HYDROGEN MASER
FREQUENCY STANDARD

EFOS

part 1

operators instruction manual

january 1983

C O N T E N T S

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F I G U R E S

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T A B L E S

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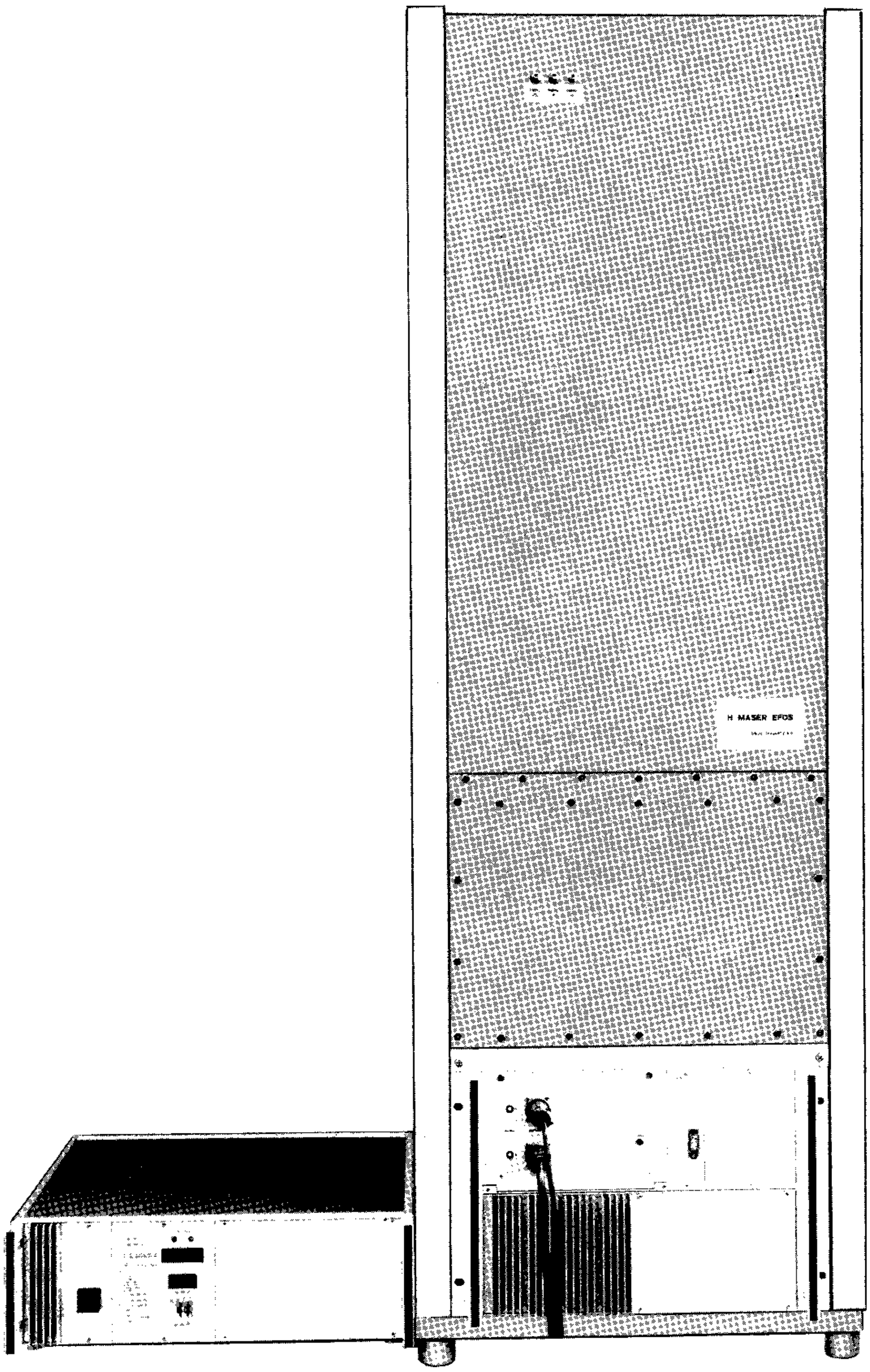
LJ/IM/CMH
Neuchâtel, January 1983

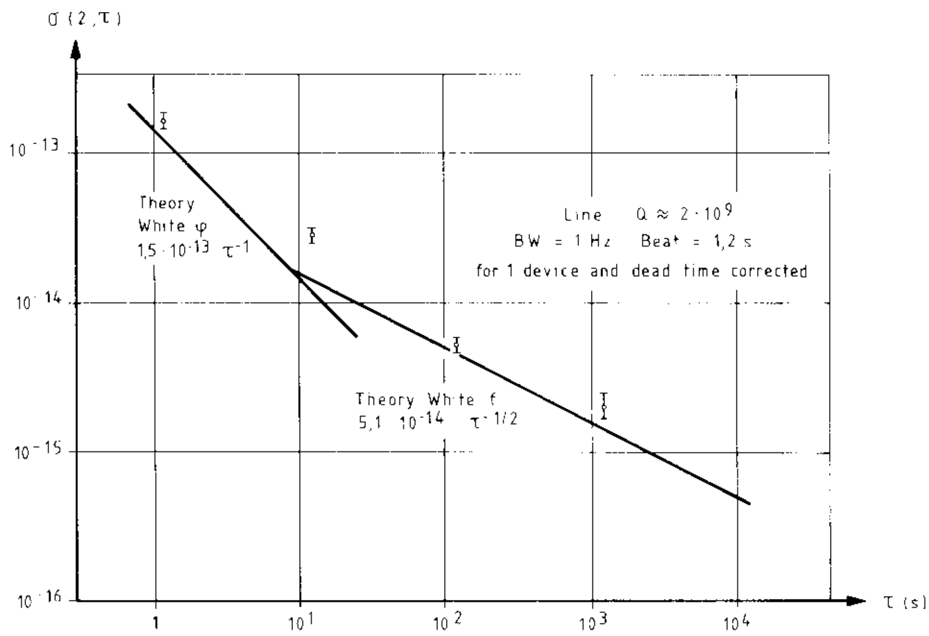


E F O S

HYDROGEN MASER AND MONITORING RECEIVER

1. DESCRIPTION

TYPICAL FREQUENCY STABILITY
(see figure)



TEMPERATURE EFFECTS

$\frac{\Delta f}{f}$ PER °C — $< 1 \times 10^{-13}/1°C$

Maser frequency fractionnal change for 1° ambient temperature step measured after ≃ 24 h

Maser cavity time constant ≃ 24 h

MAGNETIC FIELD EFFECTS

Magnetic shielding	Static attenuation of the earth magnetic field	: 25'000 X
	Residual magnetic uniformity	:< 20 μOersted

Attenuation of magnetic field variation ($\pm$ 100 m Oersted change in earth field)	: 5'000 X
Minimum operating magnetic c-field	: < 100 μOersted
$\frac{\Delta f}{f}$ per Oersted	: < 2 x 10^{-13}/ Oersted for "C" field of 500 μOersted

PRESSURE EFFECTS

OUTPUT SIGNALS

Standard	5 MHz phase locked to H-MASER, 0.5 VRMS in 50 Ω
Optional	180 MHz, 1.440 GHz, 5 MHz TTL

PHYSICAL CHARACTERISTICS

Line Q	> 2 x 10^{9}	
Output power	-105 dB m nominal	
Loaded cavity Q	35000	
Cavity pulling factor	≃ 1.25 x 10^{-5}	
Cavity tuning	By temperature and varactor	
	Cavity temperature coefficient	: -32.5 kHz/1°C
	Varactor tuning range	: ≃ 10 kHz

OVERALL CHARACTERISTICS	20" x 20" x 59"
Size	500 x 500 x 1500 mm
Weight	200 kg = 445 lbs
Power consumption	< 100 watts, 22 -30 VDC (from external batteries)

CONSTRUCTION DETAILS

- Dual chamber vacuum system
- Quadrupole state selector
- Quartz bulb for H storage : 4.5 liters
- Aluminum cavity
- 3 thermal shields
- 4 magnetic shields
- 5 thermal controls
- Receiver temperature stabilized in the maser

1.1 INTRODUCTION

This operators manual covers the ASULAB EFOS Hydrogen maser (Fig. 1.1). It provides information on performance specifications, start-up, and operation of the maser. Information contained herein is sufficient to install and put the maser in service. Operating and Calibration checks are included.

Detailed procedures for troubleshooting, parts replacement and maintenance are provided in the maintenance and repair manual.

1.2 ELECTRICAL CHARACTERISTICS

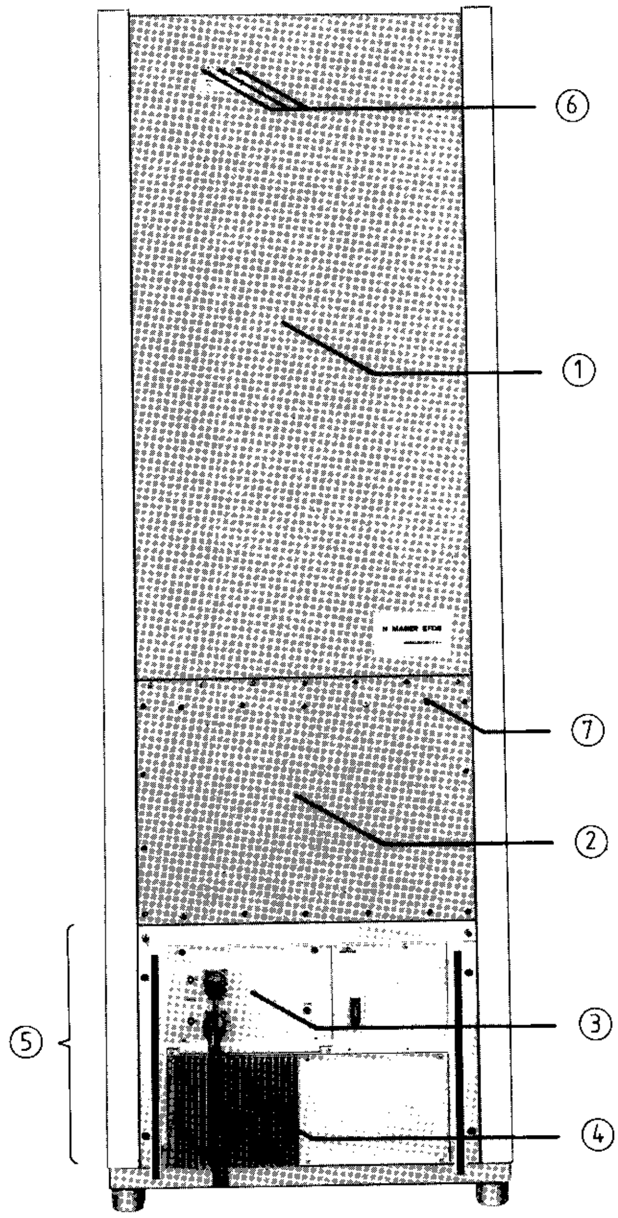
1.2.1 Inputs

a) Main-power

22-30 VDC	100 watts nominal, operating
22-30 VDC	200 watts max. start-up

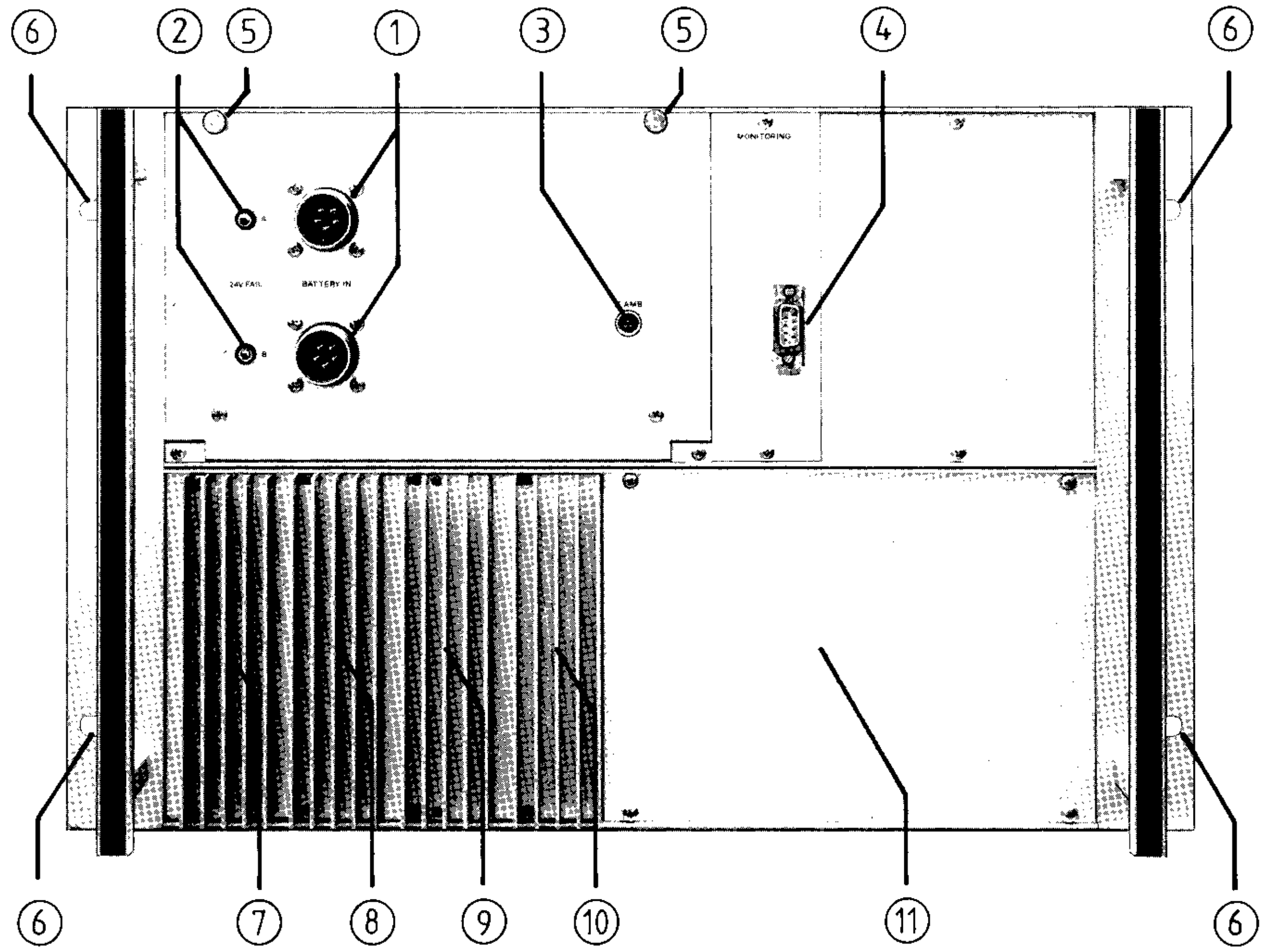
The maser is connected to D.C. supplies via two front panel connectors, (1) Fig. 1.2, and may be powered by either, or both of the supplies depending upon their actual voltage. A green lamp associated with each D.C. input indicates presence of D.C. input. Independance of the D.C. inputs enables servicing the separate supplies without interruption maser operation, D.C. negative is connected to chassis ground of the maser.

In the event of total power interruption to the maser a power input interlock system requires the operator to re-cycle the input power switch. This protective feature assures the sequence of power application to the maser circuits.



①	MASER PHYSICS COMPARTMENT
②	VACUUM MANIFOLD COMPARTMENT
③	FRONT PANEL
④	POWER SUPPLY MODULES
⑤	ELECTRONICS / CONTROL UNIT
⑥	5 MHz OUTPUTS
⑦	DISSOCIATOR LIGHT PIPE

Fig. 1.1 : E F O S HYDROGEN MASER



(1) INPUT POWER CONNECTORS
(see Fig. 1.6 for connections)

(2) POWER ON SIGNAL LIGHTS

(3) AMBIANT TEMPERATURE PROBE CONNECTOR
(see Fig. 1.6 for connections)

(4) MONITORING CONNECTOR
(see Fig 1.6 for connections)

(5) FRONT PANEL RETAINING THUMB SCREWS

(6) CONTROL UNIT MOUNTING SCREWS

(7) 24 V DISSOCIATOR POWER SUPPLY

(8) 24 V REGULATED POWER SUPPLY

(9) 5 V, ±15 VOLT POWER SUPPLY

(10) ±15 VOLT POWER SUPPLY

(11) PUMP HIGH-VOLTAGE POWER SUPPLY COMPARTMENT

Fig. 1.2 : FRONT VIEW ELECTRONICS AND CONTROL UNIT

b) Zeeman Coil

A control panel connector, (5) Fig. 1.3, is provided for a Zeeman Frequency interrogating signal.

c) Neck Coil

A control panel connector, (6) Fig. 1.3, is provided for energizing the "neck coil" of the maser. Normal utilization of the maser does not require to use this coil and it is only provided for special experiments not covered in this manual.

