

HYDROGEN MASER FREQUENCY
STANDARD
EFOS 6,7,8
OPERATORS MANUAL

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OSCILOQUARTZ SA



OSA

LJ/IM/MSC
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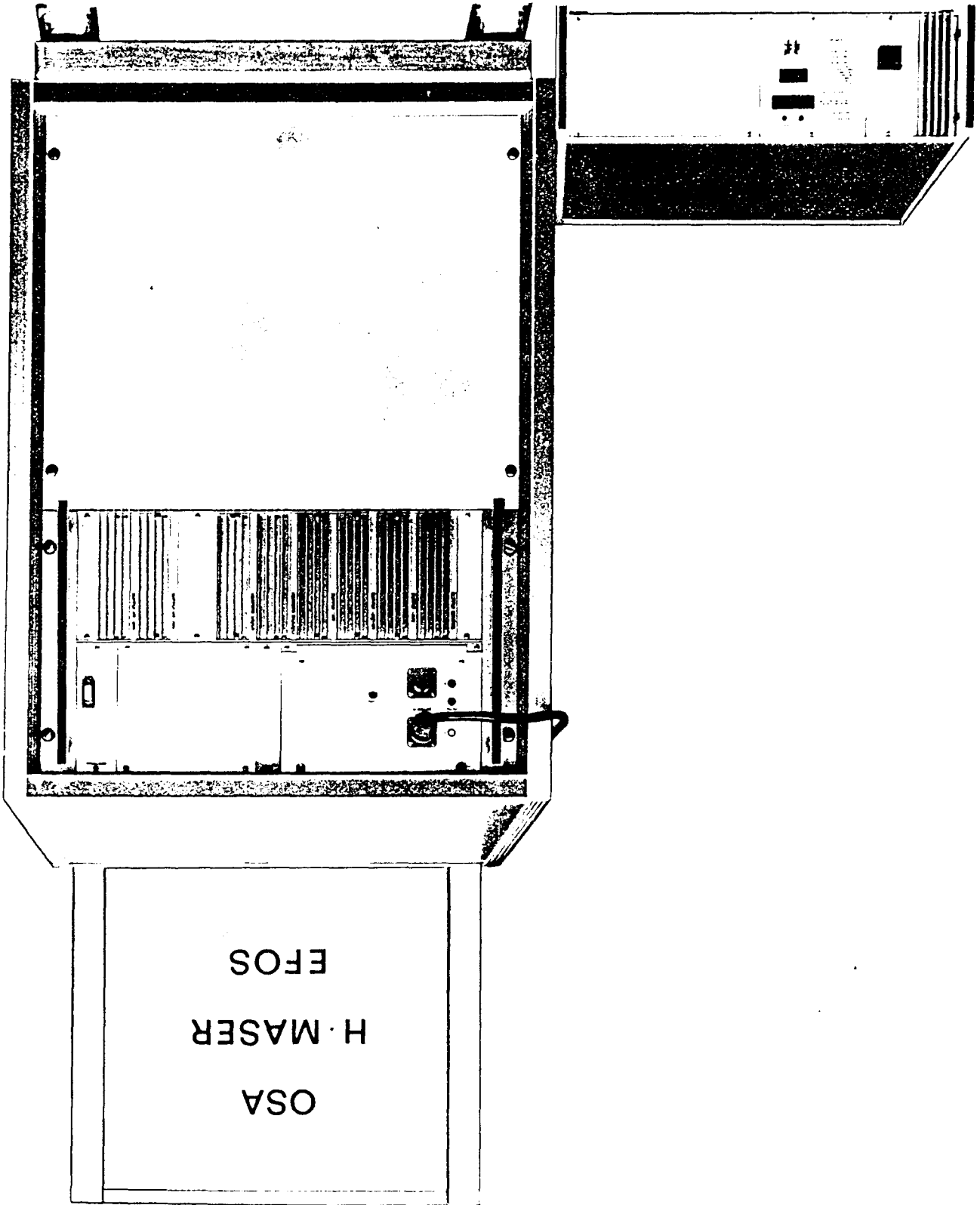
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EFOS HYDROGEN MASER AND MONITORING RECEIVER



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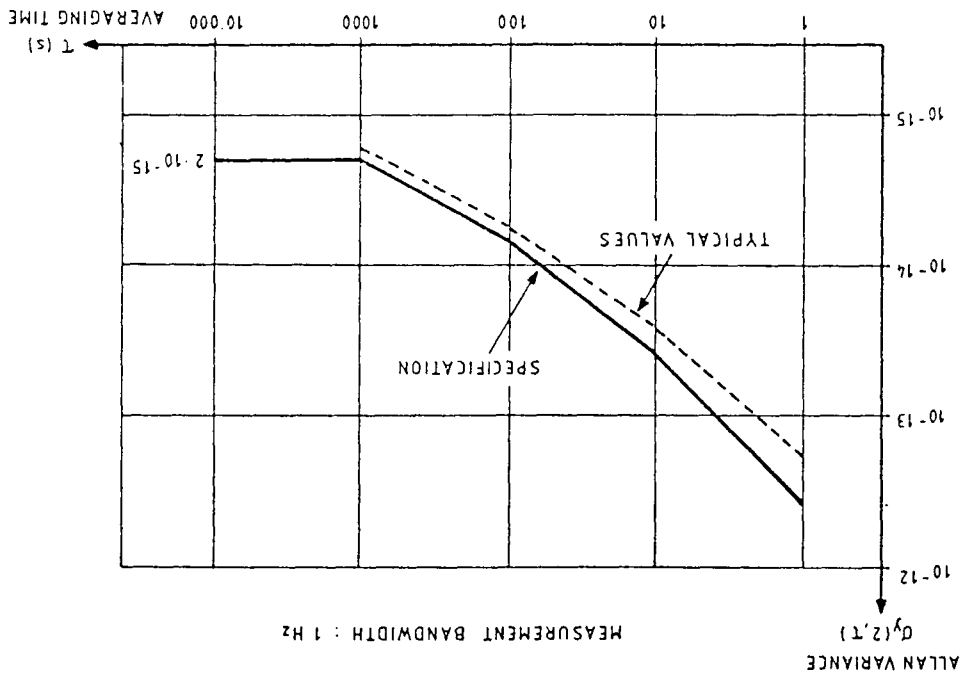
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T A B L E S

1. DESCRIPTION

TYPICAL FREQUENCY STABILITY

(see figure)



TEMPERATURE EFFECTS

$\frac{\Delta f}{f}$ per °C

: typical 3×10^{-14} /1°C,
max. 5×10^{-14} /1°C

between +20 to +30°C
: maser frequency fractional change for 1°
ambient temperature stop measured after ~
24 h.

Maser cavity time constant ~ 10 h.

MAGNETIC FIELD EFFECTS

Magnetic shielding

: minimum operating
magnetic c-field
: $\leq 100 \mu$ Oersted
 $\frac{\Delta f}{f}$ per Oersted
: $< 2 \times 10^{-13}$ /Oersted
at the nominal
operating c-field

PRESSURE EFFECTS

: $< 4 \times 10^{-16}$ /mm Hg

OUTPUT SIGNALSStandard

: two 5 MHz outputs locked to H-maser
1 VRMS in 50 Ω

Optional

: 100 MHz, 1 pps

MASER PHYSICAL CHARACTERISTICSline Q

: $> 2 \times 10^9$

Output power

: -105 dBm nominal

Loaded cavity Q

: 35'000

Cavity pulling factor

: $\approx 1.25 \times 10^{-5}$

Cavity tuning

: by temperature and varactor

cavity temperature

: -32.5 KHz/1°C
coefficient

Varactor tuning

range
: ≈ 10 KHz

OVERALL CHARACTERISTICS

Size

: 550 x 940 x 1250

Weight

: 225 kg

Power consumption

: max. 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 Oscilloquartz 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 DC 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 DC input indicated presence of DC input. Independence of the DC inputs enables servicing the separate supplies without interruption maser operation, DC negative is connected to chassis ground of the maser. If the DC input goes below 19 volts on either input (or both), a red alarm light illuminates, ③ fig. 1.2. The alarm indication must be re-set by the operator by means of a control panel re-set button, fig. 1.3.

