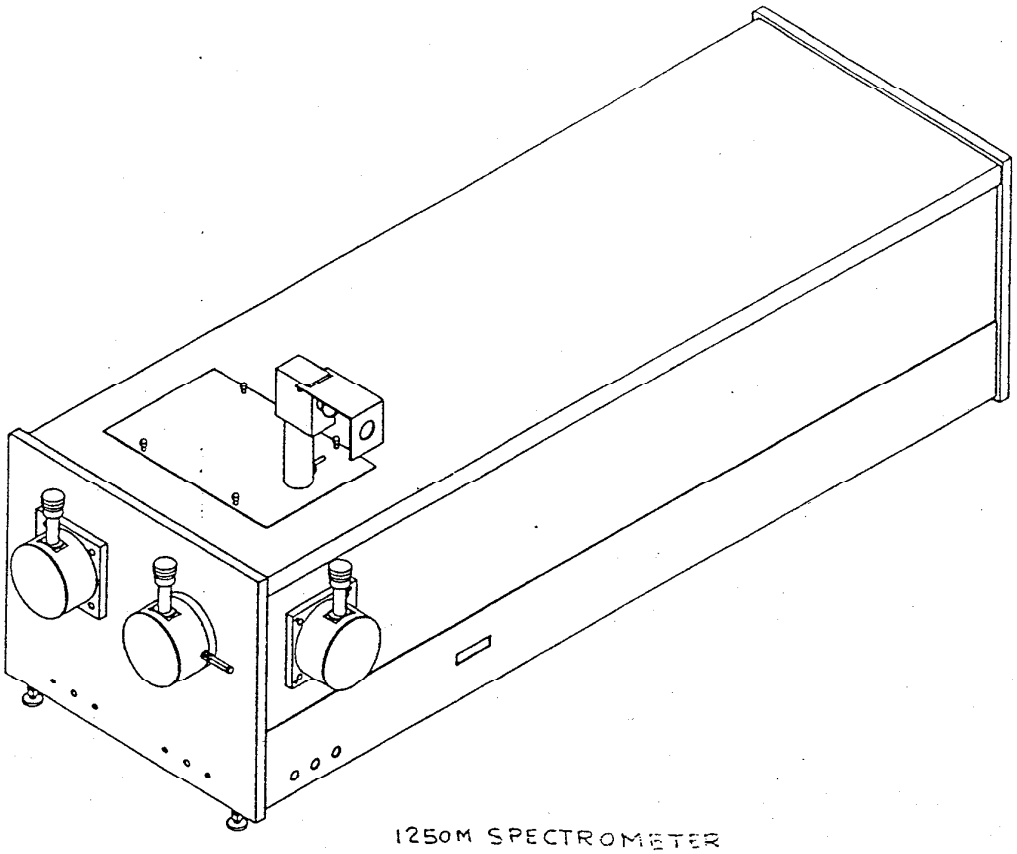
500M MONOCHROMATOR



750M SPECTROMETER



1000 M SPECTROMETER



1250M SPECTROMETER

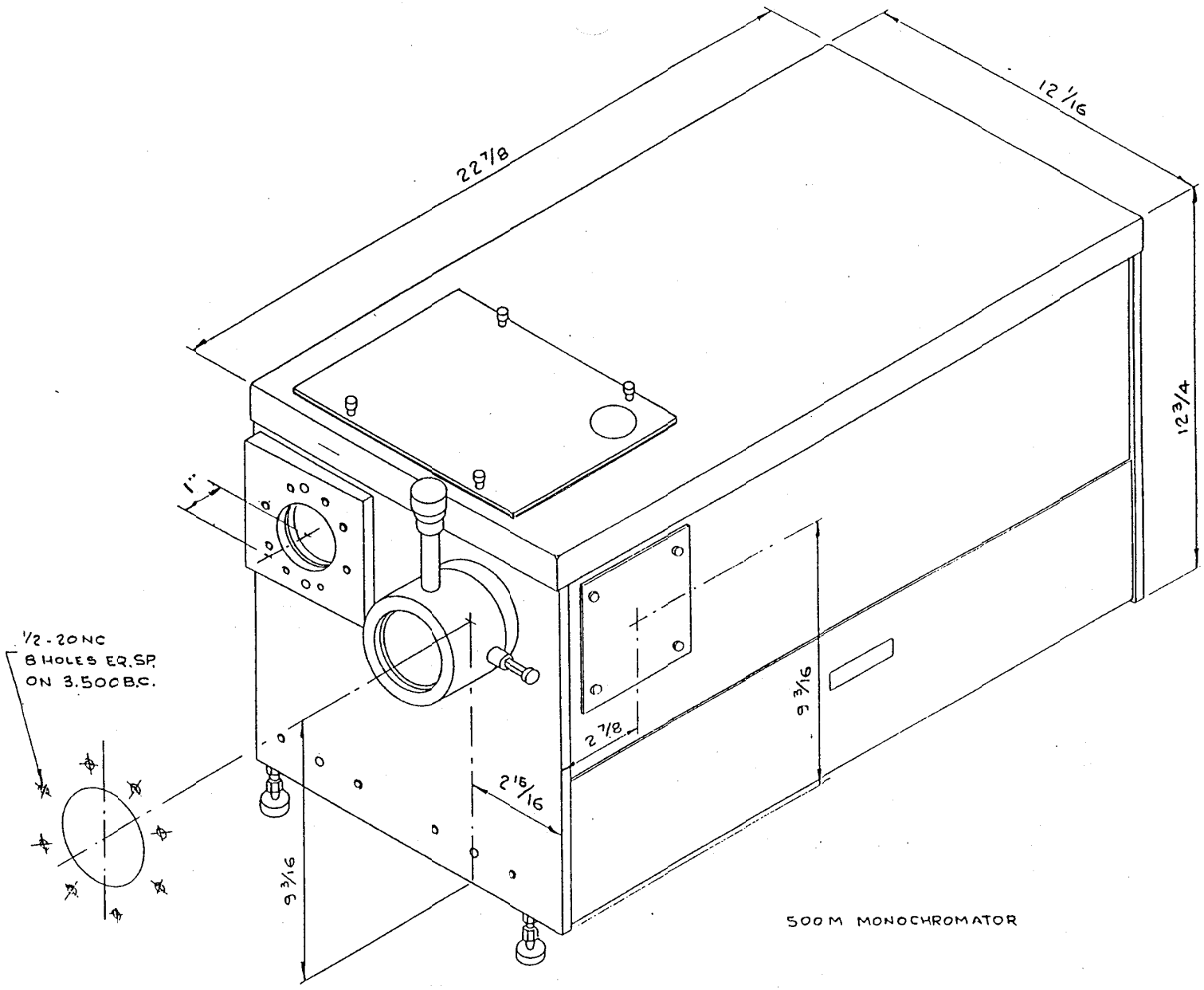

22 7/8
12 1/16
12 3/4
1"
1/2-20NC
8 HOLES EQ.SP.
ON 3.500 B.C.
2 7/8
9 3/16
2 15/16
9 3/16
500M MONOCHROMATOR
10-10-87

Figure 7

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