1.2.2 Outputs

Three RF outputs are available from SMA connectors on the maser upper front housing (6) Fig. 1.1 :

a) Main 5 MHz output

(two buffered, isolated)

0.5 VRMS in 50 Ω . This 5 MHz output is derived directly from the 5 MHz oscillator of the receiver phase lock loop. Since the oscillator is phase locked to the maser receiver signal, this output includes the temperature-dependent phase fluctuations of the multiplier chain buffer amplifier.

b) Auxiliary 5 MHz output

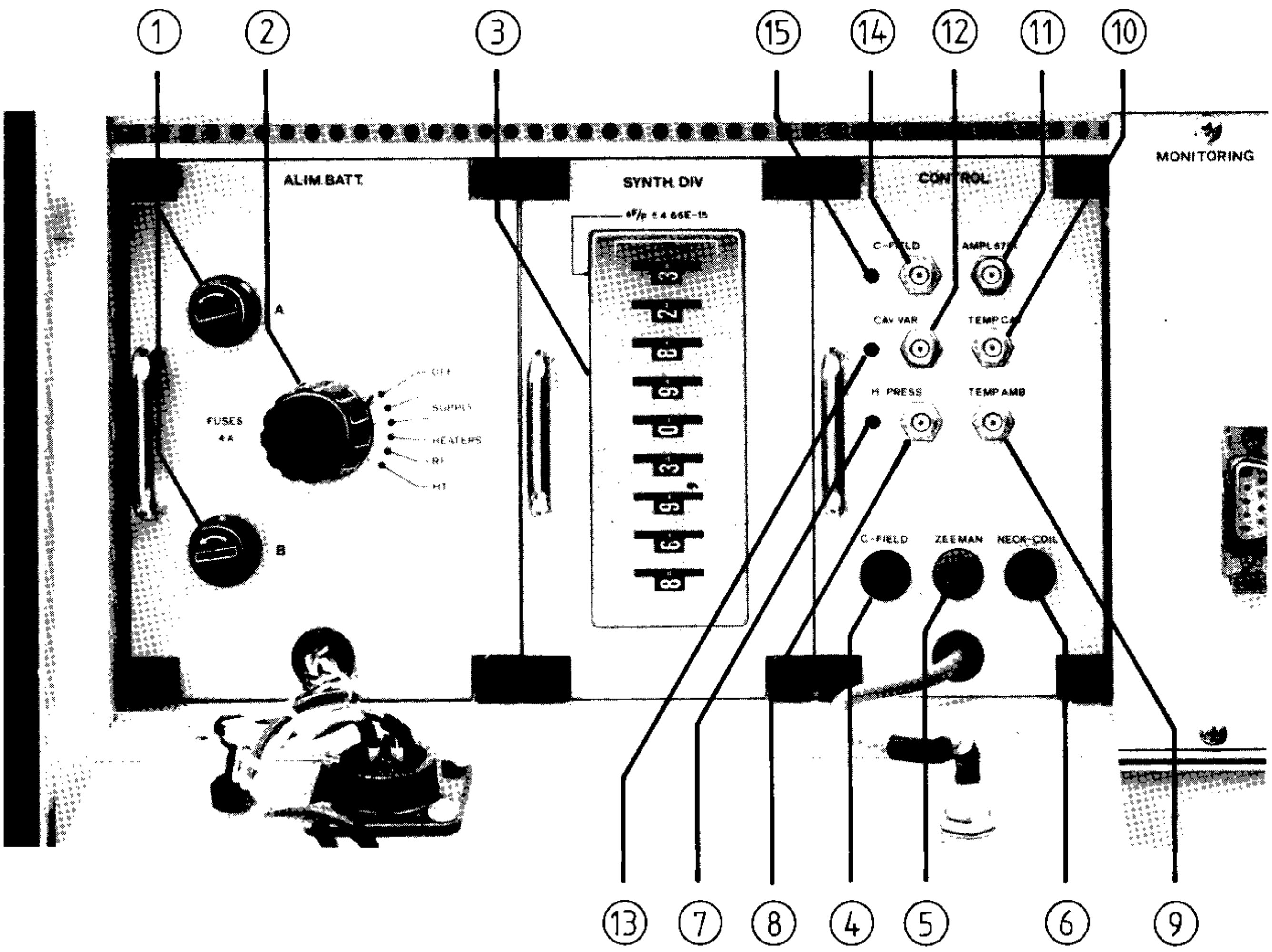
This output is a buffered TTL (50 Ω) derived by dividing from 180 MHz in the receiver multiplier chain.

1.2.3 Monitoring

Remote monitoring of thirty maser operating parameters is available from a front panel connector, (4) Fig. 1.2. The monitor display receiver Fig. 1.4 presents the selected monitor point information by means of 125 digital units scanned at a rate of one sample per second. Analog output of monitored signal is available from the rear panel Fig. 1.5.

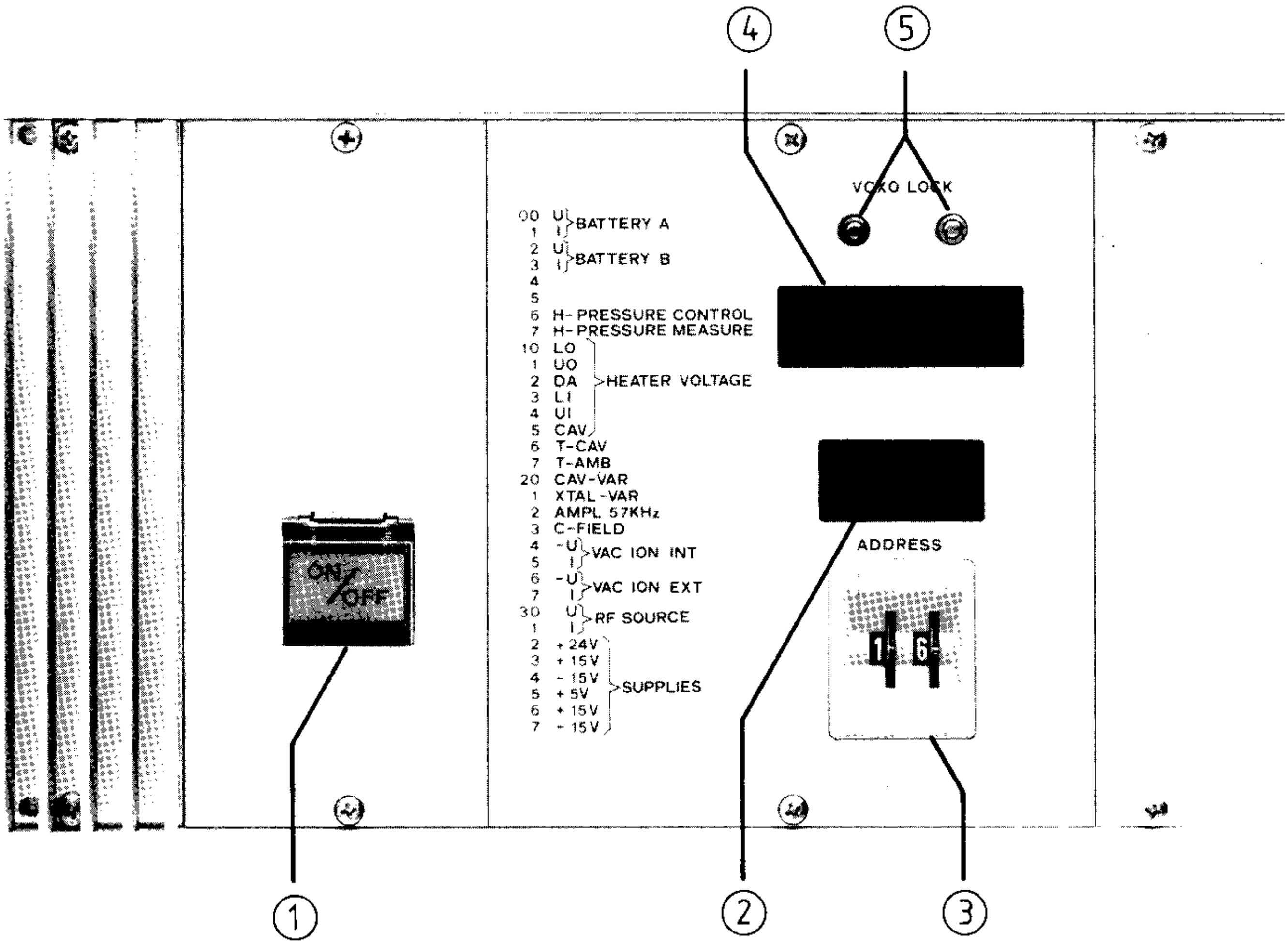
Power input to the monitor receiver may be provided from AC line, or 24 VDC independent of the maser power supplies.

In addition, the most important maser parameters are available as analog signals on the control panel, Fig. 1.3.



① DC INPUT FUSES (4 A fast blow, 5 x 20 mm)
② INPUT POWER SWITCH
③ SYNTHESIZER DIGITAL SWITCH
④ C-FIELD WINDING (SMA)
⑤ INPUT TO ZEEMAN INTERROGATING COIL (SMA)
⑥ NECK COIL INPUT (SMA)
⑦ HYDROGEN DISSOCIATOR PRESSURE SETTING POTENTIOMETER
⑧ HYDROGEN DISSOCIATOR PRESSURE REGULATOR VOLTAGE (SMA)
⑨ AMBIANT TEMPERATURE ANALOG OUTPUT (SMA)
⑩ CAVITY TEMPERATURE (SMA)
⑪ AMPLITUDE 5.751 kHz RECEIVER OUTPUT VOLTAGE (SMA)
⑫ CAVITY VARACTOR VOLTAGE MEASURE (SMA)
⑬ CAVITY VARACTOR VOLTAGE ADJUST POTENTIOMETER
⑭ C-FIELD CURRENT MEASURE (SMA)
⑮ C-FIELD CURRENT ADJUST POTENTIOMETER

Fig. 1.3 : CONTROL PANEL



(1) MAIN POWER SWITCH

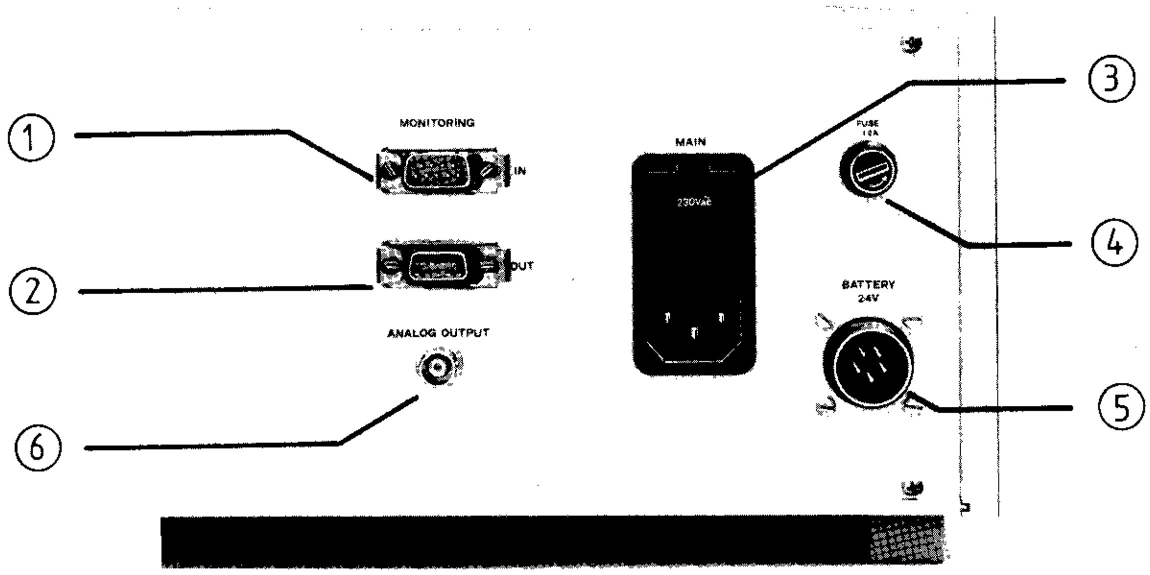
(2) SELECTED CHANNEL READOUT

(3) CHANNEL SELECT DIGITAL SWITCH "ADDRESS"

(4) PARAMETER VALUE READOUT

(5) MASER PHASE LOCK INDICATOR LIGHTS

Fig. 1.4 : MONITOR DISPLAY RECEIVER FRONT PANEL



1. MONITORING RECEIVER INPUT (see Fig. 1.6 for connections)
2. MONITORING PARALLEL SIGNAL OUTPUT (see Fig. 1.6 for connections)
3. INPUT POWER CONNECTOR AC LINE AND VOLTAGE SELECTOR SWITCH
4. DC SUPPLY FUSE (1.2 A, 5 x 20 mm)
5. DC INPUT POWER CONNECTOR (see Fig. 1.6 for connections)
6. ANALOG DC OUTPUT (BNC)

Fig. 1.5 : MONITOR DISPLAY RECEIVER REAR PANEL

1.3 MECHANICAL CHARACTERISTICS Fig. 1.1

1.3.1 Maser

Dimensions	:	500 x 500 x 1500 mm
Weight	:	200 kg
Mounting	:	Benchmount on four cushioned feet

1.3.2 Monitoring receiver

Dimensions	:	432 x 420 x 135 mm
Weight	:	7 kg
Mounting	:	Independent bench mount or 19 inch rack mount provided

1.4 ENVIRONMENTAL CHARACTERISTICS

The nominal environmental range is specified below, with the maser sensitivity to environmental changes.

1.4.1 Temperature

operating : 20° to 30°C
5 MHz frequency 3×10^{-14}/°C

storage : 0° to 50°C
Continual pumping of maser vacuum system recommended

1.4.2 Shock-Vibration

Minimum shock and vibration obtainable under laboratory conditions

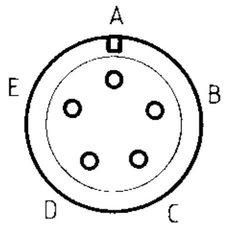
1.4.3 DC magnetic fields

0.5 m Oe external field
5 MHz frequency 5×10^{-13}/Oersted at maser C-field of 500 μ Oersted

1.4.4 Atmospheric pressure

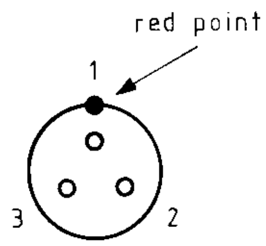
MASER AND MONITORING

DC INPUT 24 V (Amphenol MS 31Ø2A 14S 5P)



A - N.C.
B - GND
C - N.C.
D - N.C.
E - +24 V

AMBIENT TEMPERATURE (T_{AMB}) PROBE (LEMO RGØB.3Ø3C.A222)

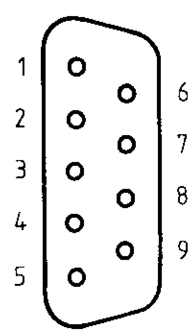


1 - +

2 - -

3 - GND

MONITORING (CANNON DE - 9S)



1 - N.C.
2 - N.C.
3 - CLOCK Nand
4 - DATA And
5 - +5 V
6 - N.C.
7 - CLOCK And
8 - DATA Nand
9 - Ø V

Fig. 1.6 : E F O S PANEL CONNECTORS WIRING CONNECTIONS

2. PACKAGING AND INSTALLATION

2.1 PACKING AND TRANSPORT

The maser is packed according to the method of transportation, but the basic structure for shipment consists of a pallete on which the maser is mounted on shock absorbers. Wire sway braces are installed from the pallete to the upper corners of the maser retaining frame.

Maximum care should be exercised in transport and handling the maser to minimize shock and vibration and to retain the apparatus in a vertical position.

2.2 INSTALLATION

The maser should be placed on a level flat surface free from shock and vibration. No special mounting fixtures are necessary.

The space in which the maser is installed should be temperature stabilized between 20° and 30°C ± 0.1°C. Movement of objects and personnel in the vicinity of the maser should be a strict minimum.

Care must be taken to avoid extraneous and variable magnetic fields around the maser, and the presence of large iron structural elements.

The magnetic shields must remain clean and unpainted in order to retain the maximum of shielding effectiveness.

2.3 POWER AND MONITORING CONNECTIONS

Figure 1.6 provides a summary of pin connections for connecting the maser and monitor.

2.3.1 DC Connections

DC is connected to the maser via two front panel connectors (1), Fig. 1.2, type MS 3102A 149 5 p and Fig. 1.6

Pin connections are as follows :

BATTERY A	BATTERY B
A - N.C.	A - N.C.
B - GND	B - GND
C - N.C.	C - N.C.
D - N.C.	D - N.C.
E - +24 V	E - +24 V

NOTE

The protective input power interlock circuitry of the maser requires a turn-on cycle of the input power switch. Special precautions are necessary before initiating the cycle when the maser is cold, and the vacuum system operating pressures have not been established (see section 3).

2.3.2 Monitoring receiver connections

The monitoring module may be connected to the maser at a distance up to 10 meters with the cable provided. Surveillance of maser operation is thus possible without being in the proximity of the maser. The monitor may be bench or rack mounted.

Power supply for the monitoring receiver is derived from the AC line, or from a DC supply via connectors on the receiver rear panel Fig. 1.5. Before connection to the AC source, set mains voltage selector switch (3) Fig.1.5, to the correct value.

DC input is via a MS 3102A 145 5P connector. Pin connections are as follows :

PIN	A	-	N.C.
	B	-	GND
	C	-	N.C.
	D	-	N.C.
	E	-	+24 V

The monitor receiver is connected to the maser at the front panel connector "MONITORING" (4), Fig. 1.2.

2.3.3 Ambiant temperature probe

Room temperature may be monitored by the monitoring system via a probe and front panel connector (3), Fig. 1.2.