FIG. 1.1. : EFOS HYDROGEN MASER

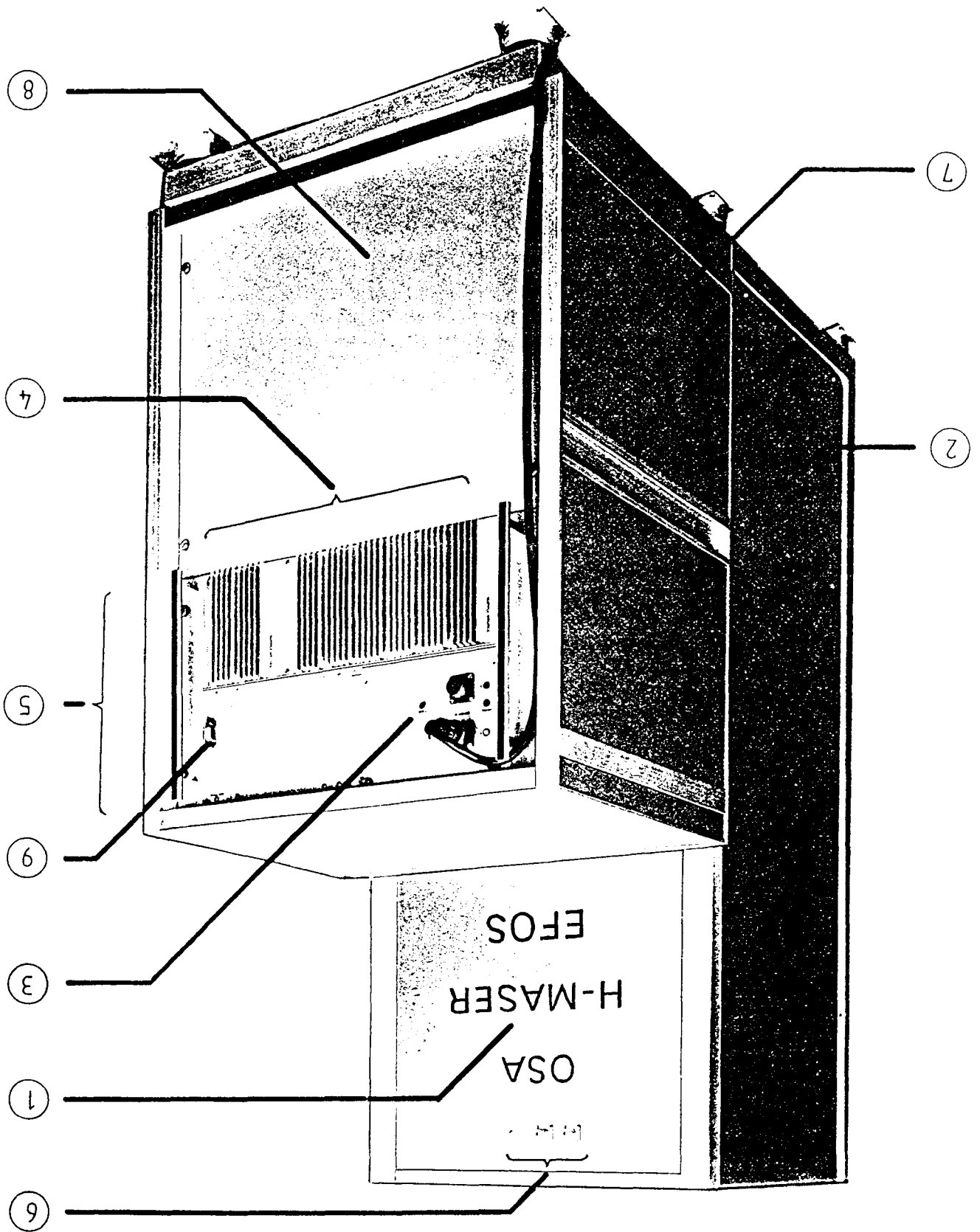
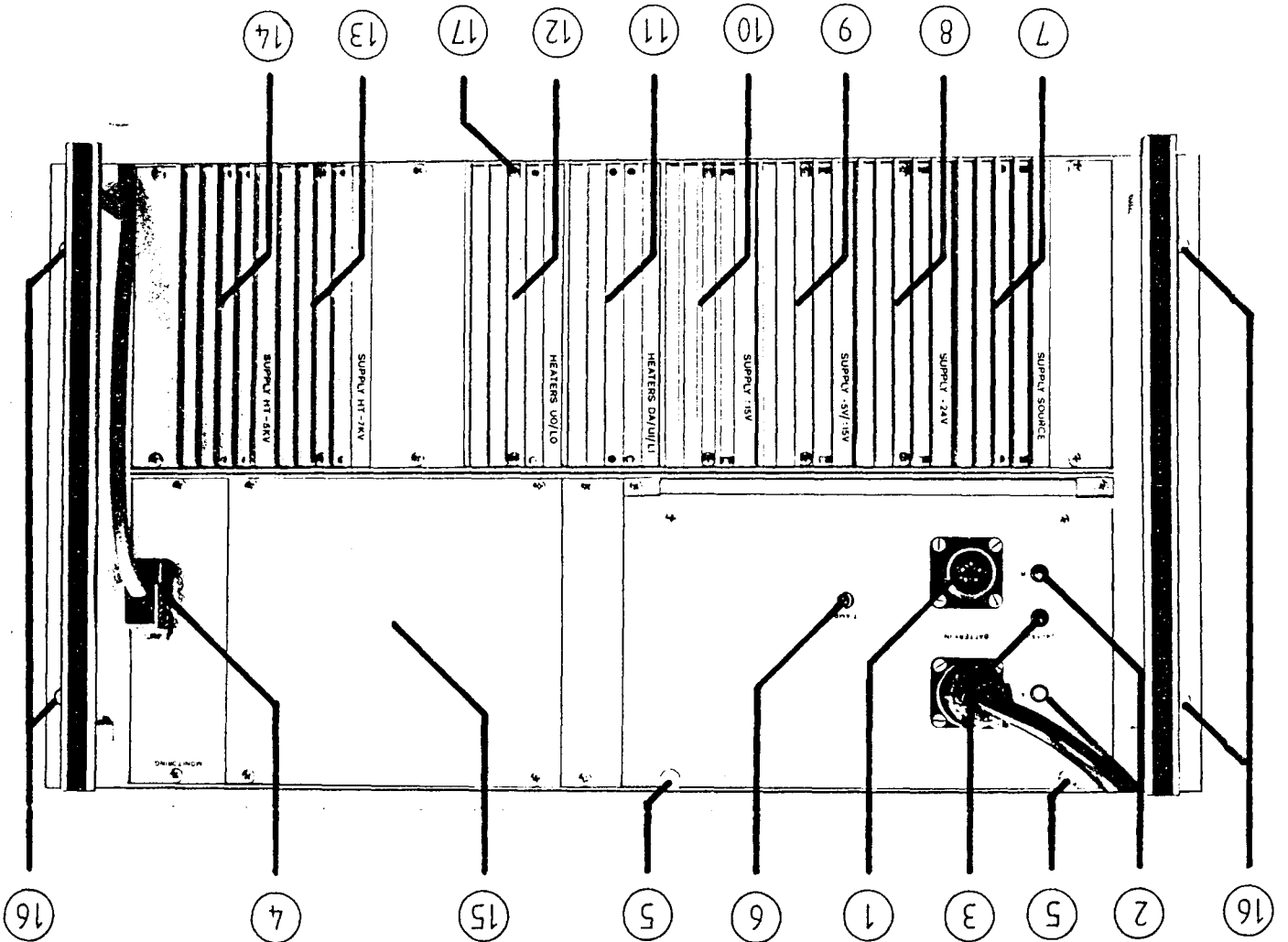


FIG. 1.1. : EFOS HYDROGEN MASER (CONTINUED)

- ① MASER PHYSICS COMPARTMENT
- ② VACUUM MANIFOLD COMPARTMENT
- ③ FRONT PANEL
- ④ POWER SUPPLY MODULES
- ⑤ ELECTRONICS / CONTROL UNIT
- ⑥ RF OUTPUTS
- ⑦ VACUUM PUMP COMPARTMENT
- ⑧ DEMAGNETIZER RETURN CONNECTION ACCESS PANEL
- ⑨ MONITORING CONNECTOR

FIG. 1.2. : FRONT VIEW ELECTRONICS AND CONTROL UNIT

- ① INPUT POWER CONNECTORS (see fig. 1.6. for connections)
- ② POWER ON SIGNAL LIGHTS
- ③ INPUT POWER ALARM LIGHT
- ④ MONITORING CONNECTOR (see fig. 1.6. for connections)
- ⑤ FRONT PANEL RETAINING THUMB SCREWS
- ⑥ AMBIANT TEMPERATURE PROBE CONNECTOR (see fig. 1.6. for connections)
- ⑦ 24 V DISSOCIATOR POWER SUPPLY



- ⑧ 24 V REGULATED POWER SUPPLY
- ⑨ 5 V, $\pm$ 15 VOLT POWER SUPPLY
- ⑩ $\pm$ 15 VOLT POWER SUPPLY
- ⑪ HEATER POWER AMPLIFIERS DA/UI/LI
- ⑫ HEATER POWER AMPLIFIERS UO/LO
- ⑬ ION PUMP H.V. POWER SUPPLY - 7 KV
- ⑭ ION PUMP H.V. POWER SUPPLY - 5 KV
- ⑮ OPTIONAL EQUIPMENT COMPARTMENT
- ⑯ CONTROL UNIT MOUNTING SCREWS
- ⑰ POWER SUPPLY RETAINING SCREWS

FIG. 1.2. : FRONT VIEW ELECTRONICS AND CONTROL UNIT (CONTINUED)

1.2.2. Outputs

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 the use of this coil and it is only provided for special tests not covered in this manual.

c) Neck coil

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

b) Zeeman coil

1.0 VRMS in 50 Ω . These 5 MHz outputs are derived directly from the 5 MHz oscillator of the receiver phase lock loop. Since the oscillator is phase locked to the maser receiver signal, these outputs include the temperature-dependent phase fluctuations of the multiplier chain/buffer amplifier.