Probe type	:	ASULAB 8002 - 1190
Probe connector type	:	LEMO RGØB 3ØC.A222
Pin connections	:	1 - +
		2 - -
		3 - GND

2.4 HYDROGEN BOTTLE INSTALLATION AND REMOVAL

(see Fig. 2.1 for location)

The hydrogen bottle and associated pressure reducing system (1), (2), (3), (4), (6), (7) and (8), Fig. 2.2 and 2.3 is removed or installed as a unit. Replacement of the hydrogen bottle is covered in paragraph 2.4.

IMPORTANT

Whenever the hydrogen bottle is to be removed or installed assure the following :

1) The hydrogen bottle valve (2), Fig. 2.2, is firmly closed

2) The palladium pressure regulating valve is set to zero with the control potentiometer full counter clockwise (7), Fig. 1.3, on the control panel

3) The hydrogen pressure regulator is set for zero pressure by turning the valve counter clockwise (8) Fig. 2.2

4) A pinch-off tool is available, see table 2.1

2.4.1 Installation

Before the bottle is installed and connected, it is convenient to open the maser supply tube (14), Fig. 2.3, to allow later purging of the hydrogen supply to the palladium valve. This can be accomplished by filing a notch near the pinch-off end of the tube then breaking, or using side-cutting pliers and being sure that there is an opening at the end of the pinch-off tube.

- loosen the mounting strap restraining screw and strap (10), (9) Fig. 2.2, to allow placing the bottle in the mounting cradle (11)

- install the bottle in the cradle with the reducing valve and pressure gage above the bottle, (5), (6) Fig. 2.2, and tighten the strap restraining screws (10).

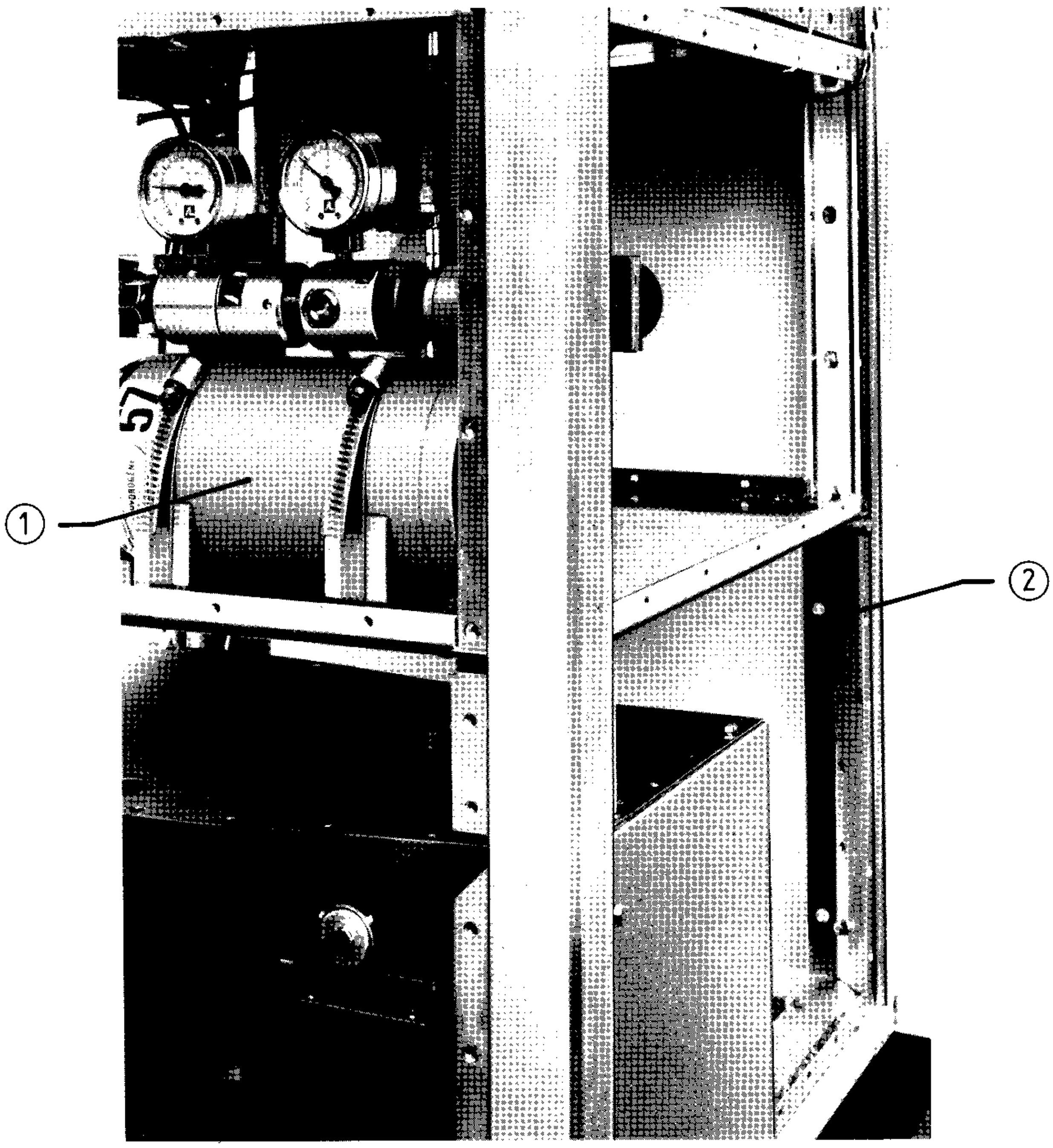
PARA.	DESCRIPTION
	<u>GENERAL</u> - Open-end/box-end wrenches; metric series M4 (4 mm) to M15 (15 mm) in 1 mm steps - Screw drivers; metric series M3 (3 mm) to M8 (8 mm) in 1 mm steps - DC voltmeter, 50 kΩ / volt (0 - 30 V)
2.4	<u>HYDROGEN BOTTLE INSTALLATION/REMOVAL</u> - Wrenches M7, M8 and M15 - Screw drivers M3 and M6 - Pinch-off tool : ERMA LTD. Wembley / ENGLAND Cat. No 2903 or THE TEAM COMPANY 233 Harvard St. Brooklin MA 02146 USA - Leak detector liquid : "AIR-TEC" AMERICAN GAS& CHEMICAL 511E 72nd St. New York, 10021
3.5.1	<u>CONNECTION OF PUMP EXTERNAL POWER SUPPLY</u> - Pump H.V. adaptor cable ASULAB Part No 8002 - 1150/1 (2 req'd) - Pump control unit (H.V. supply) VARIAN model 911-5030 (2 req'd)
3.5.3	<u>EXTERNAL PUMP CONNECTION</u> - Pinch-off tube VARIAN part 935-5018 - 5 cm length of flexible hose + 2 hose clamps

Auxiliary equipment and tools required for start-up and operating point setting of EFOS HYDROGEN MASER

T A B L E 2.1

PARA.	DESCRIPTION
	- Turbo-molecular vacuum pump PFEIFFER (Germany) type TSU 118, 40 litres/second - PIRANI-cold cathode gauge control, BALZERS model PKG 020 with probe IKR 010 - PIRANI vacuum gauge, BALZERS model TPG 060 with probe TPR 010 - Flexible tube for maser-to-pump connection (according to turbo), max length 1 meter - Pinch-off tool : see § 2.4 (TABLE 2.1)
3.10	<u>DEMAGNETIZING PROCEDURE</u> - Clip-on ammeter (AC) 0-30 A - VARIAC 250 VA - Demagnetizer connecting electrode ASULAB No 8002 - 1167 - AC arc welder 100 A or current transformer - RHEOSTAT, 0 to 1 k Ω, 1 A - Low current demagnetizer, OSA Model 3098
3.11.2	<u>ZEEMAN FREQUENCY MEASUREMENT</u> Synthesizer 0 to 10 kHz / HP model 3325 A DC voltmeter, high impedance 0 to 5 V
3.11.5	<u>CAVITY SPIN-EXCHANGE TUNING</u> - Reference oscillator : hydrogen maser or oscillator $<1 \times 10^{-14}$ in 10 minutes interval - Dual Mixer Time difference frequency measurement system (NBS) - Synthesizer HP model 3325 A - Frequency counter HP model 5328 A - SMA-to-voltmeter adapter cable

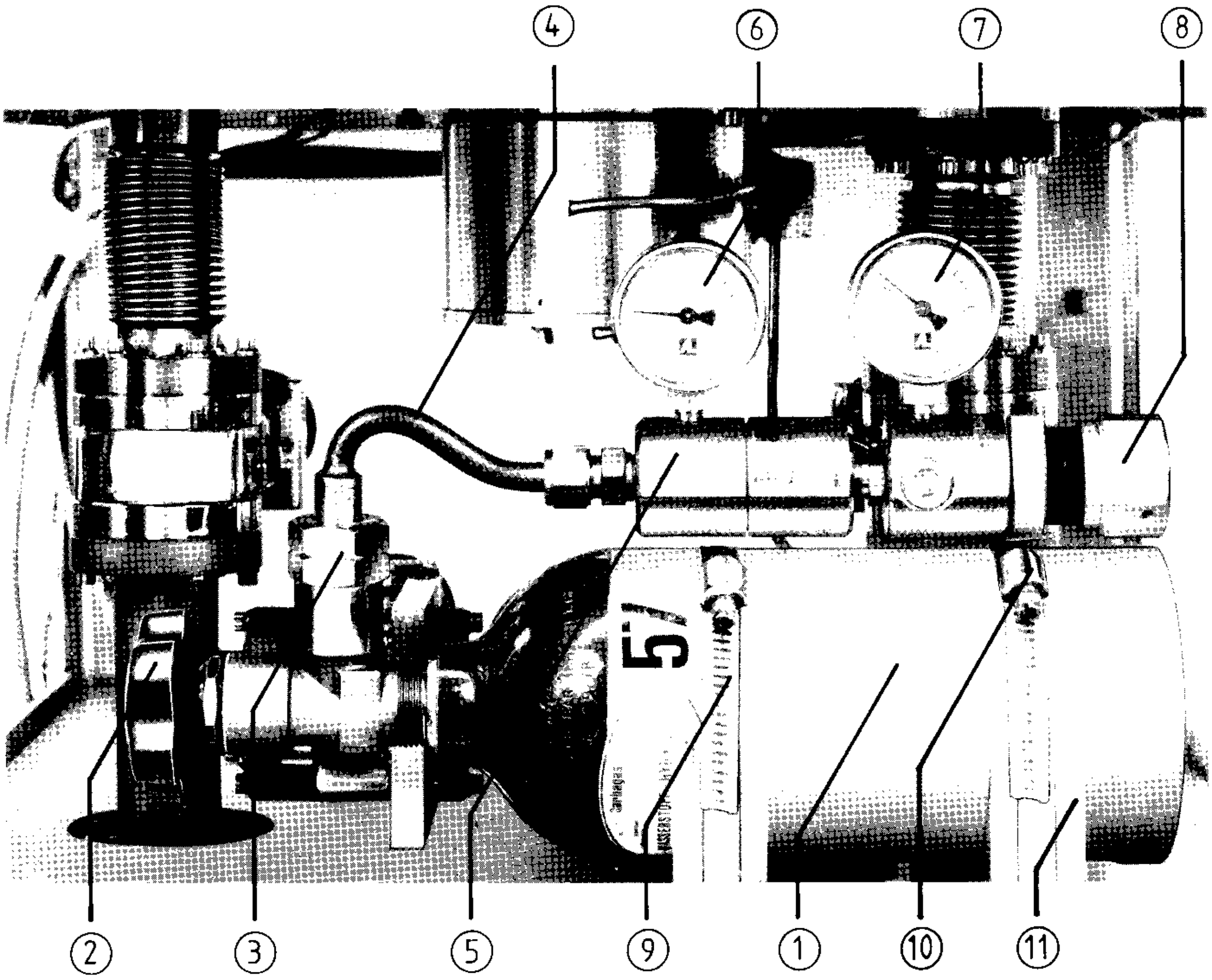
<u>T A B L E 2.1</u> (CONTINUED)



① HYDROGEN BOTTLE INSTALLATION

② ATTACHEMENT SCREW FOR DEMAGNETIZER RETURN CABLE (M 8)

Fig. 2.1 : REAR SIDE OF MASER WITH ACCESS TO HYDROGEN BOTTLE AND DEMAGNETIZER GROUND CONNECTION



(1) HYDROGEN BOTTLE
(2) HYDROGEN BOTTLE SHUT-OFF VALVE
(3) BOTTLE OUTPUT CONNECTOR
(4) HIGH PRESSURE OUTPUT TUBE
(5) PRESSURE REDUCING SYSTEM
(6) HYDROGEN BOTTLE PRESSURE GAUGE
(7) HYDROGEN OUTPUT PRESSURE GAUGE (MASER DISSOCIATOR)
(8) HYDROGEN SYSTEM PRESSURE ADJUSTMENT
(9) MOUNTING STRAP
(10) STRAP RETAINING SCREW
(11) BOTTLE MOUNTING CRADLE

Fig. 2.2 : HYDROGEN BOTTLE INSTALLATION, SIDE VIEW

- connect the output of the pressure reducer, (8) Fig. 2.3, to the maser hydrogen supply system via the coupling, (12) Fig. 2.3. The pressure reducer output fitting, (15) Fig. 2.3, should be held immobile with a wrench while the coupling (12) is being turned (either tightened or loosened). First examine the tubing end and ferrules of the coupling (12) to be sure that they are clean and undamaged. Then insert the tubing with its ferrules into the fitting body (15) and tighten (12) to a hand-tight condition. Second, with a wrench tighten the coupling nut (12), while at the same time retaining (15) immobile as mentioned above, until a sharp rise in torque is felt, then simply snug. This takes about 1/4 turn.

- open the hydrogen bottle shut-off valve slowly about 1/4 turn, (2) Fig. 2.2, counter clockwise direction. The bottle pressure gage should read between 20 and 200 atmospheres, (6) Fig. 2.2. Pressure reading on the reducer output should be 0, (7) Fig. 2.2 if valve (8) is closed (counter clockwise rotation).

- before admitting hydrogen to the maser system via the pressure regulator valve (8), Fig.2.2 have ready the pinch-off tool

- open the pressure regulator valve (8) by turning clockwise about 1/4 turn. An output pressure of 1 atmosphere will be shown on the pressure gage (7), Fig. 2.2.

- allow hydrogen to purge the maser supply tube via the open pinch-off tube (14), Fig. 2.3 for about 1 minute.

IMPORTANT

Failure to purge the maser supply system which has been opened to air will result in improper operation and possible damage of the palladium valve.

- pinch-off the tube (14) near its open end by applying a steady pressure to the pinch-off tool until the copper tube separates. Cover the exposed edge with epoxy or other means to protect the edge.

- turn the hydrogen bottle shut-off valve (2) Fig. 2.2, to the full open position (full counter clockwise rotation). Assure that maser hydrogen system pressure, (7) Fig. 2.2, is between 1 and 2 atmospheres and adjust (8) as necessary.

2.4.2 <u>Leak test</u>

The hydrogen system is tested for leaks by two methods :

a) a leak detector liquid applied to the couplings and joints

b) observing the hydrogen system pressure change. This test is made after maser is operating.

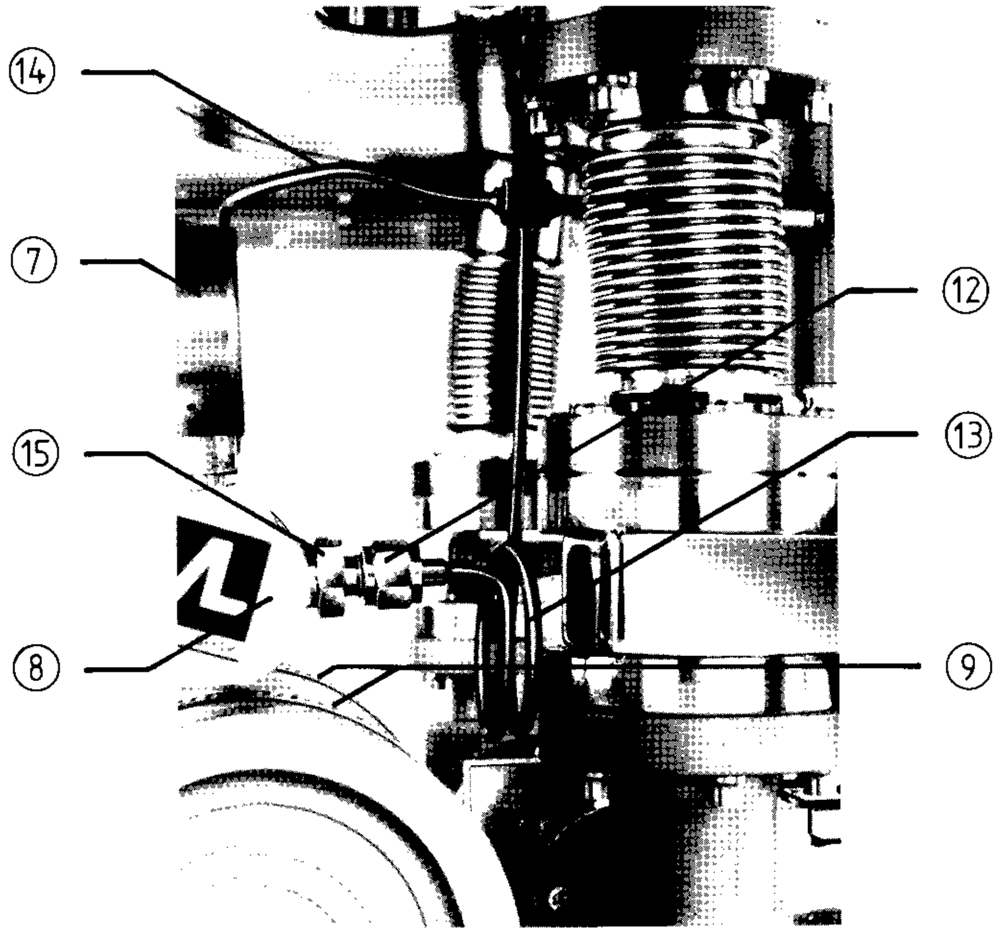
Proceed as follows :

a) use a leak detector liquid such as "air-tec" manufactured by AMERICAN GAS AND CHEMICAL, INC. 511E. 72nd Str. New York, 10021.

With a syringe or eye-dropper apply a drop of liquid on each joint in the system, Fig. 2.2 and 2.3, including the joints on the bottle-to-valve tube. Presence of any growing bubbles in the joints indicates a leak and should be corrected by tightening the joint, or in some cases replacing the washer or ferrules in the joint. (See the maintenance manual for complete replacement instructions).

b) refer to § 3.11.3 and set the dissociator pressure to about 0.2 Torr. Close hydrogen bottle shut-off valve (2), Fig. 2.2. Observe pressure reading on hydrogen bottle pressure gauge (6), Fig. 2.2. The pressure will diminish about 10 atmospheres per week for normal hydrogen consumption. If it is significantly greater than this, consult the maintenance and repair manual.

When tests are completed, open the bottle shut-off valve (2).



(7) PRESSURE GAGE
(8) HYDROGEN SYSTEM PRESSURE ADJUSTMENT
(9) MOUNTING STRAP
(10) STRAP RETAINING SCREW (see Fig. 2.2)
(11) BOTTLE MOUNTING CRADLE (see Fig. 2.2)
(12) HYDROGEN SUPPLY TUBE COUPLING
(13) HYDROGEN SUPPLY TUBE TO DISSOCIATOR
(14) HYDROGEN SUPPLY TUBE PURGE PINCH-OFF
(15) PRESSURE REDUCER OUTPUT FITTING

Fig. 2.3 : HYDROGEN BOTTLE INSTALLATION, END VIEW

2.4.3 Hydrogen bottle removal

The hydrogen bottle will normally be removed for :

1) Shipping the maser (according to the transport regulations)

2) Replacement of the bottle (removal of the bottle is essentially the reverse of installation)

   Detailed information is in paragraph 2.4.1 above

To remove the bottle, these steps are carried out :

1) Turn-off palladium valve in maser hydrogen system

2) Close pressure reducer by turning the pressure reducer valve counter-clockwise

3) Close hydrogen bottle shut-off (clockwise rotation)

4) Disconnect maser hydrogen system from the pressure reducer via coupling nut

5) Loosen retaining strap screws

6) Remove bottle

2.5 ACCESSORY TOOLS + EQUIPMENT FOR MASER INSTALLATION AND START-UP

A list of accessories necessary for maser start-up is given in table 2.1

2.6 REPACKING AND SHIPPING

ASULAB should be contacted for complete instructions prior to packing or shipping the maser.

3. MASER START-UP AND OPERATION

For the maser to oscillate the following conditions must be fulfilled :

1) Correct vacuum system pressures exist

2) Hydrogen atoms are available within the cavity in sufficient quantity to sustain oscillations

3) Cavity frequency is correct

4) Magnetic field in the maser cavity must be sufficiently homogeneous

After the unpacking and installation is completed according to part 2, the following start-up sequence is followed to assure that conditions 1) to 4) above are fulfilled.

3.1 24V POWER SUPPLY CONNECTION DURING START-UP

When full start-up power is applied to the maser, the input current at 24 V (8 A max.) exceeds the fusing capacity of the individual 24 V inputs. Under these conditions, the two maser inputs must be connected to the same DC source capable of providing the 8 A (max.) current drawn. After warm-up and establishment of normal operation the two DC inputs may be separated.

3.2 MONITORING CONNECTION

The monitoring receiver should be connected to the maser front panel connector (4) Fig. 1.2 and energized before start-up of the maser. A cable, part No 8002 - 1189/1, is provided for connection to the maser. The monitoring digital scale factors are given in Table 3.1

3.3 HYDROGEN DISSOCIATOR START-UP PRESSURE SETTING

Before power is applied for start-up, check that the dissociator pressure is set to 0 by turning the pressure control potentiometer on the control panel, (7) Fig. 1.3, full counter clockwise.

"ADDRESS"	MASER PARAMETER	DIGITAL UNIT	FULL SCALE 100 UNITS
0 0	U } BATTERY A	240 mV	24 V
0 1	I	100 mA	10 A
0 2	U } BATTERY B	240 mV	24 V
0 3	I	100 mA	10 A
0 4			
0 5			
0 6	H-PRESSURE CONTROL	100 mV	10 V
0 7	H-PRESSURE MEASURE	100 mV	10 V
1 0	LO	200 mV	20 V
1 1	UO	200 mV	20 V
1 2	DA	200 mV	20 V
1 3	LI } HEATER VOLTAGE	200 mV	20 V
1 4	UI	200 mV	20 V
1 5	CAV	200 mV	20 V
1 6	T - CAV	10 m°C	1°C
1 7	T - AMB	0.1°C	10°C
2 0	CAV - VAR	100 mV	10 V
2 1	XTAL - VAR	100 mV	10 V
2 2	AMPL 5.7 kHz	40mVRMS	4VRMS
2 3	C-FIELD	2 A	200 A
2 4	-U	50 V	5 kV
2 5	I } VAC ION INT	20 A	2 mA
2 6	-U	50 V	5 kV
2 7	I } VAC ION EXT	20 A	2. mA
3 0	U	240 mV	24 V
3 1	I } RF SOURCE	10 mA	1 A
3 2	+24 V	240 mV	24 V
3 3	+15 V	150 mV	15 V
3 4	-15 V	150 mV	15 V
3 5	+ 5 V } SUPPLIES	50 mV	5 V
3 6	+15 V	150 mV	15 V
3 7	-15 V	150 mV	15 V

TABLE 3.1 : MONITOR DIGITAL SCALE FACTORS

3.4 MASER TURN-ON

Set the input power switch, (2) Fig. 1.3, on the control panel to OFF, and monitor "ADDRESS" to position 00, (3) Fig. 1.4. Turn the switch (2) through two steps to the second position of SUPPLY. On the monitor check that the following parameters and readout values, as given in Table 3.2., are indicated.

"ADDRESS"	MASER PARAMETER	
0 0	U	BATTERY A
0 1	I	BATTERY A
0 2	U	BATTERY B
0 3	I	BATTERY B
0 6	H-PRESSURE CONTROL	
0 7	H-PRESSURE MEASURE	
1 6	T - CAV	
1 7	T - AMB	
2 0	CAV - VAR	
2 1	XTAL - VAR	
2 3	C - FIELD	
3 2	+24 V	SUPPLIES
3 3	+15 V	SUPPLIES
3 4	-15 V	SUPPLIES
3 5	+ 5 V	SUPPLIES
3 6	+15 V	SUPPLIES
3 7	-15 V	SUPPLIES

"ADDRESS"	MASER PARAMETER	READOUT
0 0	U } BATTERY A	100
0 1	I	40 MAX
0 2	U } BATTERY B	100
0 3	I	40 MAX
0 4		
0 5		
0 6	H-PRESSURE CONTROL	0
0 7	H-PRESSURE MEASURE	0
1 0	LO } HEATER VOLTAGE	80 ± 5
1 1	UO	90 ± 5
1 2	DA	110 ± 5
1 3	LI	115 ± 5
1 4	UI	115 ± 5
1 5	CAV	110 ± 5
1 6	T - CAV	-100
1 7	T - AMB	
2 0	CAV - VAR	10 - 100
2 1	XTAL - VAR	±128
2 2	AMPL 5.7 kHz	0
2 3	C-FIELD	25
2 4	-U } VAC ION INT	SEE PARAGR. 3.4
2 5	I	
2 6	-U } VAC ION EXT	
2 7	I	
3 0	U } RF SOURCE	115 ± 5
3 1	I	40 - 70
3 2	+24 V } SUPPLIES	100 ± 2
3 3	+15 V	100 ± 2
3 4	-15 V	100 ± 2
3 5	+ 5 V	100 ± 2
3 6	+15 V	100 ± 2
3 7	-15 V	100 ± 2

TABLE 3.2 : MONITOR NOMINAL START-UP VALUES

If values of readout are normal, proceed to the next step, otherwise, recycle the input switch (2), Fig. 1.3 to OFF and consult the troubleshooting guide in the maintenance and repair manual.

- Turn input power switch (2) to HEATERS and check the following readout values given in Table 3.2.

"ADDRESS"	MASER PARAMETER	
10	LO	HEATER VOLTAGE
11	UO	
12	DA	
13	LI	
14	UI	
15	CAV	

confirm normal values before proceeding to the next step

The maser cavity temperature change when full heat is applied is about 0.1°C per hour. From a cold start at 25° it will be about one week before the cavity temperature is at nominal value.

- Turn input power switch (2) to RF SOURCE and check the following monitor readout values given in Table 3.2.

"ADDRESS"	MASER PARAMETER	
30	U	RF SOURCE
31	I	

confirm normal values before proceeding to the next step.

- Turn input power switch (2) to HT position and check the following monitor readout values given in Table 3.3

"ADDRESS"	MASER PARAMETER	
24	-U	VAC ION INT
25	I	
26	-U	VAC ION EXT
27	I	

Table 3.3 indicates the action to be taken according to pump voltage and current values read above

"ADDRESS"	READOUT	INTERPRETATION	ACTION TO TAKE
25 and 24 27 and 26	< 1.5 mA > 4 kV < 1.5 mA > 4 kV	pumping normal with dissociator non-operating	observe pressure descend to $\sim 2 \times 10^{-7}$ Torr internal pressure, $\sim 1 \times 10^{-6}$ Torr external pressure
25 and 24 27 and 26	> 1.5 mA 2 to 5 kV > 1.5 mA 2 to 5 kV	outside of limit of internal power supply. Must use external H.V. power supply	connect external supply per § 3.5.1
25 and 24 27 and 26	0 mA > 4 kV 0 mA > 4 kV	pump does not start. Pressure too high	connect extern. turbo molecular pump per § 3.5.3
25 and 24 27 26	0 mA < 1 kV 0 mA < 1 kV	pump power supply inoperative	connect extern. power supply to retain vacuum refer to maintenance manual for power supply replacement

TABLE 3.3 : VACUUM SYSTEM OPERATION AND START-UP PARAMETERS

"ADDRESS"	READOUT	INTERPRETATION	ACTION TO TAKE
Panel meter on ext. H.V. supply	<100 mA >2 kV	external H.V. power supply normal and vacuum Ion is pumping	when pump current <5 mA, int. pump power supply may be connected (see § 3.5.2)
Panel meter on ext. H.V. supply	>100 mA <1.5 kV	after 10 min. if current is not <100 mA capacity of pump is at maximum	turn off power supply. Recycle pumping action (according to § 3.5.1.1)
Panel meter on ext. H.V. supply	>100 mA <1.5 kV	after 3x 10 min. cycles if current is not < 100 mA capacity of pump is exceeded	connect ext. turbo molecular pump (see § 3.5.3)

TABLE 3.3 : ... (CONTINUED)

3.5 VACUUM SYSTEM START-UP AND OPERATION

When the maser VAC Ion pumps are de-energized, there will be an eventual pressure rise in the vacuum system (interior and exterior). Should this pressure rise exceed the power supply capacity of the maser vacuum pumps it will be necessary to connect external auxiliary elements for pumping.

TABLE 3.3 : summarizes vacuum system operation and start-up parameters

The pump current is an indication of the existing pressure at the pump.

Fig. 3.1 : gives the pressure for a given pump current for the VARIAN model 911-5030 VAC Ion pump used in the EFOS-2 maser

Normal operating range for internal and external vacuum systems is shown in the figure. Shown also is the nominal voltage-current characteristic of the pump power supply.

The capacity of the maser pump power supplies is 2 mA. If the current exceeds this value an external high voltage supply (VARIAN model 911-5030 control unit or equivalent) is connected having a capacity of least 100 mA (between 10^{-3} and 10^{-4} Torr). Should the pressure exceed this value (4×10^{-4} Torr) an external turbo-molecular roughing pump is used to pump down the system (refer to Table 3.3)

In normal operation the maser external vacuum system is maintained at a nominal pressure of 10^{-6} Torr (200 to 400 μA to 1 mA pump current). With no hydrogen pressure the maser internal vacuum can attain 1×10^{-7} Torr (20 μA pump current).

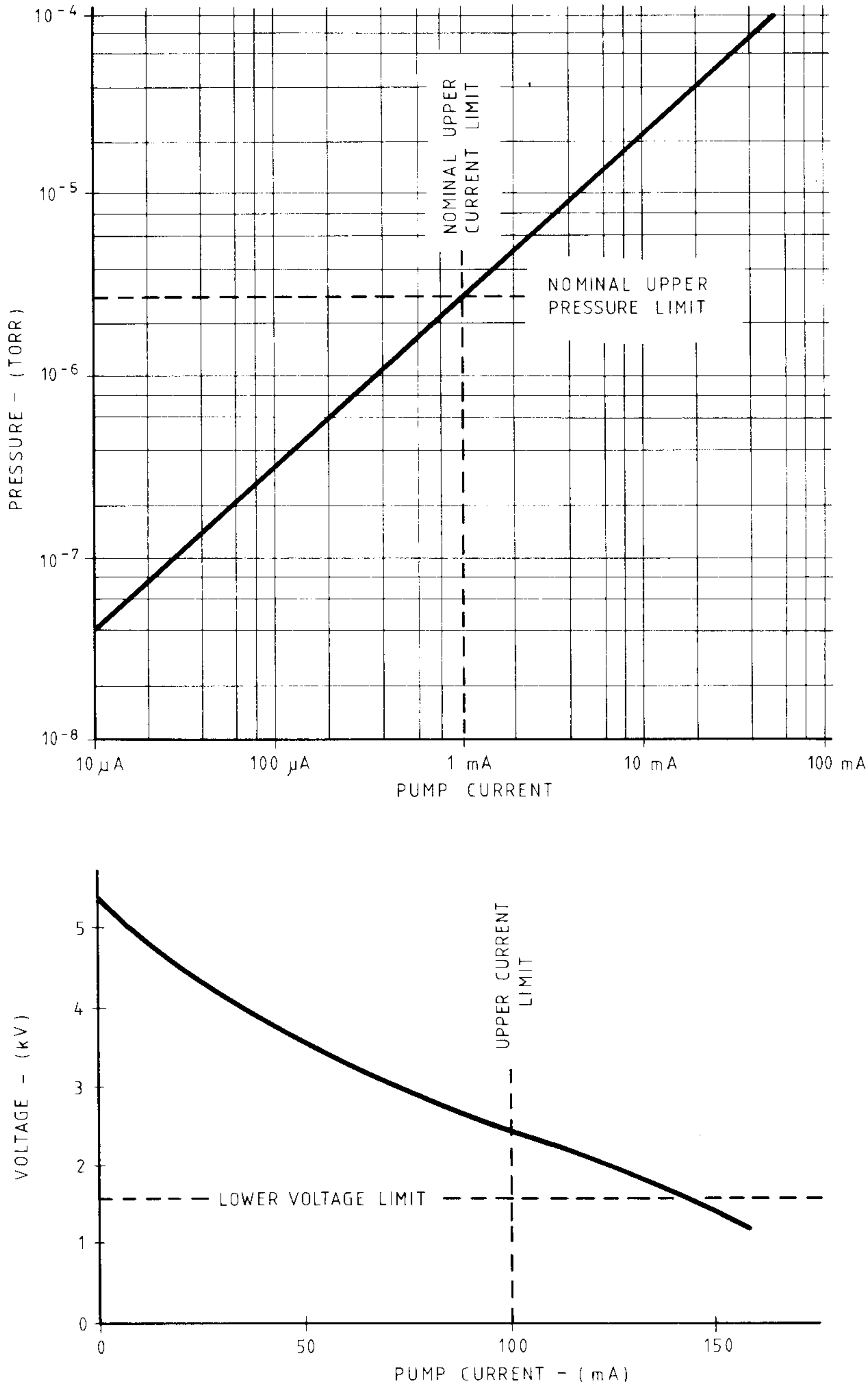


Fig. 3.1 : VAC ION PUMP CHARACTERISTICS

3.5.1 Connection of external pump power supplies

The maser VAC Ion power supplies are contained in a compartment in the electronics and control unit, (11) , Fig. 1.2, to connect the VAC Ion pumps to external power supplies proceed as follows :

- remove the control unit mounting screws (6) , Fig. 1.2, and slide the control unit out of the maser housing. The H.V. pump cables and connection to the maser power supply module are accessible at the rear of the power supply compartment (1) , Fig. 3.2.

CAUTION

> Dangerous voltages exist in the VAC Ion pump system. Be sure that H.V. power supplies are de-energized and sufficient time has elapsed for complete discharge of the high voltage circuits, before disconnecting or connecting the power supply coaxial cables.