b) 100 MHz output

This output is derived from the receiver frequency multiplier chain and does not include the temperature-dependent phase fluctuations of the multiplier/buffer amplifier. Output level : ± 2 dbm, 5 MHz harmonics ≤ -40 dbc.

c) 1440 MHz output

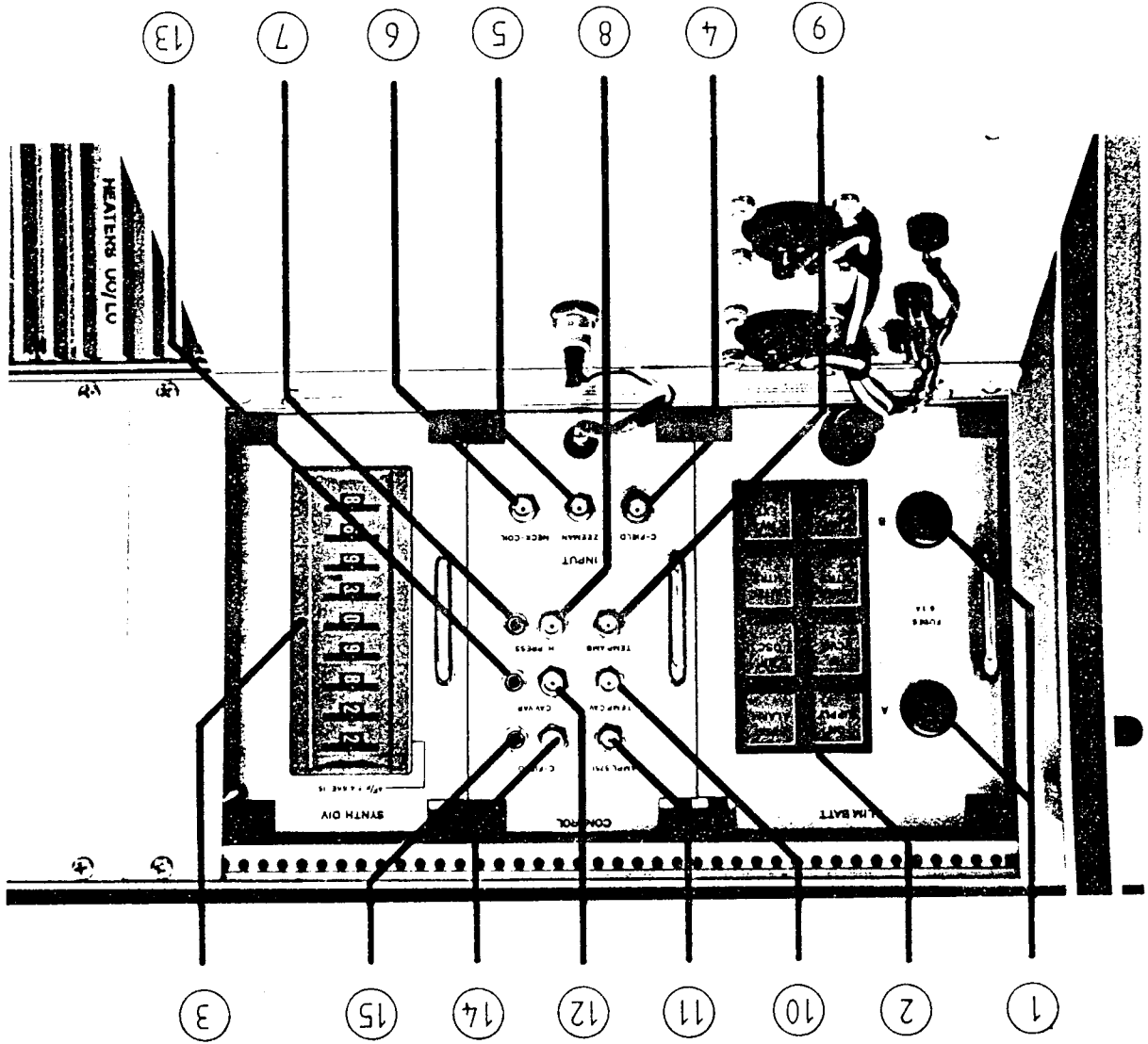
This output is derived from the receiver L.O. signal. This frequency is directly stabilized by the maser, and thus does not exhibit the temperature sensitivity of the frequency multiplier chain (phase fluctuations). Output level : ± 0 dbm (5 mw typ.), 5 MHz harmonics ≤ -20 dbc. Its primary function is to check L.O. power level when evaluating receiver performance.

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. The most important maser parameters are available as analog signals on the control panel, fig. 1.3.

FIG. 1.3. : CONTROL PANEL



① DC INPUT FUSES (6.3 A slow blow, 5x20 mm)

② POWER CONTROL SWITCHES SEE FIG. 1.3.1.

③ SYNTHESIZER DIGITAL SWITCH

④ C-FIELD WINDING (SMA)

⑤ INPUT TO ZEEMAN INTERROGATION 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 (CONTINUED)

FIG. 1.3.1. : POWER CONTROL SWITCHES

INT HV	INNER HTRS	HF RCVR	ON SUPPLY
EXT HV	OUTER HTRS	RF OSC	RESET ALARM

FIG. 1.4. : MONITOR DISPLAY RECEIVER FRONT PANEL

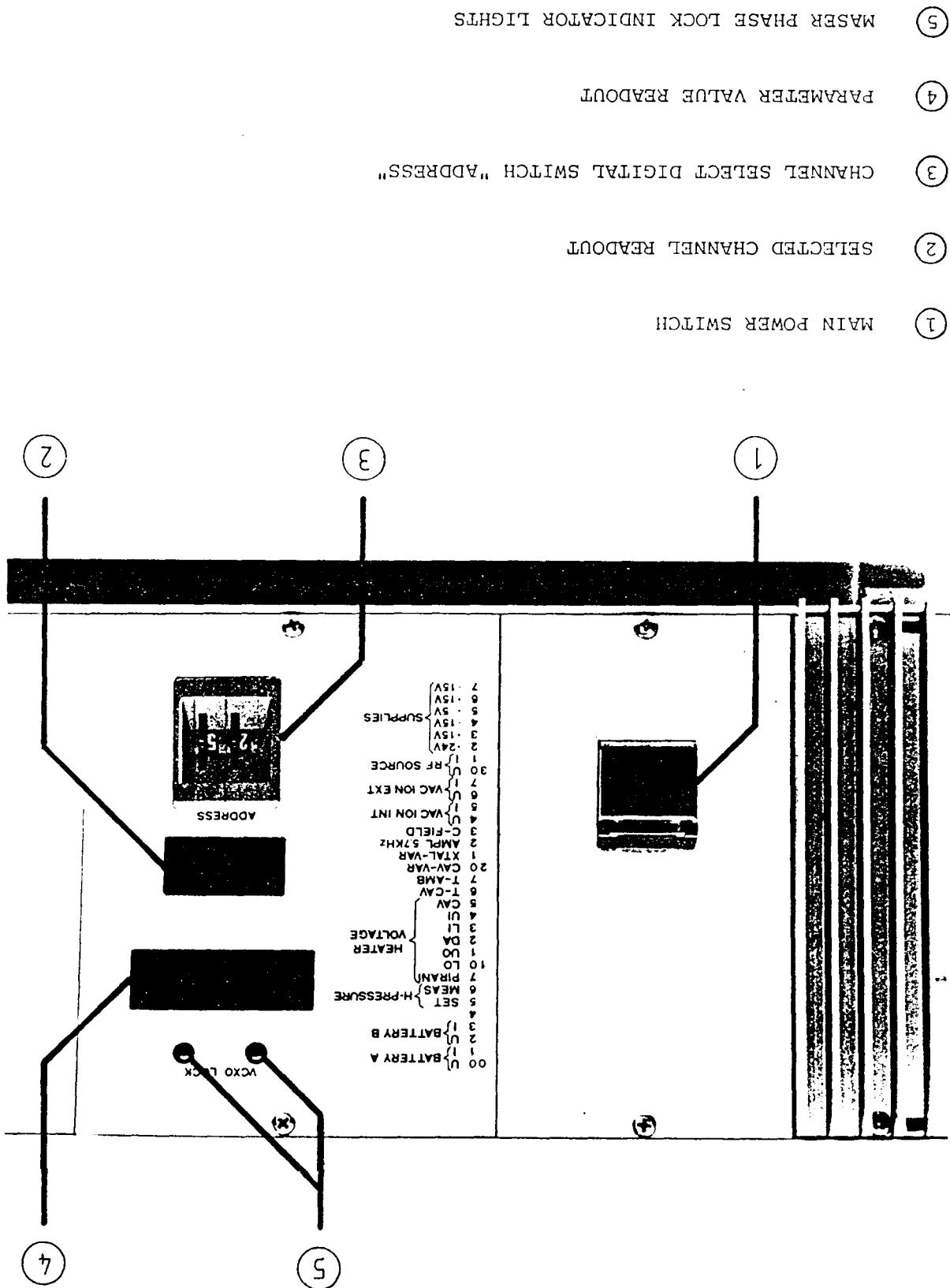


FIG. 1.5. : MONITOR DISPLAY RECEIVER REAR PANEL

- 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
AC SUPPLY FUSE 220 V OPERATION 350 mA 5x20 mm
115 V OPERATION 630 mA 5x20 mm
- ④ DC SUPPLY FUSE (1.2 A, 5x10 mm)
- ⑤ DC INPUT POWER CONNECTOR (see fig. 1.6. for connections)
- ⑥ ANALOG DC OUTPUT (BNC)