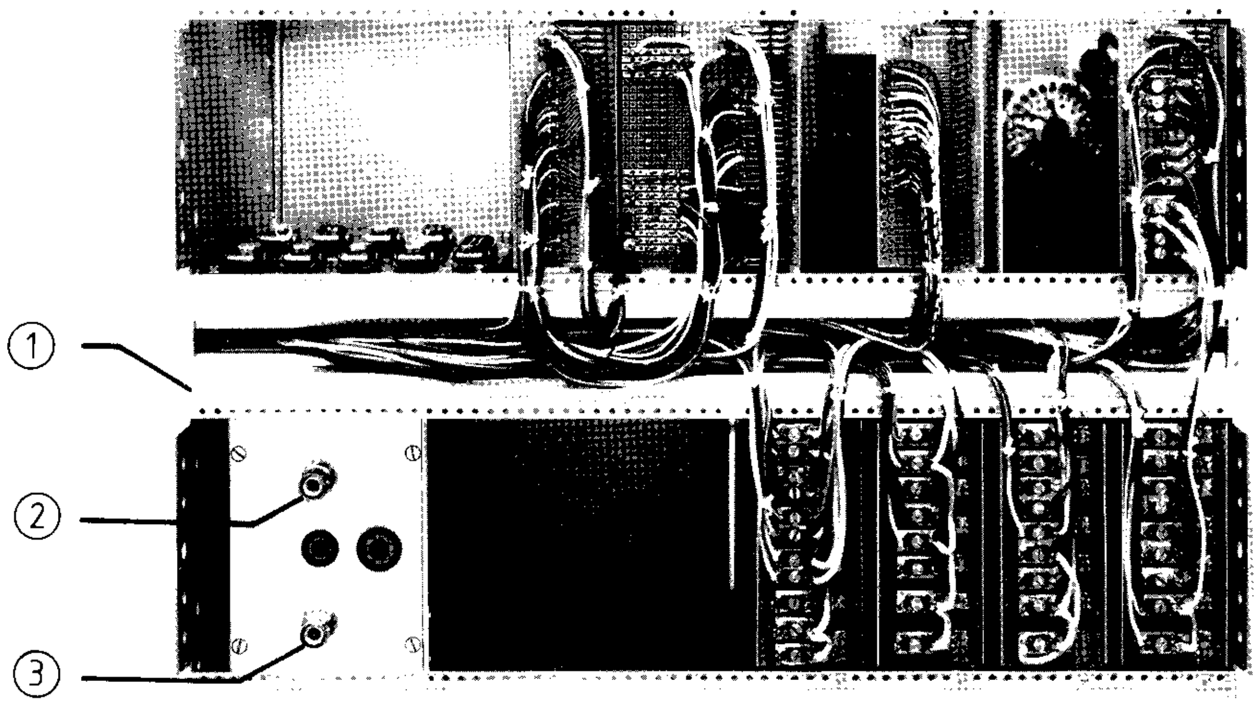
- set maser input power switch (2) , Fig. 1.3, to RF and monitor "ADDRESS" to <u>24</u> and <u>26</u>. Check that voltage indication goes to zero before disconnecting pump coaxial cables.

- connect the pump external power supply (VARIAN model 911-5030 control unit) to AC mains, set input switch to OFF

- connect the adaptor cable (ASULAB No 8002 - 1150/1) to the connector on the rear of the pump external power supply

- disconnect the pump coaxial cable at the rear of maser control unit (2),(3), Fig. 3.2, and connect the adaptor cable from the external supply to the pump cable. This cable is labelled to correspond with the maser pump to which it is connected : <u>INT VAC</u>, or <u>EXT VAC</u>.

- turn on the external power supply and note pump current on the supply panel meter (consult Table 3.3 for action to take according to the current reading).



1. ELECTRONICS AND CONTROL UNIT
2. COAXIAL CONNECTOR TO INTERNAL VACUUM SYSTEM PUMP
3. COAXIAL CONNECTOR TO EXTERNAL VACUUM SYSTEM PUMP

Fig. 3.2 : PUMP H.V. CONNECTIONS

3.5.1.1 VAC Ion pump cycling with external power supply

The pumping time at full pump capacity (100 mA, 1.5 kV) should be limited to 10 minutes because of heating of the pump. It may nevertheless be possible to obtain the required vacuum by applying several 10 minutes pumping cycles, provided that the initial pressure is not too high.

To apply pumping cycles, proceed as follows :

- turn on pump for 10 minutes
- turn off pump for 30 minutes
- repeat this cycle three times

(total pumping time is half an hour)

Consult Table 3.3 for action to take according to current reading.

3.5.2 Connection of pump internal power supply

This procedure is necessary after pumping down to $<3 \times 10^{-6}$ TORR. with the pump external power supply. The maser control unit (5) , Fig. 1.1 will normally be outside the maser housing (§ 3.5.1) :

- check that input power switch (2) , Fig. 1.3, is NOT in HT position.
- turn off the pump external power supply. Check external power supply voltage at zero before proceeding with changing connections.
- disconnect pump power supply coaxial cable from the internal pump cable.
- connect pump coax to the internal power supply connector (2) , Fig. 3.2
- set monitor "ADDRESS" to VAC Ion current position 25 or 27
- set maser input power switch to HT position and observe pump current on monitor. The current should decrease to the nominal value
- slide the control unit in position and attach the retaining screws (6) , Fig. 1.2.

3.5.3. External pump connection

> NOTE
>
> Before attaching the external turbo pump two things must be well understood :
>
> 1) The manner in which the vacuum system valves must be operated
>
> 2) The manner in which the vacuum tight joints are formed

To close the valve [V2] or [V3], turn in the clockwise direction from the full open (counter clockwise) position. Near to end of travel the torque necessary to turn the valve will increase, then decrease again. The valve is now closed, and turning further is unecessary and should be avoided. Do not force turn against the valve stop. This may damage the mechanism.

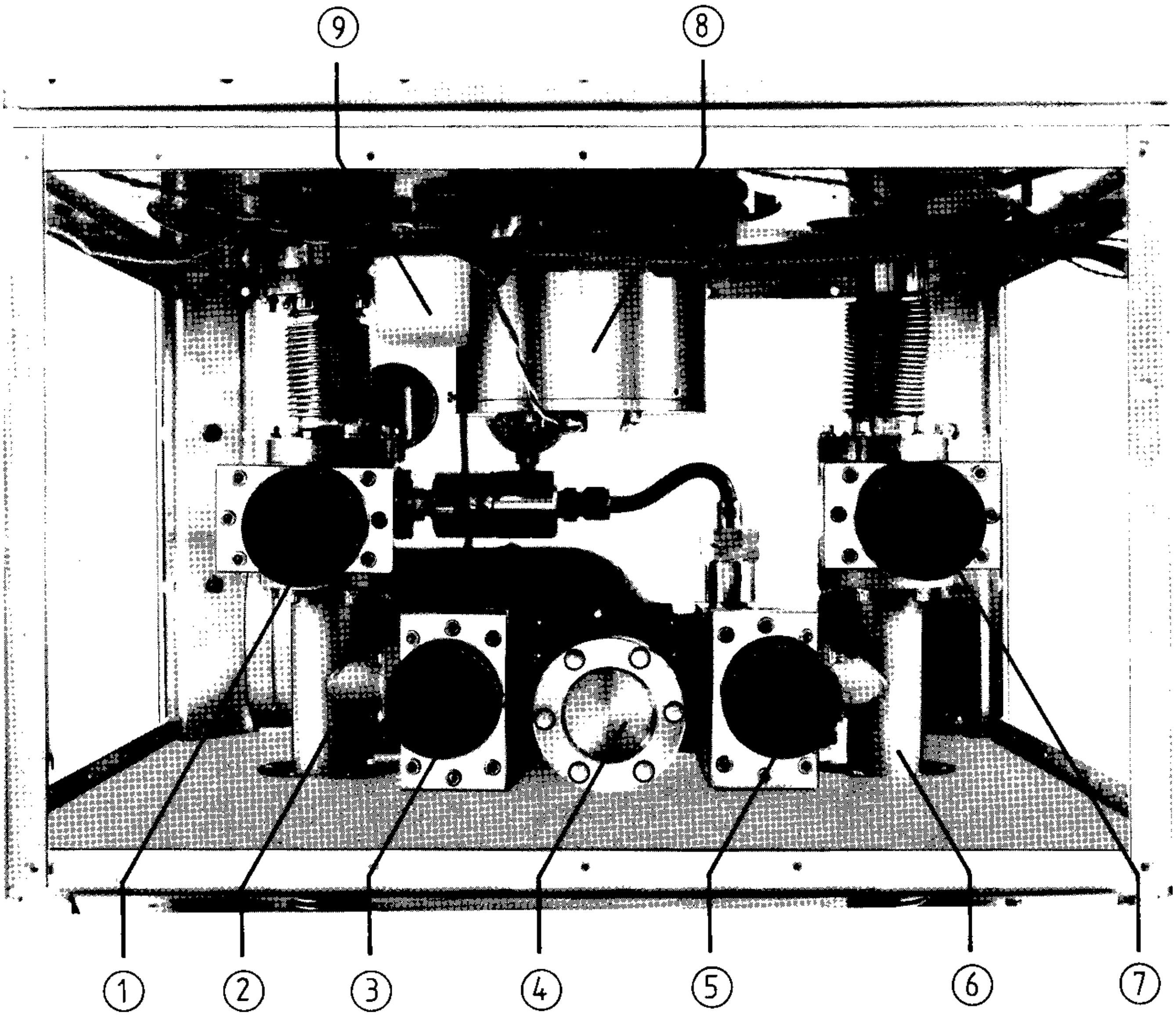
Vacuum tight joint is formed by placing an unused annealed copper disc between the flanges, installing and tightening the bolts in the mounting flange to hand-tight around the periphery. Then, with the 1/4 inch box-end wrench tighten each bolt successively around the flange by 1/4 turn always keeping the two faces parallel until the faces are in contact. In this manner the ridge of the vacuum system flange is pressed into the soft annealed copper assuring a hermetic seal.

- The VAC Ion external supplies are connected before using the turbo pump (§ 3.5.1 and Table 3.3). They should be turned off until system pressure is below 10^{-4} Torr.

- Remove the vacuum manifold compartment front cover (2), Fig. 1.1. The external pump is connected at the flange located in the center (4), Fig. 3.3.
  Assure that valves [V2], [V3] (3), (5), Fig. 3.3 are closed (clockwise turning) before removing the flange cover plate (4).

- Using a 1/4 inch box-end type wrench remove the bolts and cover flange plate and connect a flexible line (1 1/4 inch min. diam.) from the turbo pump at this point. Turn on the turbo pump and keep the valves closed until pressure in the line from the turbo to the maser vacuum manifold has descended to $< 1 \times 10^{-4}$ Torr.

- Open valve [V3] (maser external vacuum system) or [V2] (maser internal vacuum system) or both as appropriate. Continue to pump with the turbo in this configuration until system pressure has descended to $< 10^{-4}$ Torr. When pressure has reached this value, external VAC Ion power supply may be energized.



① INTERNAL VACUUM SYSTEM, INTERNAL VALVE [V1]
② INTERNAL VACUUM SYSTEM PUMP LINE
③ INTERNAL VACUUM SYSTEM, EXTERNAL VALVE [V2]
④ EXTERNAL PUMP ATTACHEMENT
⑤ EXTERNAL VACUUM SYSTEM, EXTERNAL VALVE [V3]
⑥ EXTERNAL VACUUM SYSTEM PUMP LINE
⑦ EXTERNAL VACUUM SYSTEM, INTERNAL VALVE [V4]
⑧ HYDROGEN DISSOCIATOR
⑨ DISSOCIATOR PRESSURE CONTROL

Fig. 3.3 : VACUUM MANIFOLD COMPARTMENT

- Turn on external VAC Ion H.V. power supply and monitor the pump current and voltage during the pump-down (Fig. 3.1 illustrates the nominal pump voltage-current characteristics of the VARIAN model 911-5030 pump).

- When pressure has reached 2 x 10^{-5} Torr. (10 mA pump current) close valves [V2], [V3] by rotating clockwise.

  Turn off turbo pump and disconnect at the maser flange.

- Continue pumping the maser vacuum systems with external power H.V. supplies until pressure is at normal operating level (< 1 mA). The maser vacuum manifold to the turbo should be closed off before transferring the pumps to the maser internal H.V. supplies.

- Valves [V1] and [V4] are normally open during this procedure.

3.5.3.1 External pump close-off

The pinch-off disc which was removed to connect the turbo pump may not be reused. A replacement piece (VARIAN part No 953-5018) must first be connected to the turbo by means of a short length of rubber tube as shown in Fig. 3.4.

The pinch-off disc and tube are of annealed oxygen-free (OFHC) copper. Bolt the disc to the maser manifold flange using the original flange rings and bolts, and the method indicated above.

- connect the turbo pump in the same fashion and pump down the system to lower than 10^{-4} Torr. Valves [V2] and [V3] must remain closed during this attachment and pump-down.

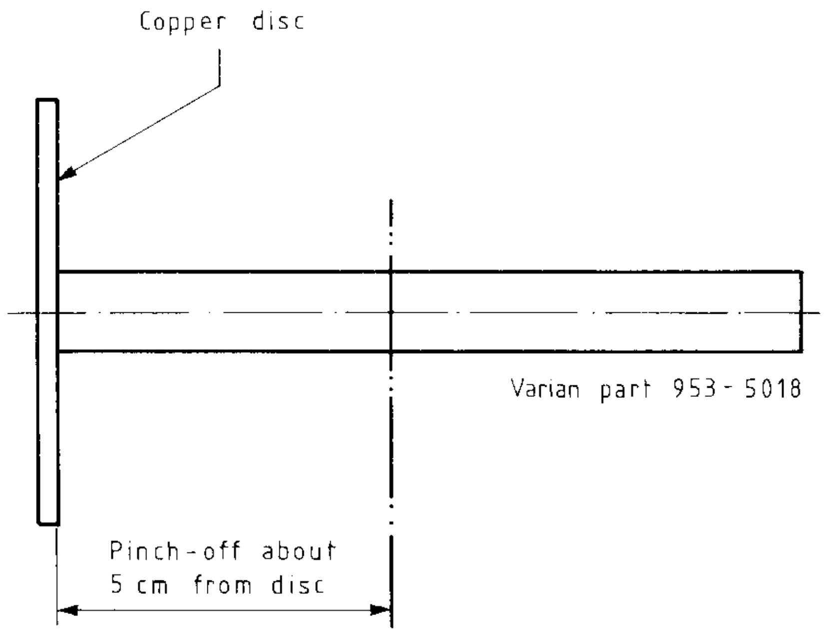
- when turbo pressure is below 10^{-4} Torr., make the pinch-off (see table 2.1). Assure that a continuous pressure is applied to the pinch-off tool to the point that the copper tube separates.

CAUTION

The edge formed on the copper pieces in the pinch-off process are extremely sharp so that care should be exercised in order not to be injured by accidental contact with these pieces. Epoxy or silicone cement should be applied to the pinch-off edge

- open valve [V3] (maser exterior vacuum system) of the maser. Leave [V2] (maser internal vacuum system) closed. Observe pump current (§ 3.5.1 monitor "ADDRESS" 27 Table 3.4) to assure that the seal to the turbo flange is good. Leave valve [V3] open.

- complete the pump-down with the external supply and connect to internal power supply according to § 3.5.2



PINCH - OFF TUBE

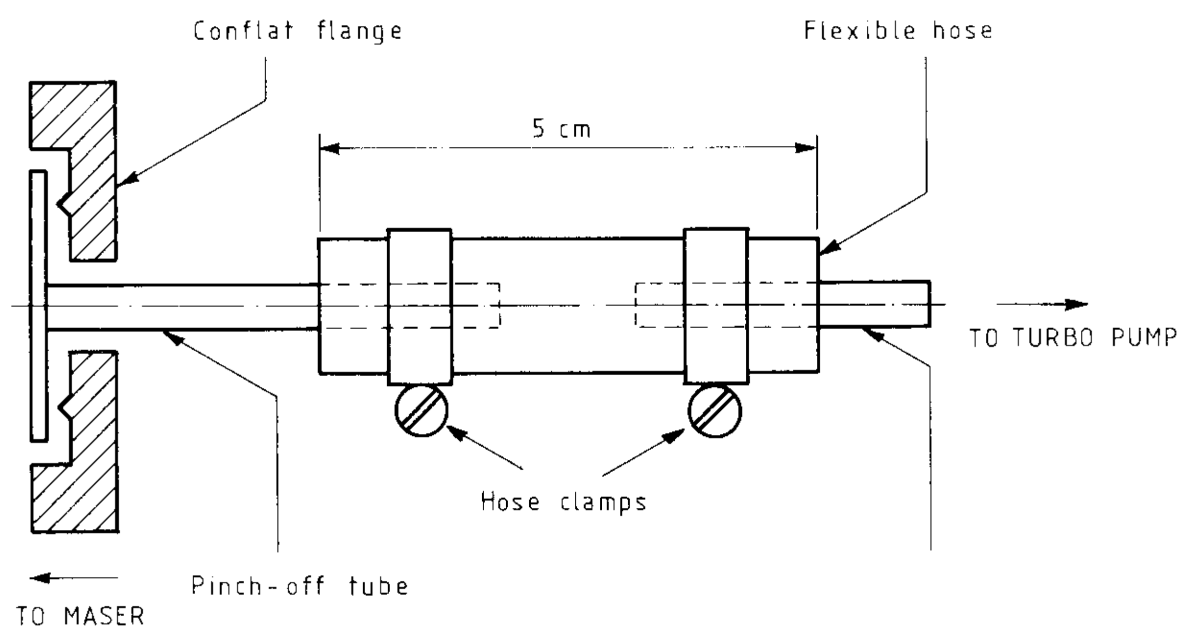


Fig. 3.4 : PINCH - OFF ASSEMBLY

3.6 HYDROGEN DISSOCIATOR PRESSURE SETTING - START-UP

Normal dissociator pressure setting for maser start-up is 0 (§ 3.3). The potentiometer for setting the pressure is located on the control panel (7), Fig. 1.3. The RF power oscillator exciting the hydrogen dissociation is energized when the input power switch (2), Fig. 1.3 is set to RF. With no hydrogen present in the dissociator the oscillator draws full load-limit current from its power supply (about 0.7 A).