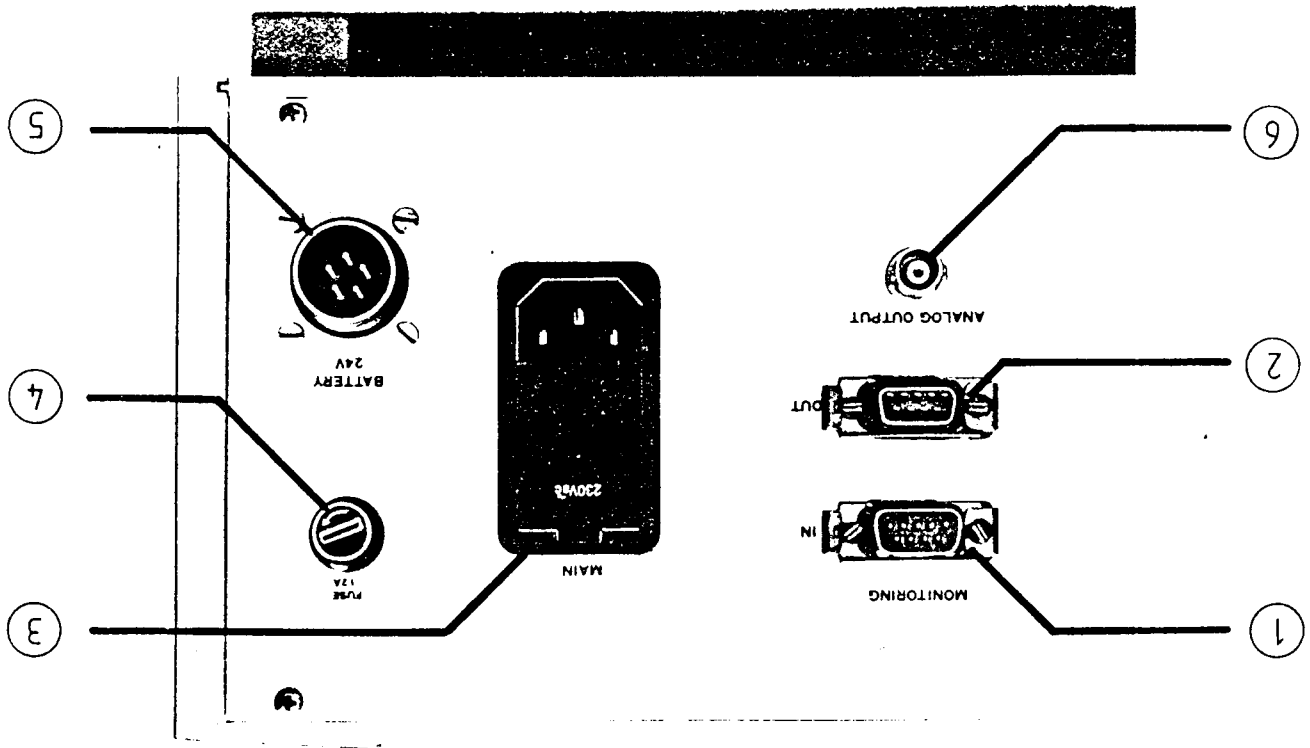
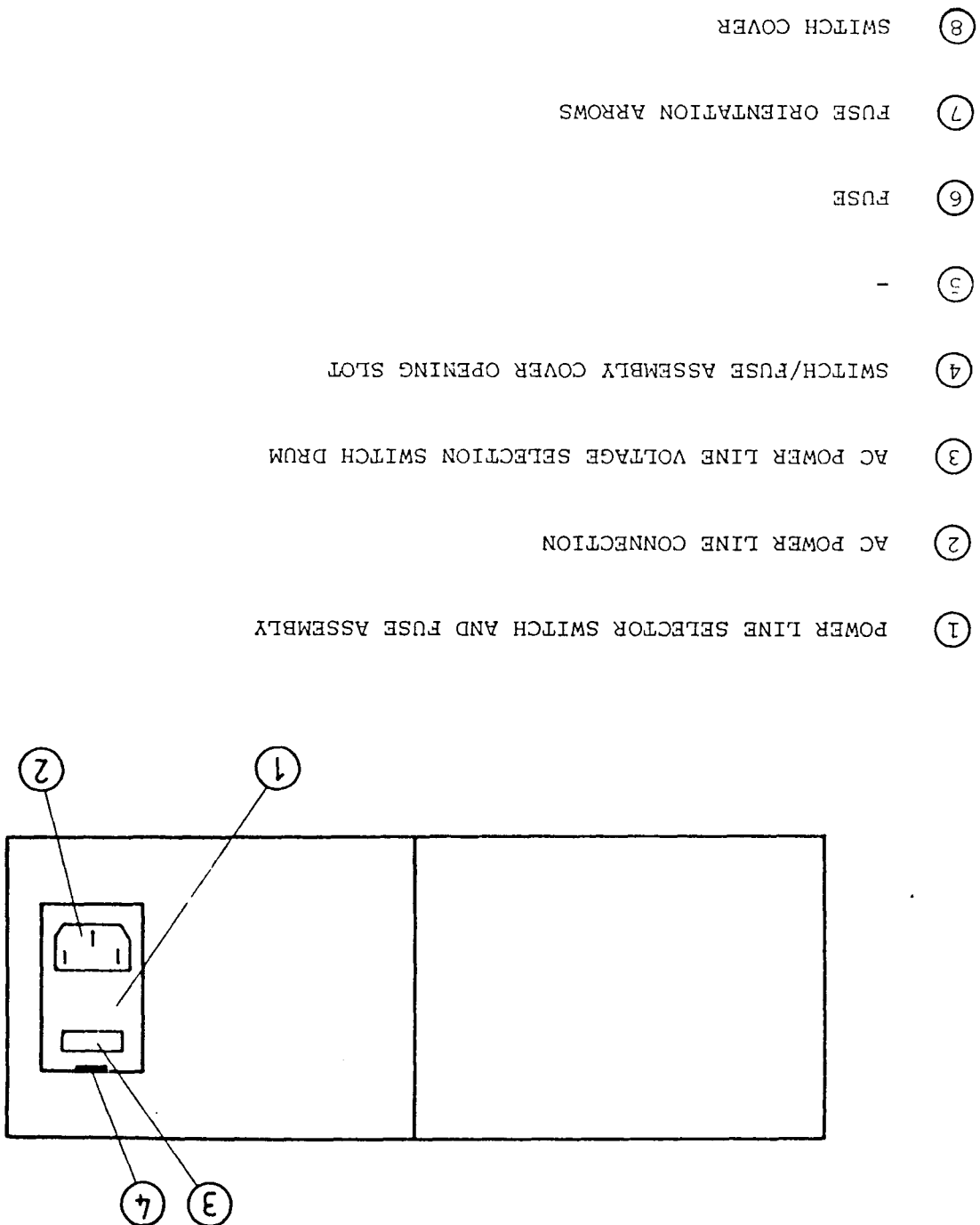


FIG. 1.5.1 : AC POWER CONNECTOR DETAIL



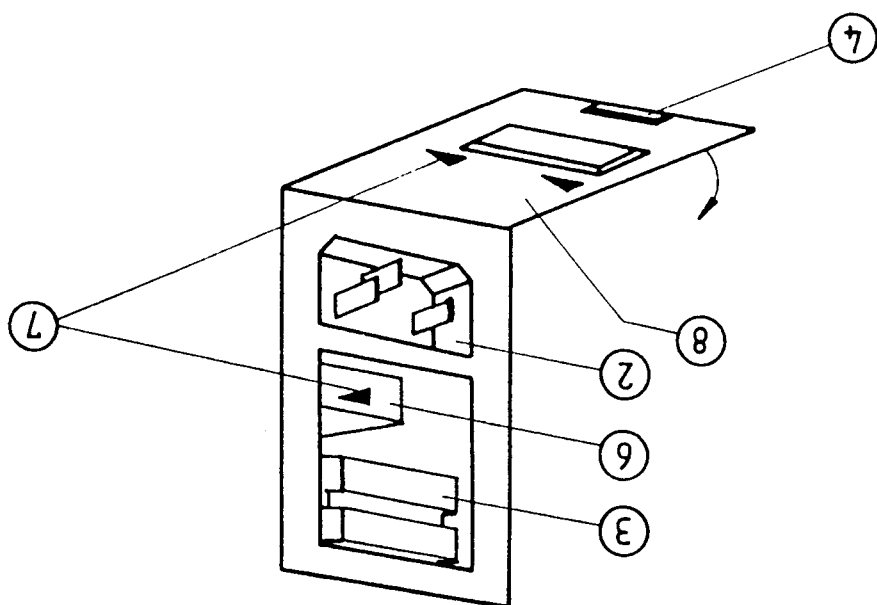


FIG. 1.5.1 : AC POWER CONNECTOR DETAIL (CONTINUED)

1.3. MECHANICAL CHARACTERISTICS (Fig. 1.1.)

1.3.1. Maser

Dimensions : 550 x 940 x 1250 mm

Weight : 225 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

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 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.

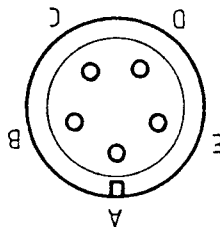
1.4.4. Atmospheric pressure

Normal atmospheric variations.

MASER AND MONITORING

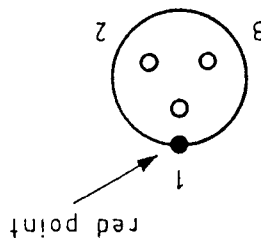
DC INPUT 24 V (Amphenol MS 3102A 14S 5P)

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

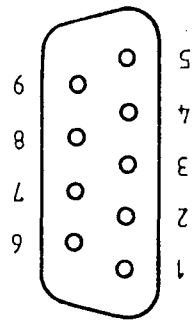


AMBIENT TEMPERATURE (T_{AMB}) PROBE (LEMO RG0B.303C.A222)

- 1 - +
- 2 - -
- 3 - GND



MONITORING (CANNON DE - 9S)



- 1 - N.C.
- 2 - N.C.
- 3 - CLOCK N and
- 4 - DATA A and
- 5 - +5 V
- 6 - N.C.
- 7 - CLOCK A and
- 8 - DATA N and
- 9 - $\emptyset$ V

FIG. 1.6. : EFOS 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 pallette on which the maser is mounted on shock absorbers. Wire sway braces are installed from the pallette 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 $\pm$ 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.

2.3. POWER AND MONITORING CONNECTIONS

Figure 1.6. provides a summary of pin connections for connection 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	A - N.C.	B - GND	C - N.C.	D - N.C.	E - +24 V
BATTERY B	A - N.C.	B - GND	C - N.C.	D - N.C.	E - +24 V

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., 1.5.1., 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. (see fig. 1.5. for fuse requirements)

2.3.3. Ambient 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

The zero reference setting for the temperature probe is +25°C. Monitor digital readout provides an indication +25°C ± 10°C (table 3.1.). Voltage sensitivity : ± 0.4 V/°C.

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, high impedance (0 - 30 V)
2.4.	<u>HYDROGEN BOTTLE INSTALLATION/REMOVAL</u> - Wrenches M7, M8 and M15, 9/16" (M14), 11/16" (M17), M30 - 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 - U.S.A. - Leak detector liquid : "AIR-TEC" - AMERICAN GAS & CHEMICAL 511E 72nd St. - New York, 10021 - U.S.A. - Adaptor for vacuum purge of hydrogen supply time
3.5.1.	<u>CONNECTION OF PUMP EXTERNAL POWER SUPPLY</u> - Pump H.V. adaptor cable OSA part No. 8002 - 1150/1 - Pump control unit (H.V. supply) VARIAN model 911-5030. - For external ion pump. - Pump H.V. adaptor cable OSA part No. 8003-1407. - For internal ion pump. - Pump control unit (H.V. supply) VARIAN model 929-0070 - for internal ion pump.

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

PARA.	DESCRIPTION
3.5.3.	EXTERNAL PUMP CONNECTION - Pinch-off tube VARIAN part 935-5018 - 5 cm length of flexible hose + 2 hose clamps - Turbo-molecular vacuum pump PREIFER (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.	DEMAGNETIZING PROCEDURE - Demagnetizer, OSA model 3098 A
3.11.2.	ZEEMAN FREQUENCY MEASUREMENT Synthesizer 0 to 10 KHz / HP model 3325 A, DC voltmeter, high impedance 0 to 5 V
3.11.5.	CAVITY SPIN-EXCHANGE TUNING - Reference oscillator : hydrogen maser or oscillator $> 1 \times 10^{-14}$ in 10 minutes interval - Frequency measurement system (fig. 3.9. for example) - SMA-to-voltmeter adapter cable

2.4. HYDROGEN BOTTLE INSTALLATION AND REMOVAL

Access to the hydrogen bottle installation is obtained by removing the left and right side panels of the vacuum manifold compartment (2), fig. 1.1.

The hydrogen bottle and pressure regulator are separated to facilitate installation, (1), (5), fig. 2.2., 2.3.

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. 2.3.
- 4) A pinch-off tool is available, see table 2.1.
- 5) Vacuum pump and adapter on hand for purge and pinch-off.

Removal of the hydrogen bottle is covered in § 2.4.3.

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 filling a notch near the pinch-off end of the tube then breaking, or preferably using a conventional tube cutter (4.5 mm tubing)

- loosen the mounting strap restraining screw and strap (10), (9), fig. 2.2., to allow placing the bottle in the mounting cradle (11)
- check that the hydrogen bottle is securely closed
- remove the cover cap on the output orifice of the bottle and assure that there is a nylon gasket in place
- refer to fig. 2.2., 2.3.

FIG. 2.2. : HYDROGEN BOTTLE INSTALLATION, RIGHT SIDE VIEW

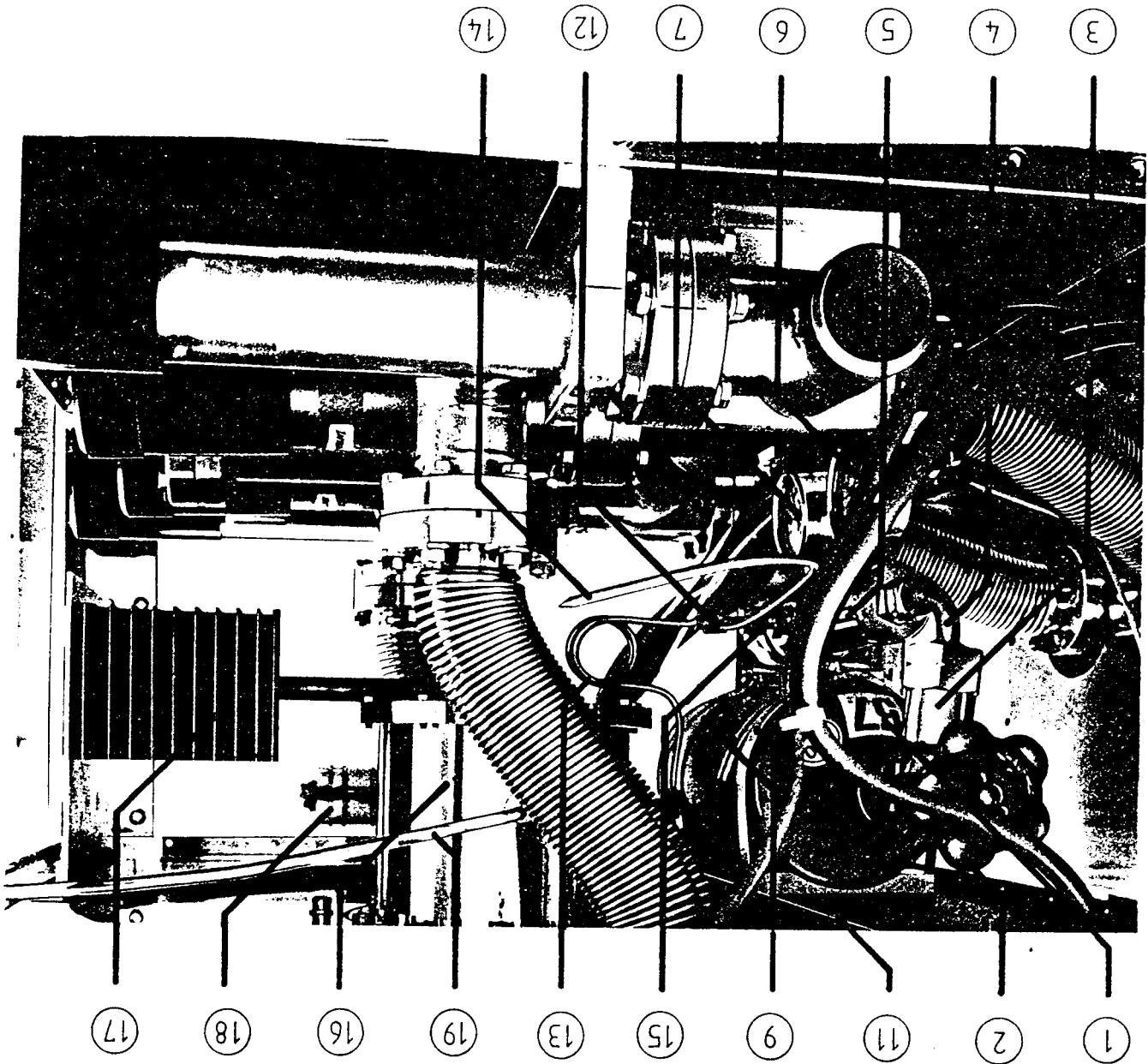
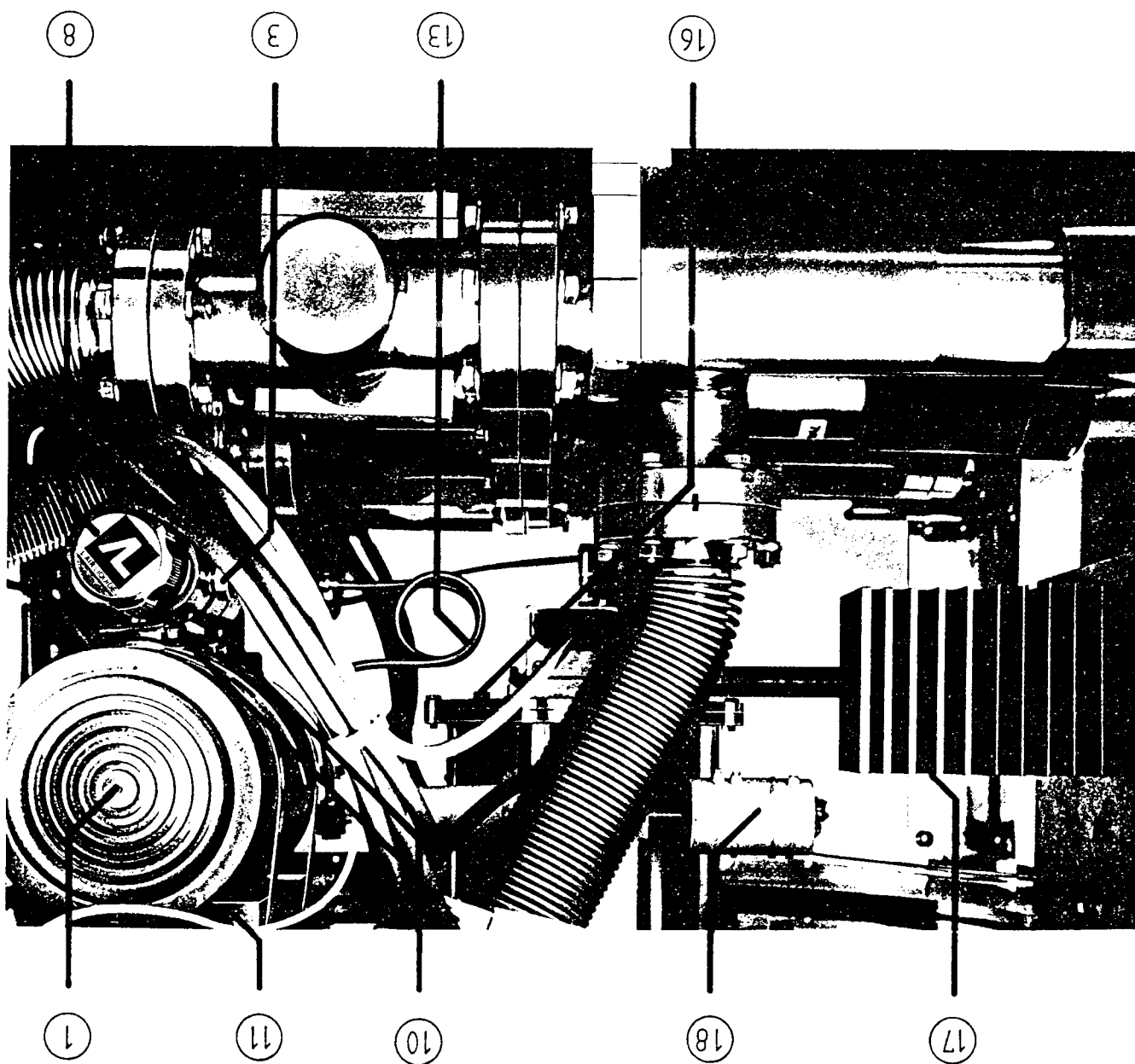