When hydrogen pressure rises to the value necessary for the dissociation to take place, oscillator current drops to a value between 0.3 and 0.5 A. A rich pink light is seen on the light pipe located on vacuum manifold compartment panel (7), Fig. 1.1. At the same time pressure will rise in the maser internal vacuum system. Proceed as follows :

- set monitor "ADDRESS" to 06:H-PRESSURE CONTROL
- turn pressure setting potentiometer (7), Fig. 1.3, to obtain monitor readout of 7 V (70 units)
- monitor "ADDRESS" 07:PRESSURE MEASURE
  This value will increase until the set value and measured value correspond closely.

NOTE

> A small difference may exist between the two readings (± 2 digits). This is normal.

3.7 OPERATING TEMPERATURE CHECK

Taking note of the fact that temperature change of the cavity during warm-up is about 0.1°C/hour, cavity temperature as indicated on monitor "ADDRESS" 16 will indicate -100 on the readout until the cavity temperature is within 1° of the set value. During the warm-up, cavity heat on monitor "ADDRESS" 15 will indicate full heating power, 125. When the cavity temperature and heat are at their nominal values as indicated in Table 3.4 the maser should be capable of oscillating provided the magnetic field is sufficiently homogeneous.

3.8 MASER OSCILLATION START-UP

After establishing operating conditions of § 3.5, 3.6 and 3.7 initial maser oscillation tests can be carried out.

- set C-field to nominal value according to § 3.11.1
- set monitor "ADDRESS" to 22-AMPL 5.7 kHz, or connect a DC voltmeter to the coax output AMPL 5.751 on the control panel (11) ,Fig. 1.3
- if an output at 5.7 kHz is obtained, proceed to threshold measurements § 3.9
- if no output at 5.7 kHz is obtained, check all maser operating values on the monitor (Table 3.3) to assure normal operation of vacuum and electronics systems. Proceed to § 3.8.1.

3.8.1 Maser output signal check

Set C-field current to 200 μ A according to § 3.11.1. Allow several minutes for maser oscillations to build up.

- if oscillation (output at 5.7 kHz) is obtained this confirms operation of the maser and possibility of magnetic inhomogeneities. Demagnetize the maser according to § 3.10, and then proceed to threshold measurements § 3.9
- if no oscillation is obtained large magnetic inhomogeneities may be present or some other malfunction may prevent oscillations. Demagnetize according to § 3.10.
- if oscillation is not obtained after this demagnetization consult troubleshooting guide in the maintenance manual. After oscillations are obtained proceed to threshold tests (§ 3.9)

"ADDRESS"	MASER PARAMETER	READOUT
0 0	U } BATTERY A	100
0 1	I } BATTERY A	15
0 2	U } BATTERY B	100
0 3	I } BATTERY B	15
0 4		
0 5		
0 6	H-PRESSURE CONTROL	73
0 7	H-PRESSURE MEASURE	72
1 0	LO } HEATER VOLTAGE	55
1 1	UO } HEATER VOLTAGE	33
1 2	DA } HEATER VOLTAGE	27
1 3	LI } HEATER VOLTAGE	37
1 4	UI } HEATER VOLTAGE	29
1 5	CAV } HEATER VOLTAGE	58
1 6	T - CAV	±01
1 7	T - AMB	according to the room temperature
2 0	CAV - VAR	44
2 1	XTAL - VAR	39
2 2	AMPL 5.7 kHz	40
2 3	C-FIELD	25
2 4	-U } VAC ION INT	100
2 5	I } VAC ION INT	20 to 40
2 6	-U } VAC ION EXT	100
2 7	I } VAC ION EXT	20 to 0
3 0	U } RF SOURCE	115
3 1	I } RF SOURCE	41
3 2	+24 V } SUPPLIES	98
3 3	+15 V } SUPPLIES	99
3 4	-15 V } SUPPLIES	-99
3 5	+ 5 V } SUPPLIES	99
3 6	+15 V } SUPPLIES	99
3 7	-15 V } SUPPLIES	-99

TABLE 3.4 : MONITOR NOMINAL OPERATING VALUES

3.9 MASER OSCILLATION THRESHOLD MEASUREMENT

Threshold tests are made to evaluate the quality of magnetic homogeneity. Threshold of oscillation is also affected by the hydrogen flux in the cavity. For start-up, and until the hydrogen flux (H-dissociator pressure, § 3.11.3) is set, the threshold tests serve to determine whether additional demagnetizing is necessary, and may not be the ultimate value attained.

- set monitor "ADDRESS" to 22-AMPL 5.7 kHz, or connect a voltmeter (5V F.S.) to 5.751 coax (11) Fig. 1.3
- connect a voltmeter (5V F.S.) to coax connector C-field current adjustment
- reduce C-field current slowly or in small steps (e.g. 5 μA) until maser output signal rapidly drops to zero. Note C-field current.
- increase the C-field in small increments, and wait several minuts at each step. Note C-field current when oscillations are re-established.

The threshold of oscillations is between these two C-field current values, and should be less than 20 μA. If the threshold is greater than 50 μA, the demagnetization cycle should be repeated according to § 3.10.

3.10 DEMAGNETIZING PROCEDURE

The quality of magnetic shielding of the maser is important, and any change in the magnetic environment of the maser may require a demagnetization of the shields. These changes are most likely to occur during transport and installation of the maser.

The maser is contructed so that a demagnetizing (alternating) current can be passed axially through the center of the maser. This strong magnetic field, created by a high current, can penetrate the shields sufficiently to demagnetize them. Ideally, the demagnetizing current diminishes from the high value slowly and continuously to zero. In a practical way this is difficult to realize with only one equipment and one demagnetizing cycle.

The first demagnetizing cycle is accomplished by passing a high (30 A) current through the center of the maser; this is usually sufficient.

If oscillation or a satisfactory threshold of oscillation is not achieved with this cycle, a second cycle may be applied by passing a lower (10 A) current through the center conductor.

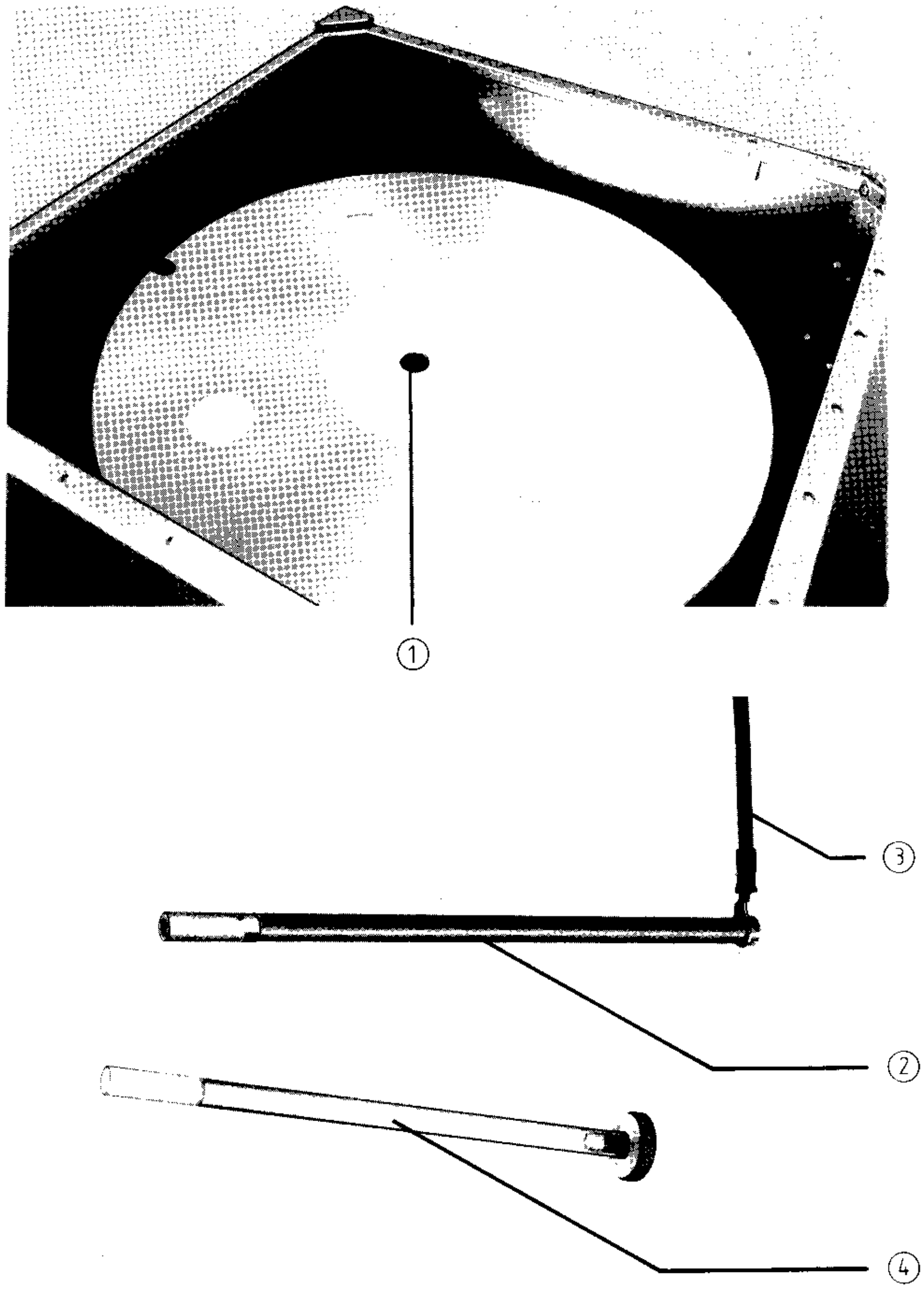
If oscillation is not obtained after this demagnetization consult troubleshooting guide in the maintenance manual. After oscillations are obtained proceed to threshold test § 3.9 (see low current cycle below).

- prepare the maser for connection of the demagnetizing system by removing the internal electrode cover (1), Fig. 3.5, and inserting the external demagnetizing electrode (2), Fig. 3.5, to engage the internal demagnetizing electrode. Travel of this engagement is about 20 mm. Connect this cable to the current transformer (3).
- connect the demagnetizing return cable (4), Fig. 3.5, to the maser at the tapped hole provided on the main frame of the maser (2), Fig. 2.1. Do not connect at this time to the current transformer.
- connect the demagnetizing equipment (1) to (3), Fig. 3.6, and before connecting to the AC line set the VARIAC (1) and the rheostat (2) to zero position. Then connect to the AC line.
- connect maser return cable (4) to the current transformer (3) and, with the VARIAC, rapidly increase the demagnetizing current to 30 amps, then decrease following the current-time profile illustrated in Fig. 3.6 until the demagnetizing current has been reduced to about 10% (3 A) - P A U S E
- increase the rheostat resistance slowly (about one minute) to maximum value 1 k Ω
- complete the VARIAC cycle to zero continuing the current time profile
- disconnect the demagnetizer cables (4), Fig. 3.6, before turning off the AC line

Low current cycle :

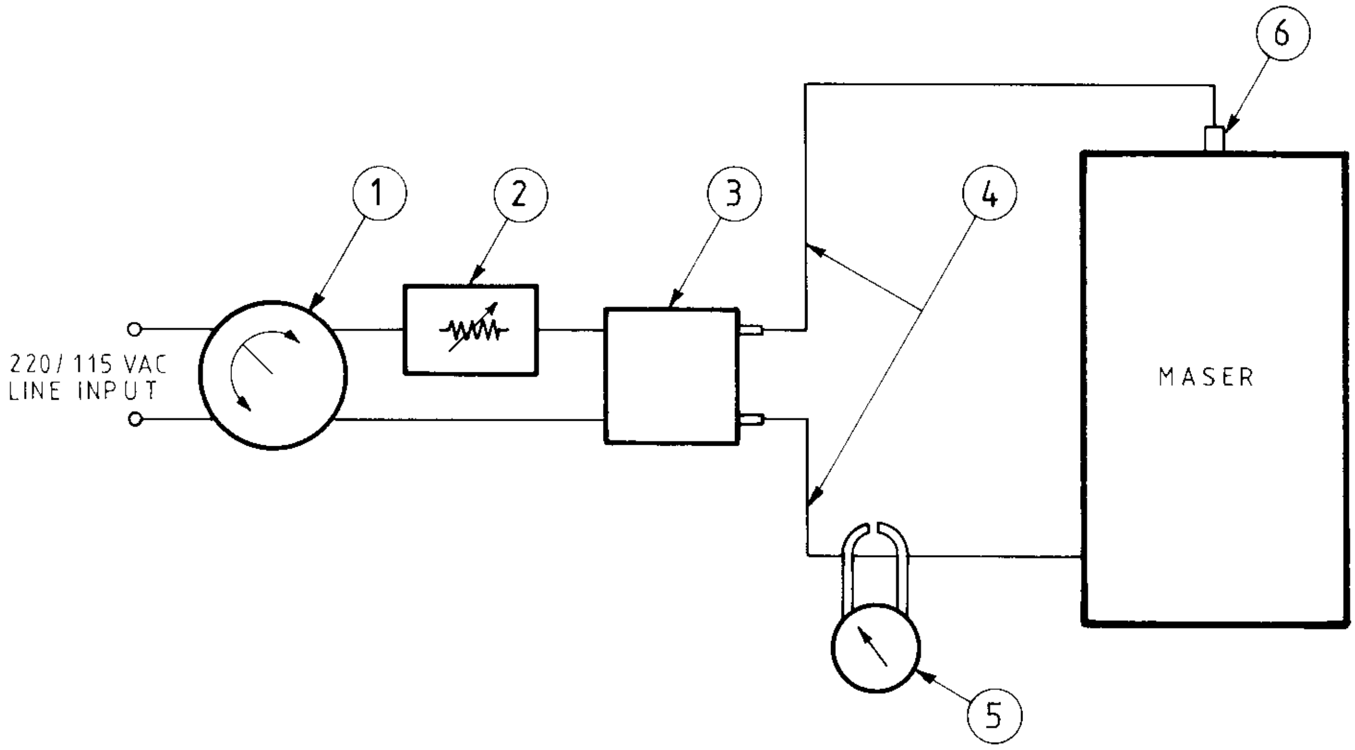
Procedure is the same as for the high current cycle except maximum current is 10 A instead of 30 A. At this time it is usually adviseable to make a low current - square-wave demagnetization cycle using the special apparatus (OSA Model 3098).

The model 3098 is substituted for the equipment (1), (2) and (3), Fig. 3.6, in these tests. See maintenance section for operating details of the Model 3098.



①	DEMAGNETIZING ELECTRODE (INTERNAL) ACCESS COVER
②	DEMAGNETIZER ELECTRODE (EXTERNAL)
③	CABLE TO DEMAGNETIZER
④	INSULATED PLUG

Fig. 3.5 : DEMAGNETIZER CONNECTIONS TO MASER



(1) INPUT LINE AUTOTRANSFORMER, VARIAC : 250 VA
(2) RHEOSTAT : 1 kΩ , 1A
(3) CURRENT TRANSFORMER OR ARC WELDER : 30 AMP
(4) CONNECTING CABLE ; 2 METERS, 6 mm^2 (10 AWG)
(5) 0-30 AMP CLIP-ON AMMETER
(6) DEMAGNETIZER ELECTRODE

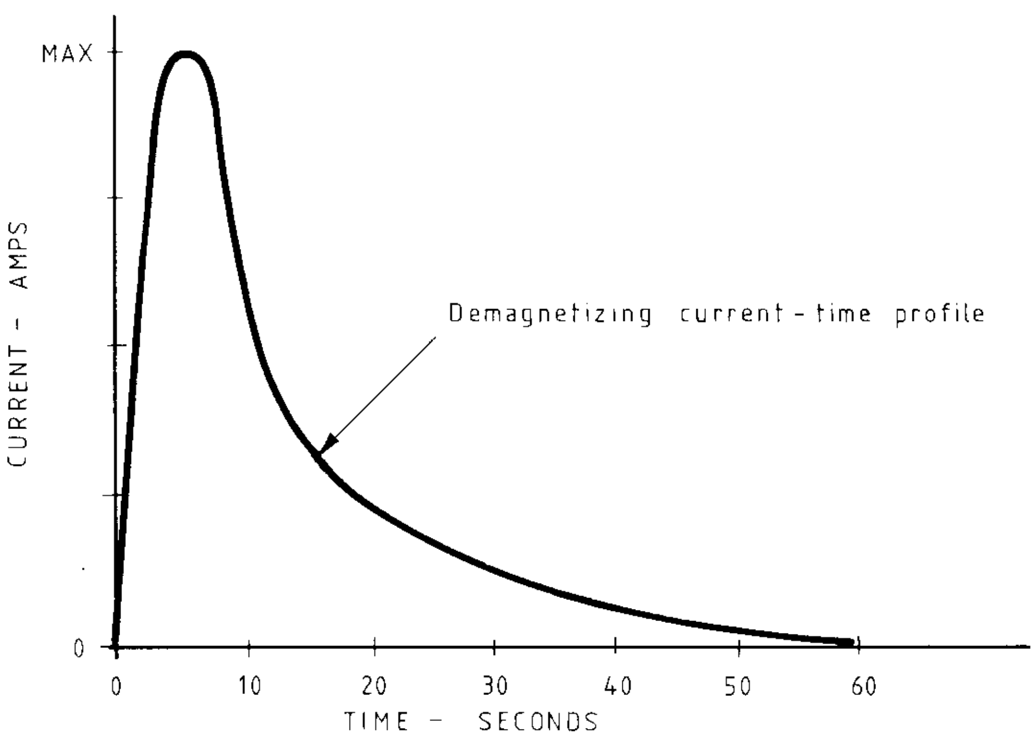


Fig. 3.6 : DEMAGNETIZING EQUIPMENT SET-UP

3.11 MASER OPERATING ADJUSTMENT

Only those parameters of the maser operation which can be accomplished by external access to the controls, and which can be monitored by the monitoring system of the maser are described here.