FIG. 2.3. : HYDROGEN BOTTLE INSTALLATION, LEFT SIDE VIEW



- ① HYDROGEN BOTTLE
- ② HYDROGEN BOTTLE SHUT-OFF VALVE
- ③ PRESSURE REDUCER-TO-BOTTLE CONNECTION
- 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
- ⑫ HYDROGEN SUPPLY TUBE COUPLING
- ⑬ HYDROGEN SUPPLY TUBE TO DISSOCIATOR
- ⑭ HYDROGEN SUPPLY TUBE PURGE PINCH-OFF
- ⑮ PRESSURE REDUCER OUTPUT FITTING
- ⑯ HYDROGEN DISSOCIATOR

FIG. 2.2. : HYDROGEN BOTTLE INSTALLATION, RIGHT SIDE VIEW

FIG. 2.3. : HYDROGEN BOTTLE INSTALLATION, LEFT SIDE VIEW

①7 HEAT - PIPE / RADIATOR

①8 , PIRANI GAUGE CONTROL ELEMENT

①9 DISSOCIATOR LIGHT - PIPE

FIG. 2.2. : HYDROGEN BOTTLE INSTALLATION, RIGHT SIDE VIEW (CONTINUED)

FIG. 2.3. : HYDROGEN BOTTLE INSTALLATION, LEFT SIDE VIEW (CONTINUED)

- from the right hand side of the compartment slide the bottle into the cradle, (11) , fig. 2.2., orient the output orifice of the bottle downward and lightly tighten the strap, (9) , retaining screws, (10) , just sufficiently to allow adjustment of position of the bottle
- check that the pressure reducer fitting (15) is clean and not damaged
- connect the pressure reducing system, (5) , by means of the reducer-to-bottle connector, (3) , and hand tighten
- orient the bottle/reducer assembly to align the pressure reducer output fitting, (15) , with the hydrogen supply tube coupling, (12)
- tighten the retaining strap screws, (9)
- tighten the reducer-to-bottle connector fitting, (3)
- connect the output of the pressure reducer, (15) , to the maser hydrogen supply system via the coupling, (12) . The pressure reducer output fitting, (15) , should be held immobile with a wrench (11/16") 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 (9/16") 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.

2.4.2. Hydrogen supply purge and pinch-off

- Connect an adapter from the hydrogen supply pinch-off which is compatible with the external pumping system, fig. 2.4.
- 2.2. - check that the hydrogen bottle is firmly closed (2), fig. 2.2.
- connect the vacuum pump, table 2.1., § 3.5.3., to the pinch-off tube via the adaptors
- have pinch-off tool ready, table 2.1.
- turn on pump and pump down to 10⁻⁵ torr. Maintain this pressure from 5 to 10 minutes
- pinch-off the tube (14) near its open end by applying a steady pressure to the pinch-off tool until the copper tube separates.

2.4.3. Leak test

- 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) - open the hydrogen bottle shut-off valve slowly about 1/4 turn, (2), counter clockwise direction. The bottle pressure gage should read between 20 and 200 atmospheres, (6), pressure reading on the reducer output should be 0, (7), if valve (8) is closed (counter clockwise rotation).
- open the pressure regulator valve (5) by turning clockwise to obtain an output pressure of 1.5 atmosphere shown on the pressure gage (7).
- check for large leaks by assuring that output pressure of 1.5 atmosphere can be obtained and that there is no audible evidence of leaks.

b) 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 and the pinch-off. 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). The pinch-off should be redone if there is evidence of leak (purge is not necessary).

c) 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 atmosphere 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 1/2 turn.

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

— I M P O R T A N T —

2.4.4. Hydrogen bottle removal

The hydrogen bottle will normally be removed for :

- 1) Shipping the maser (according to the transport regulations)
- 2) Changing the bottle when hydrogen supply is exhausted

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 -9/16", retaining wrench -11/16"
- 5) Disconnect pressure reducer from bottle and remove
- 6) Loosen retaining strap screws
- 7) Remove bottle

Detail of manipulations are contained in § 2.4.1. above.

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

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

3. MASER START-UP AND OPERATION

GENERAL

Whenever circumstances permit, the maser will be delivered in an operating condition thus avoiding the necessity of a start-up procedure. However, if the maser is shut down for any reason, the procedures in this section should be followed.

In particular, shut-down of the maser will stop the vacuum pumps and this allows a pressure rise to occur. This process is not rapid, usually occurring at a rate related to outgassing of the internal components. If the pressure exceeds the maximum allowable pressure for starting the ion pumps, then an external pump must be used to reduce pressure to the necessary level.

As a general rule, the following sequence of operating is used :

- hydrogen pressure to zero (§ 3.3.)
- turn-off dissociation oscillator
- turn-on and initial check of vacuum system
- establish vacuum
- energize dissociator

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

TABLE 3.1. : MONITOR DIGITAL SCALE FACTORS

"ADDRESS"	MEASURED PARAMETER	DIGITAL UNIT	FULL SCALE 100 UNITS
0 0	U } BATTERY A	240 mV	24 V
0 1	I } BATTERY A	100 mA	10 A
0 2	U } BATTERY B	240 mV	24 V
0 3	I } BATTERY B	100 mA	10 A
0 4	SOURCE TEMP	1 °	100°
0 5	SET	100 mV	10 V
0 6	MEASURE } H-PRESSURE	100 mV	10 V
0 7	PISTON PALLADIUM VOLTAGE	200 mV	20 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	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 (REF = +25°C)	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	100 mVRMS	10 V RMS
2 3	C-FIELD	2 µA	200 µA
2 4	-U } VAC ION INT	70 V	7 kV
2 5	U } VAC ION INT	20 µA	2 mA
2 6	-U } VAC ION EXT	50 V	5 kV
2 7	I } VAC ION EXT	20 µA	2 mA
3 0	U } RF SOURCE	300 mV	30 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	50 mV	5 V
3 6	+15 V	150 mV	15 V
3 7	-15 V	150 mV	-15 V

3.1. 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. 8002-1180/1, is provided for connection to the maser. The monitoring digital scale factors are given in table 3.1.

3.2. 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.

3.3. H.V. INT., H.V. EXT., RF OSC.

These power supplies should be off for the initial steps of the procedure, fig. 1.3.1.

3.4. 24 V POWER SUPPLY CONNECTION DURING START-UP

When full start-up power is applied to the maser, the input current at 24 V is between 5 and 6 amps. The 24 V supply to the maser should have at least this capacity for start-up.

3.5. MASER TURN-ON

Note: The switches, fig. 1.3.1., are illuminated when power is applied to the circuit indicated on the switch.

3.5.1. Initial turn-on

Connect maser to power supply as indicated in 3.4.
- turn on power to maser by pushing the "ON SUPPLY" switch as indicated by switch illumination
- check that "RF OSC", "HV INT" and "HV EXT" are off
- turn on "HF RCVR", "INNER HTRS", "OUTER HEATERS". Reset "RESET ALARM"
- check monitor readings table 3.2.

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

3.5.2. Pump power supply turn-on

- set monitor "ADDRESS" to 24 and turn on "HV INT" power supply, fig. 1.3.1.
- observe readings on monitor position 24 and 25 and consult table 3.3. for interpretation of readings
- set monitor "ADDRESS" to 25 and repeat measurements as indicated above. Consult table 3.3.
Proceed with vacuum system start-up (§ 3.6.) as indicated from analysis in table 3.3.

TABLE 3.2. : MONITOR NOMINAL START-UP VALUES

"ADDRESS"	MEASURED PARAMETER	READOUT
0 0	U } BATTERY A	100
0 1	I }	40 MAX
0 2	U }	100
0 3	I }	40 MAX
0 4	SET	0
0 5	MEASURE }	0 < 30
0 6	H-PRESSURE	
0 7	PIRANI	
1 0	LO	see maser logbook
1 1	UO	80 ± 5
1 2	DA	90 ± 5
1 3	LI	110 ± 5
1 4	UI	115 ± 5
1 5	CAV	110 ± 5
1 6	T -CAV	-100
1 7	T - AMB	000 ± 100
2 0	CAV - VAR	see maser logbook
2 1	XTAL - VAR	± 128
2 2	AMPL. 5.7 KHZ	0
2 3	C-FIELD	25
2 4	-U }	
2 5	VAC ION INT	
2 6	-U }	see paragraph 3.5.
2 7	VAC ION EXT	
3 0	U }	0
3 1	I }	0
3 2	+24 V	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

"ADDRESS"	READOUT	INTERPRETATION	ACTION TO TAKE
25 and 24 27 and 26	< 1.5 mA > 6 kV < 1.5 mA > 4 kV	pumping normal with dissociator non-operating	observe pressure -7 descend to $\sim 2 \times 10^{-6}$ Torr internal pres- sure, $\sim 1 \times 10^{-6}$ Torr external pressure
25 and 24 27 and 26	2 mA 3 to 6 kV 2 mA 2 to 5 kV	outside of limit of internal power supply. Must use external H.V. power supply	connect external supply per § 3.6.1.
25 and 24 27 and 26	0 mA > 6 kV 0 mA > 4 kV	pump does not start. Pressure to high.	connect external turbo molecular pump per § 3.6.3.
25 and 24 27 and 26	0 mA < 1 kV 0 mA < 1 kV	pump power supply inoperative	connect external power supply to retain vacuum refer to maintenance ma- nual for power sup- ply 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 pump- ping	when pump current > 5 mA, int. pump power supply may be connected (see § 3.6.2.)
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 sup- ply. Recycle pump- ping action (accor- ding to § 3.6.1.1.)
Panel meter on ext. H.V. supply	< 100 mA > 1.5 kV	after 3x10 min. cycles if current is not < 100 mA capacity of pump is exceeded	connect ext. turbo molecular pump (see § 3.6.3.)

TABLE 3.3. : CONTINUED

3.6. VACUUM SYSTEM START-UP AND OPERATION

C A U T I O N

Large pressure difference between internal and external vacuum systems should be avoided during all vacuum system manipulations to prevent possible breakage of the quartz bulb in the maser cavity

When the maser 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 maser ion pump power supply capacity, 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.

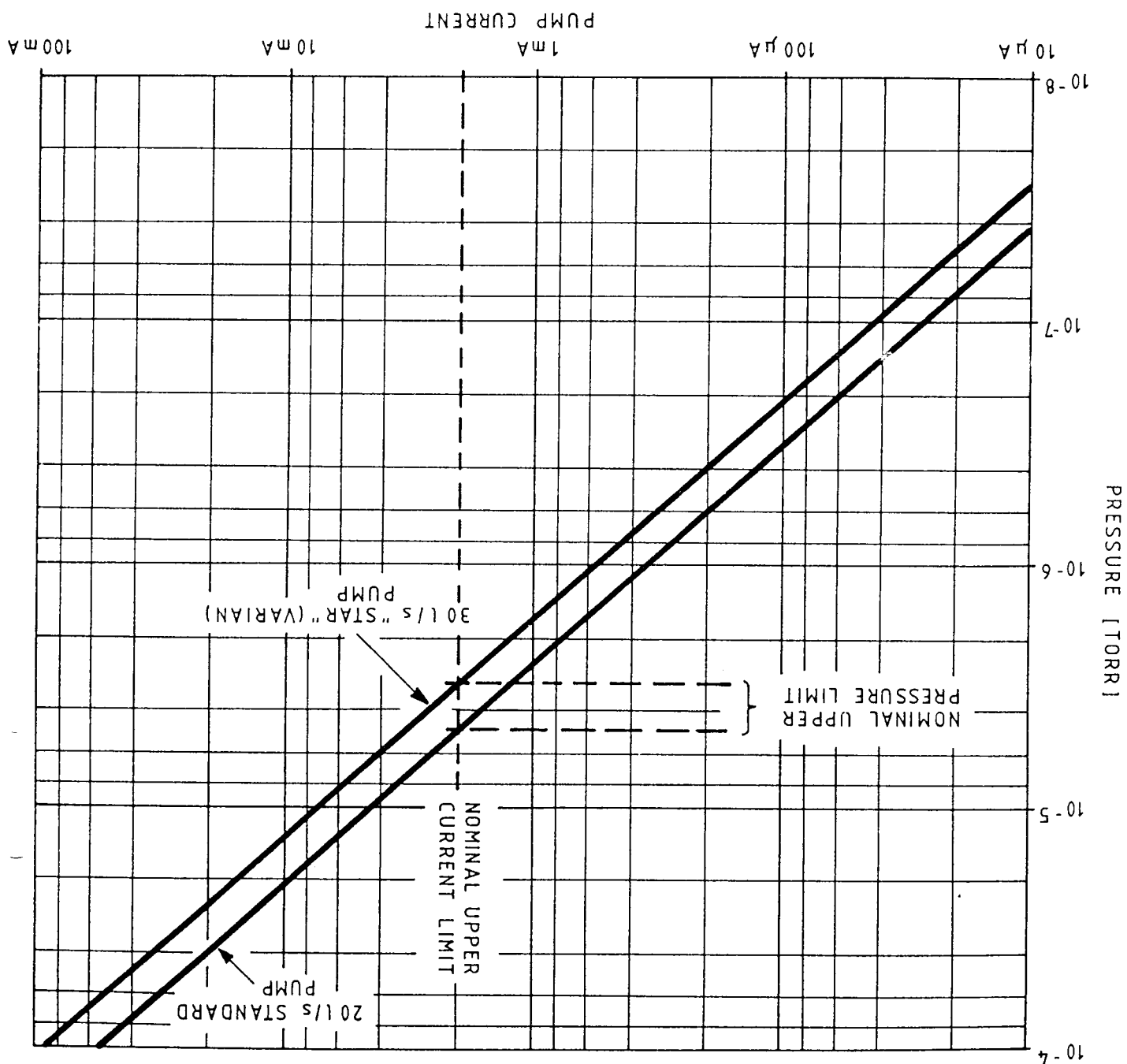
Fig. 3.1. : gives the pressure for a given pump current for the ion pumps used in the EFOS maser

Normal operating range for internal and external vacuum systems is shown in the figure.

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 μ A to 1 mA pump current). With no hydrogen pressure, the maser internal vacuum can attain 1×10^{-7} Torr (20 μ A pump current).

FIG. 3.1. : ION PUMP CURRENT AND PRESSURE LIMITS ON WAFER
INTERNAL POWER SUPPLIES



3.6.1. Connection of external pump power supplies

The maser ion pump supplies are contained in the electronics and control unit, (13), (14), fig. 1.2. To connect the ion pumps to external power supplies, proceed as follows :

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.