It should be borne in mind that the precision of measurement and the resolution provided by the external monitoring system are limited, thus the precision of establishing the desired operating point is limited.

Those adjustments requiring access to elements enclosed within the maser, and requiring more precise measurements are described in the maintenance and repair manual.

The following adjustments and measurements can be made on the operation of the maser (subject to the limitations noted above) :

1. Maser C-field current setting
2. Zeeman frequency
3. Dissociator pressure setting
4. Cavity tuning
5. Spin exchange tuning
6. Synthesizer frequency setting

3.11.1 Maser C-field current setting

The C-field current setting potentiometer is accessible from the control panel of the maser (15) , Fig. 1.3.

A C-field current analog is available at the SMA connector adjacent to the potentiometer (14) , Fig. 1.3.

This analog output is provided by a buffer amplifier having a scale factor of 20 mV per 1 μA of C-field current. Thus full scale output voltage is 5V for the C-field current maximum of 250 μA. One digital unit or the external monitor readout is 2 μA (Table 3.1). The control panel analog output is recommended for any precise setting of C-field current.

Proceed as follows :

- connect a high impedance DC voltmeter to the coaxial connector adjacent to the C-field pot
- adjust the potentiometer to the desired value of current allowing for the analog conversion factor (20 mV/ μ A)
- the nominal operating current is 50 μ A giving a C-field of 410 μ Oersteds

3.11.2 Zeeman frequency measurement

The Zeeman frequency is a precise measure of the average magnetic field within the active volume of the maser cavity. This measurement is made by slowly sweeping through the Zeeman frequency and observing the maser output signal. The maser output signal will decrease when the interrogating signal corresponds to the Zeeman freuqency, and may even stop oscillating if the interrogation is very strong.

The line width of the Zeeman response is in the order of one Hz, so sweep rate must be sufficiently slow for monitoring system detection. To facilitate measurement of maser receiver output signal, an analog DC voltage is available at the coaxial connector, 5.7 kHz (11) , Fig. 1.3. Response is more easily seen, is more rapid, and has greater resolution then the digital readout on the monitor receiver.

Proceed as follows :

- determine the expected Zeeman frequency from formulas given in Fig. 3.7.

  For example, for

  C-field current : 50 μ A;
  H : 8.2 μ Oe x 50 μ A = 410 μ Oe
  F_{Zeeman} : 1.4 Hz x 410 μ Oe = 574 Hz

- connect a H.P 3325A synthesizer to the control panel (Zeeman) connector (5) , Fig. 1.3
- set output level on synthesizer to 1 VRMS
- set synthesizer frequency to value calculated from C-field current

- connect a high impedance voltmeter to 5.7 kHz receiver output coax (11) , Fig. 1.3

- manually sweep the synthesizer frequency until maser stops oscillating. This must be done slowly because of the response time of the maser output
(sweep using the 0.1 Hz frequency varation available on the synthesizer)

- reduce the synthesizer output and continue to sweep the frequency until the maser has a small dip in signal level (4) , in Fig. 3.7, at the Zeeman frequency

- stop the synthesizer sweep at minimum signal output and record frequency (Zeeman)

3.11.3 <u>Dissociator pressure setting</u>

The flux of hydrogen atoms leaving the dissociator and eventually arriving within the microwave cavity (via the state-selecting system) is dependent upon the hydrogen pressure within the dissociator (fig. 3.8). The nominal pressure range used in the EFOS 2 maser is 0.1 to 0.5 Torr. and is established on the basis of the maser output signal. Thus, the absolute dissociator pressure is not as important as is the operating characteristics of the maser.

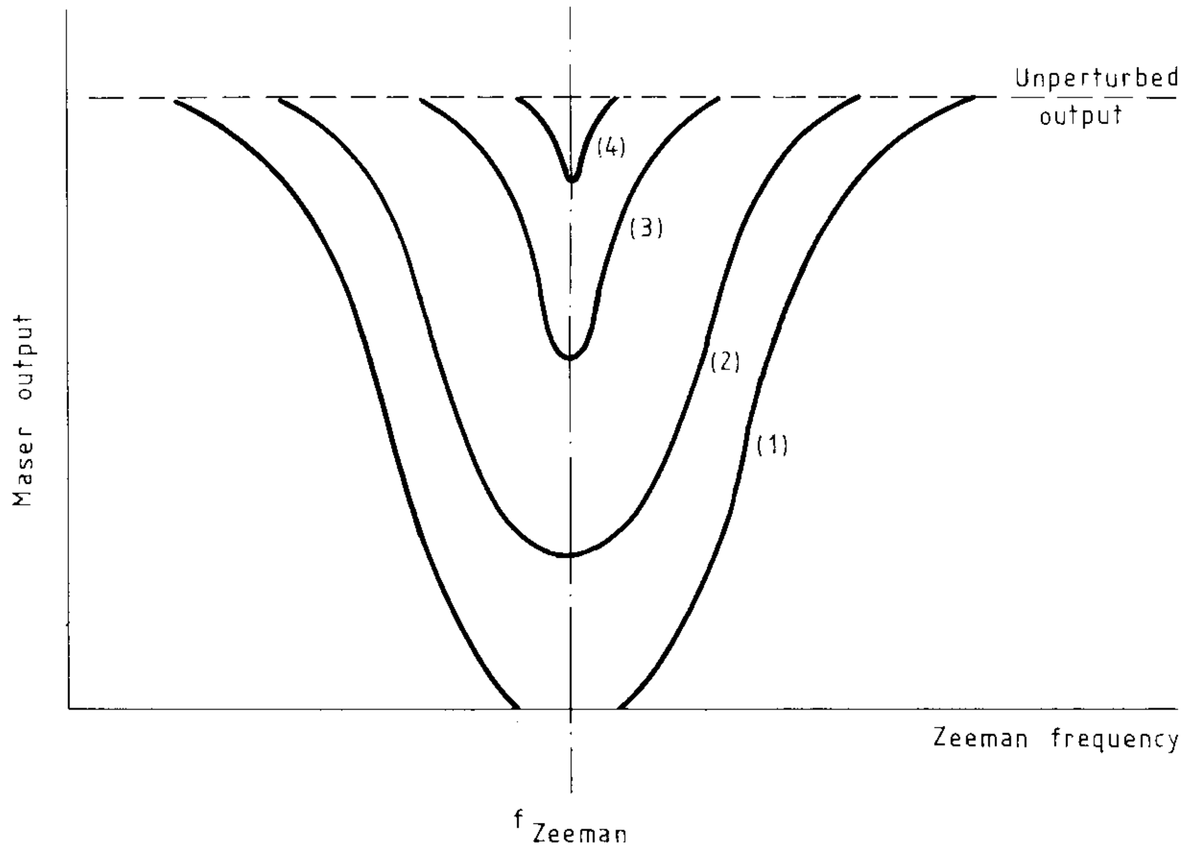
- set C-field to 50 μA reference value before the following steps are undertaken

- set monitor "ADDRESS" to 06 - <u>H-PRESSURE CONTROL</u> and set 7 volts (70 digital units) by adjusting the pressure control potentiometer (7) , Fig. 1.3. Turning the potentiometer clockwise increases pressure

- connect a high impedance DC voltmeter (10 V F.S.) to the coaxial connector (8) , Fig. 1.3 adjacent to the pressure control (7) . This voltage corresponds to the pressure at the Pirani gage Fig. 3.8 and will normally be slightly different (< 0.5 V) from the pressure control setting

- set monitor "ADDRESS" to 22 - AMPL 5.7 kHz

- adjust pressure setting pot. (7) until 4 volts (40 $\pm$ 2 digital units) is obtained on the monitor.



C-FIELD CALIBRATION :

H = 8.2 µOersted / µ A

F_{Zeeman} = 1.4 Hz / µ Oersted

VOLTAGE READING ON H-P 3325A SYNTHESIZER :

(1) = 1 VRMS

.

.

(4) = 0.2 VRMS
(approx. depending on Zeeman frequency)

Fig. 3.7 : C-FIELD CALIBRATION

(Zeeman frequency measurement)

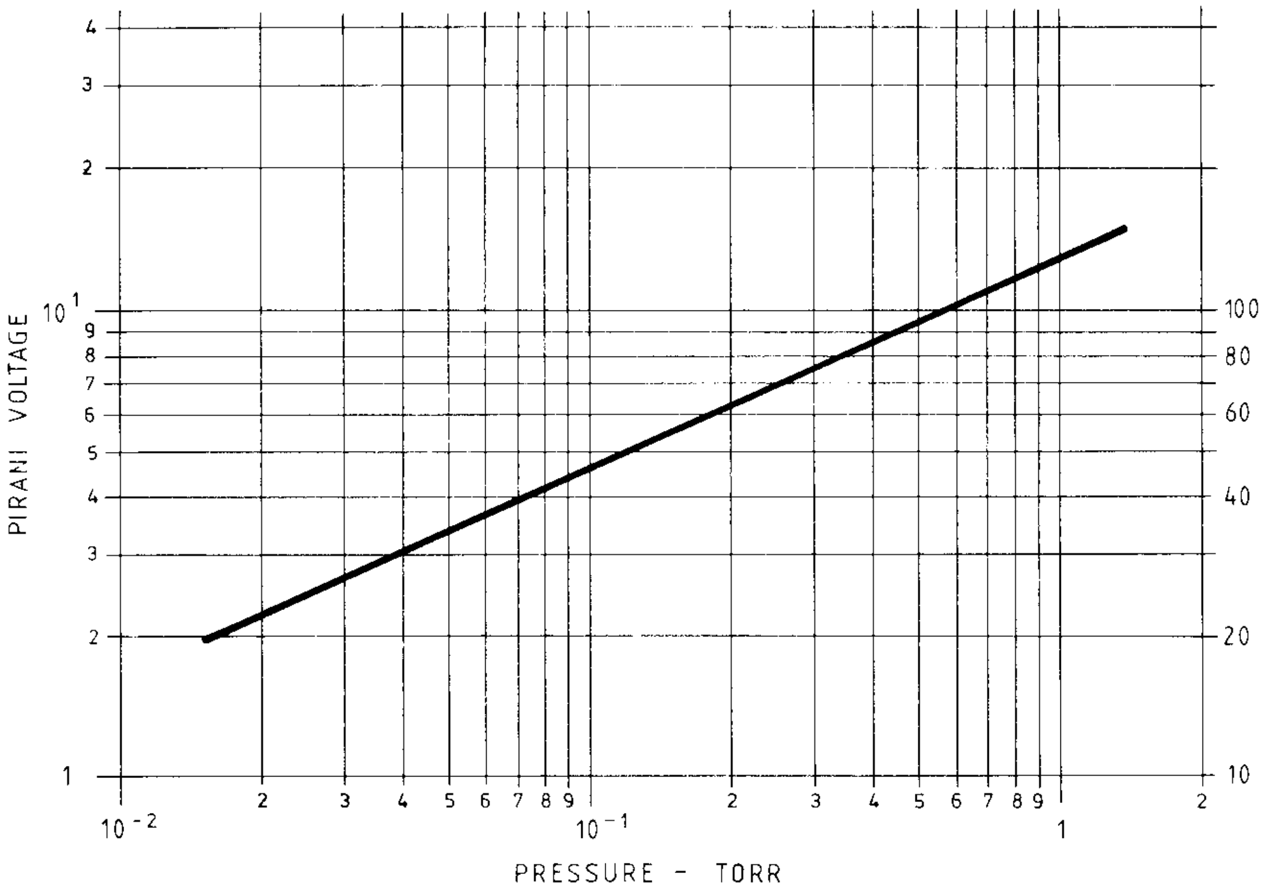


Fig. 3.8 : PIRANI PRESSURE-VOLTAGE CHARACTERISTICS

NOTE

> Rate of pressure increase or decrease depends upon the pumping speed through the hydrogen supply system, and the pressure regulating characteristics of the Palladium valve.
>
> It is necessary to wait several minutes for the pressure to stabilize in the discharge.

The internal vacuum pump current depends upon the dissociator pressure and will be between 0.3 mA and 1.5 mA.

3.11.4 Cavity tuning

The output frequency characteristics of the maser is directly influenced by the cavity tuning. The cavity tuning can be changed by means of

1 - the voltage applied to a varactor in the cavity

2 - the temperature of the cavity

3 - mechanical change of cavity dimensions

Method 1
is covered in this manual

Method 2

requires internal access to temperature control circuits and is covered in the maintenance manual

Method 3

requires a dismantling of the maser physical package, and is not practical without special equipment

The precise coefficients of cavity tuning on output frequency are discussed in detail in the section on theory of operation in the maintenance and repair manual

The cavity varactor voltage is accessible at the coaxial connector (12), Fig. 1.3, on the maser control panel. Voltage range is 10 V and may be measured by a high impedance DC voltmeter.

- varactor voltage is adjusted by means of the potentiometer CAV VAR (13) , Fig. 1.3

The varactor frequency voltage characteristics are shown in Fig. 3.9.

3.11.5 Cavity spin-exchange tuning

The operating point for cavity tuning is determined on the basis of spin-exchange (§ 4.8.11).

For these measurements a stable frequency reference is required : either another hydrogen maser or a quartz oscillator having a frequency drift $<1 \times 10^{-11}$ per day $< 1 \times 10^{-14}$ in a 10 minute interval

The measurement technique consists of determining the frequency change of the maser as a function of cavity frequency for at least two different values of atom density in the cavity.

.1 set up the equipment according to Fig. 3.10 for maser frequency measurement

.2 set cavity varactor voltage to 1 V, (12) Fig. 1.3, § 3.11.4

determine cavity frequency (fcl) from Fig. 3.9 and record V1, fcl (Fig. 3.11)

.3 set dissociator pressure to 7 volts (typical) (§ 3.11.3) and record P1, Fig. 3.11

.4 record maser frequency by obtaining an average of 3-5 measures using 100 sec intervals after the frequency is stabilized (fml), Fig. 3.11

.5 set dissociator pressure to 8 volts (typical) and record P2, Fig. 3.11

.6 measure maser frequency and record fm2, Fig. 3.11

.7 set varactor voltage to 6 volts and record V2, fc2, Fig. 3.11

.8 measure maser frequency and record fm4, Fig. 3.11

.9 set dissociator pressure to 7 volts and record P1, Fig. 3.11

.10 measure frequency and record fm3, Fig. 3.11

.11 from the recorded data plot Δfm1 and Δfm2 for corresponding cavity frequencies fc1 and fc2. Where the line connecting the two points crosses the Δfm axis at zero determines the spin exchange cavity tuning point, fco.

.12 from the cavity varactor tuning curve and the fco (.11) determine the varactor tuning voltage. Set this voltage on the cavity varactor (§ 3.11.4)

3.11.6 Phase lock-loop synthesizer setting

The maser 5 MHz output frequency may be changed from its nominal value by changing the counter ratio in the PLL synthesizer. The range of frequency adjustment is from about $+1.4 \times 10^{-9}$ to -3.3×10^{-9} parts. See Fig. 3.12 for the detailed frequency setting information.

3.11.7 Receiver

No operational adjustments can be made on the maser receiver. A plot of the 5.7 kHz amplitude as a function of maser output power is included in the maser lock-loop (a typical plot is shown in Fig. 3.13).

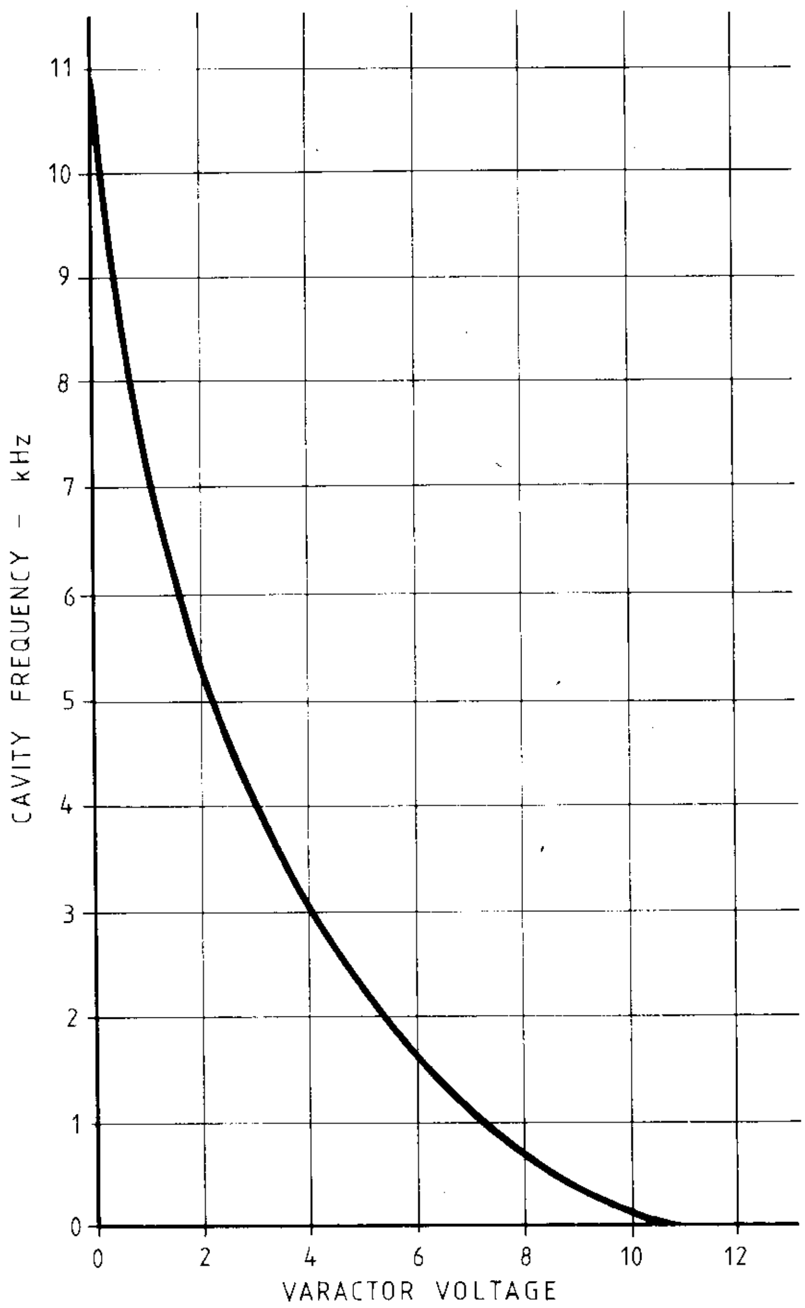


Fig. 3.9 : CAVITY VARACTOR TUNING

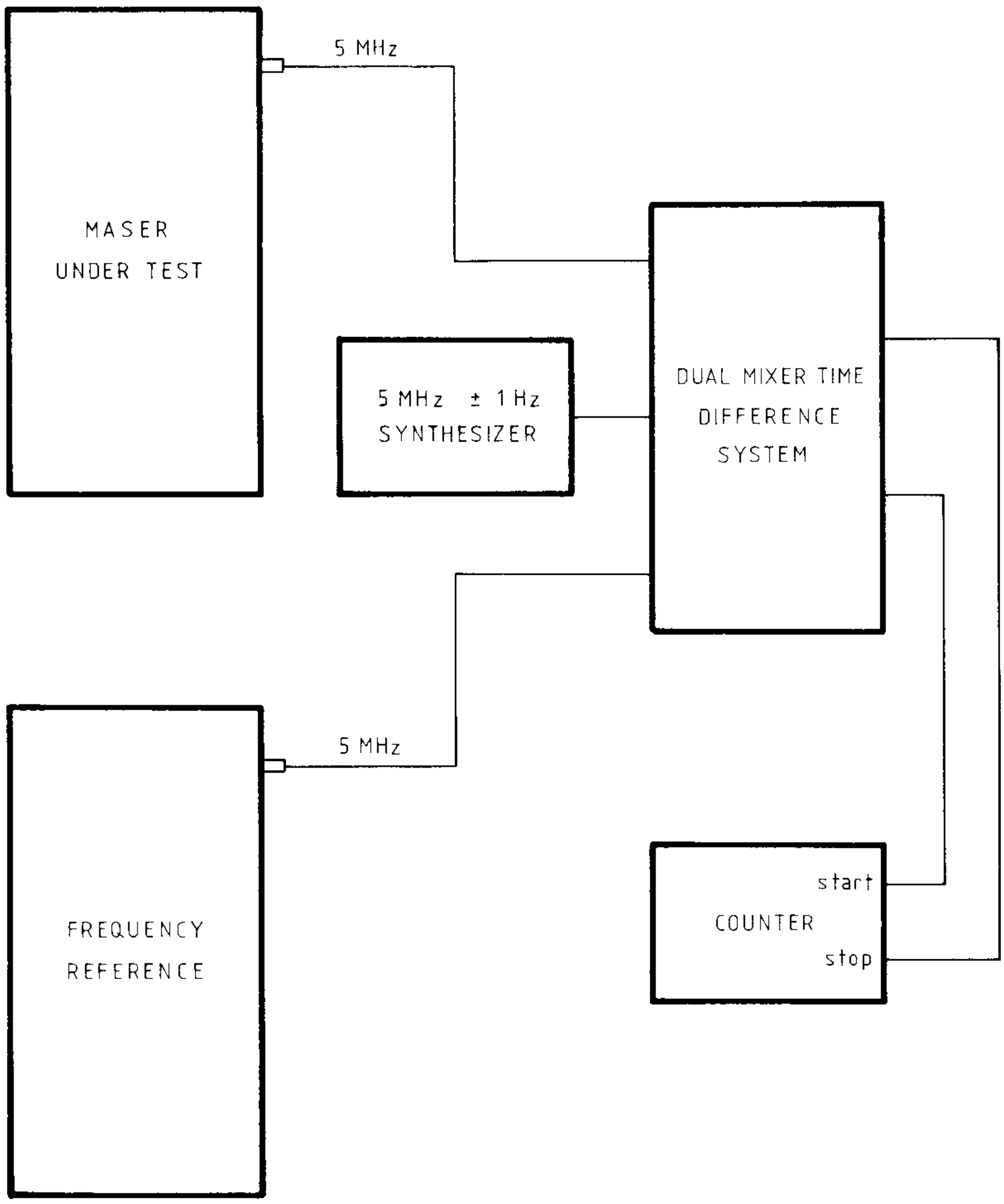


Fig. 3.10 : FREQUENCY MEASURING SET-UP FOR SPIN - EXCHANGE TUNING

PARAGR.	VARAC. VOLT.	CAVITY FREQ.	DISSOC. PRESS.	MASER FREQ.	ΔF MASER
3.11.5.2 .3	V1	fc1	P1	fm1	Δ fm1
....5 .6	V1	fc1	P2	fm2	
....9 .10	V2	fc2	P1	fm3	Δ fm2
....5 .7 .8	V2	fc2	P2	fm4	

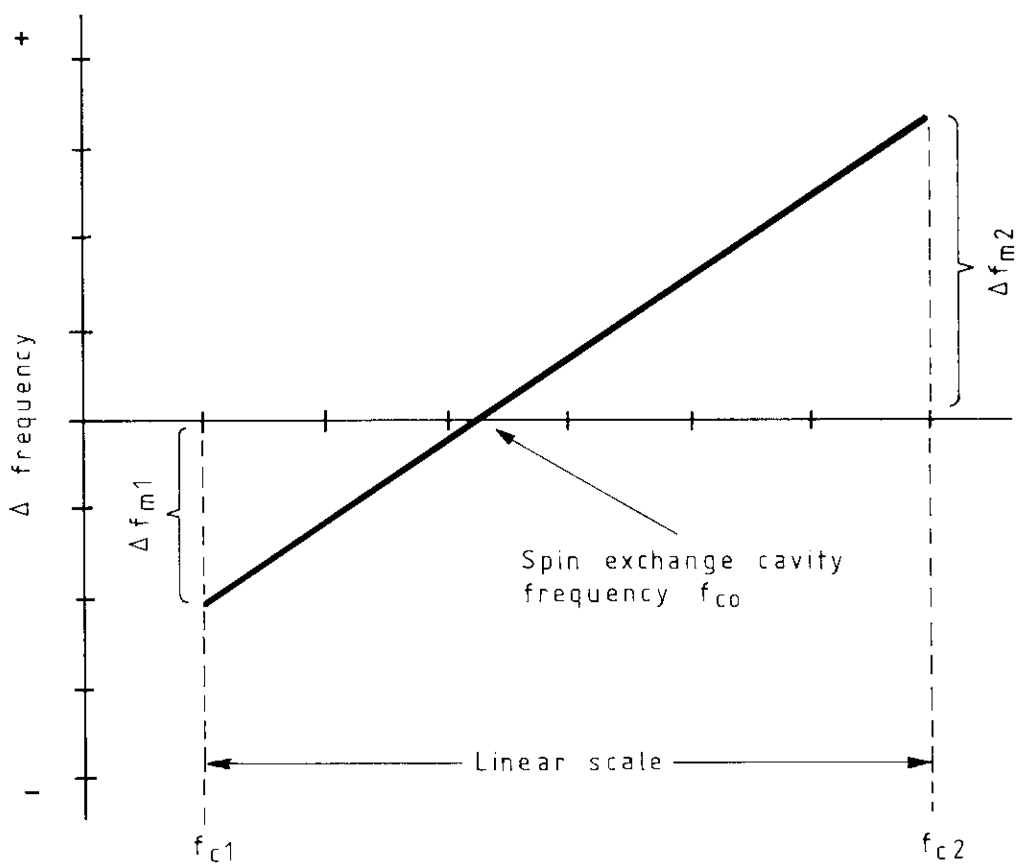
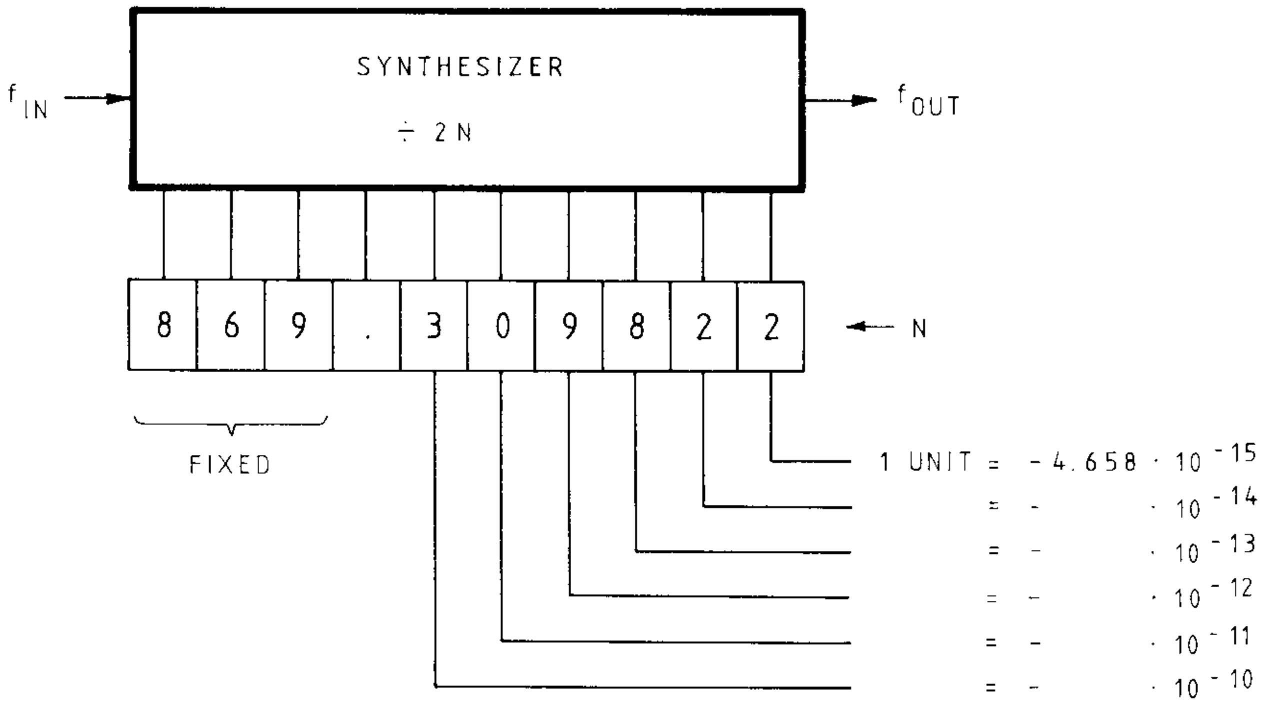


Fig. 3.11 : SPIN-EXCHANGE TUNING



Synthesizer $f_{out} = \frac{fin}{2N}$

$$\Delta f_{out} = \frac{fin}{2N^2} \times \Delta N \text{ (for small } \Delta N)$$

$$\frac{\Delta f_{out}}{f_H} = \frac{fin}{2N^2\, f_H} \times \Delta N$$

f_H = hydrogen maser frequency = 1420405751, 6893 Hz

f_{IN} = 10^7 Hz

N = 869.309822

ΔN = 10^{-6} (last digit)

$\frac{\Delta f}{f_H}$ = -4.658×10^{-15} for one unit in last digit

Fig. 3.12 : SYNTHESIZER DIGITAL SWITCH SETTING

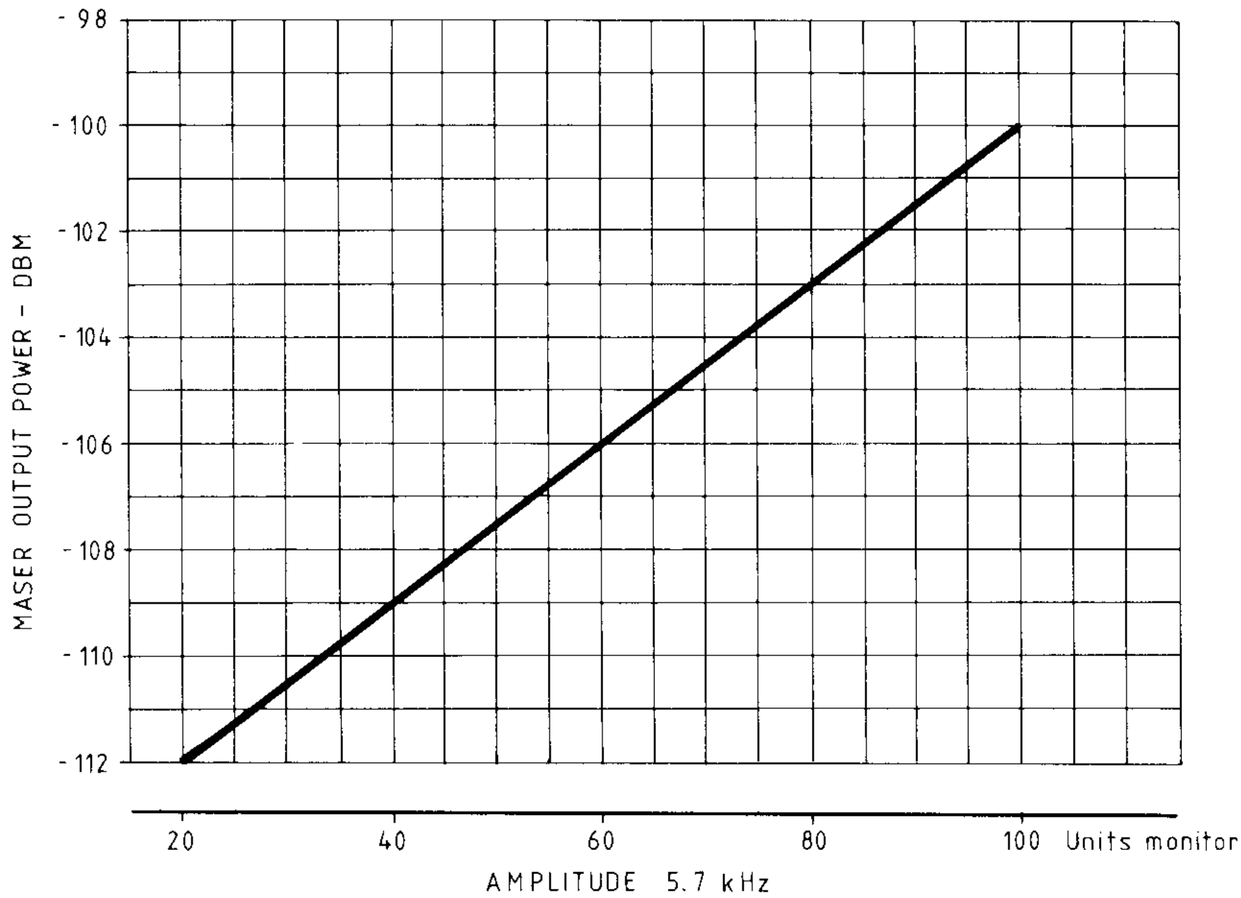


Fig. 3.13 : 5.7 kHz AMPLITUDE VS MASER OUTPUT POWER

(typical)