C A U T I O N

- set "H.V. INT" and "H.V. EXT" switches OFF (non lighted)
- set monitor "ADDRESS" to 24 and 26. Check that voltage indication goes to zero before disconnecting pump coaxial cables.
- remove power supply retaining screws (17), fig. 1.2. on H.V. supply modules (13), (14), and pull the module out of the rack.
- The H.V. coaxial connectors are mounted on the printed circuit board. Disconnect the coax cable to the pump here.
- connect the pump external power supply (VARIAN model 911-5030 control unit or 929-0070) to AC mains, set pump supply switch to OFF
- connect the adaptor cable OSA No. 8'002-1150/1 or 8003-1407) to the connector on the rear of the pump external power supply
- connect the adaptor cable from the external supply to the pump cable available on the printed circuit card
- 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).

3.6.1.1. VAC ion pump cycling with external power supply

The pumping time at full pump capacity (100 mA) 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.

3.6.2. 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.
- check that "H.V. INT" and "H.V. EXT" switches, fig. 1.3.1., are off

- 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 on the circuit card

- reconnect pump coax to the internal power supply connector

- set monitor "ADDRESS" to ion current position 25 or 27

- slide the power supply module in position and attach the retaining screws (17), fig. 1.2.

- set "H.V. INT" and "H.V. EXT" switches to ON and observe pump current on monitor. The current should come to the nominal value

3.6.3. External pump connection

3/11

Before attaching the external turbo pump, the following must be understood :

- 1) If a turbo pump is not available and a diffusion pump must be used, such a pump must have at least a liquid nitrogen trap to avoid oil contamination of the vacuum system.
- 2) The manner in which the vacuum system valves must be operated
- 3) The manner in which the vacuum tight joints are formed

To close the valves [V1], [V2] or [V3], [V4] 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 unnecessary 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 ring between the flanges, installing and tightening the bolts in the mounting flange to hand-tight around the peripheral. 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 ion pump external supplies are connected before using the turbo pump (\$ 3.6.1. and table 3.3.). They should be turned off until system pressure is below 10^{-4} Torr.

- Remove the vacuum manifold compartment rear 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] (5), (3), 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 $< 1 \times 10^{-4}$ Torr. When pressure has reached this value, external VAC ion power supply may be energized.

- Turn on external VAC ion power supply and monitor the pump current during the pump-down (fig. 3.1. illustrates the nominal pump current characteristics of the VARIAN model 911-5030 929-0070 pumps)

- After assuring that ion pumps are pumping, 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. See procedures for pump or dissociator replacement for manipulation of these valves.

3.6.3.1. 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.). Assume that a continuous pressure is applied to the pinch-off tool to the point that the copper tube separates.

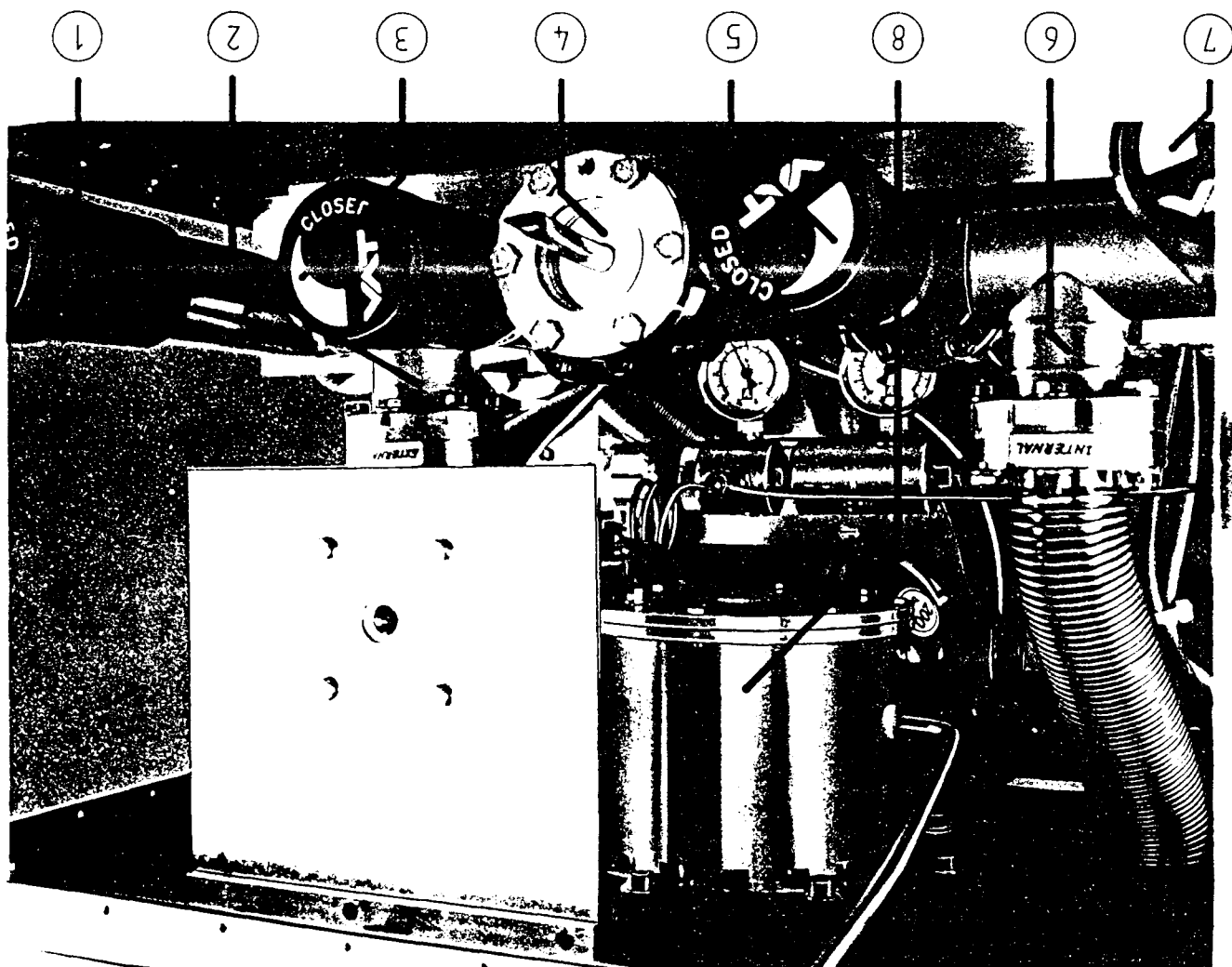
CAUTION

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.

- complete the pump-down with the external power supply and connect to internal power supply according to § 3.6.2.

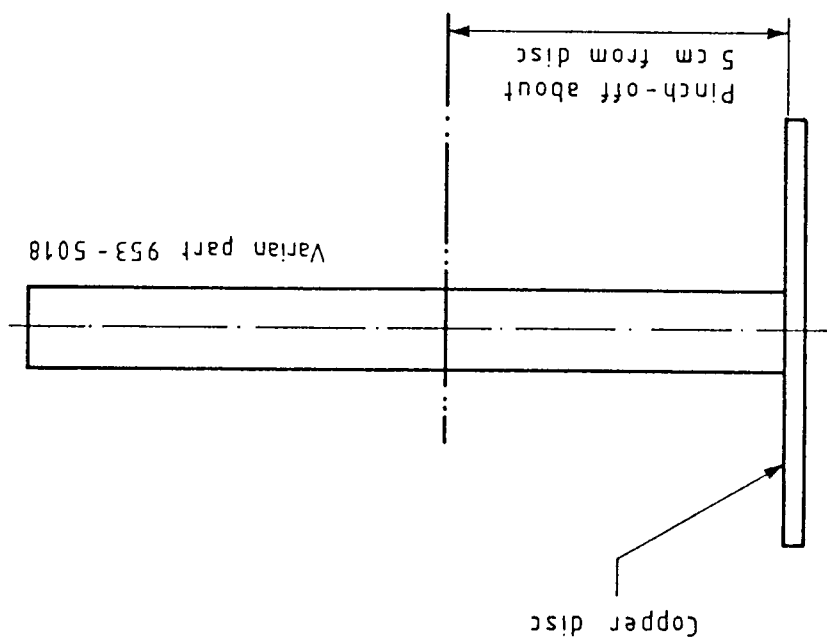
FIG. 3.3. : VACUUM MANIFOLD COMPARTMENT

- ④ EXTERNAL PUMP ATTACHMENT, PINCH OFF
- ③ EXTERNAL VACUUM SYSTEM, EXTERNAL VALVE [V3]
- ② EXTERNAL VACUUM SYSTEM, T-COUPLING
- ① EXTERNAL VACUUM SYSTEM, INTERNAL VALVE [V4]



- ⑤ INTERNAL VACUUM SYSTEM, EXTERNAL VALVE [V2]
- ⑥ INTERNAL VACUUM SYSTEM, T-COUPLING
- ⑦ INTERNAL VACUUM SYSTEM, INTERNAL VALVE [V1]
- ⑧ HYDROGEN DISSOCIATOR

FIG. 3.3. : VACUUM MANIFOLD COMPARTMENT (CONTINUED)



PINCH - OFF TUBE

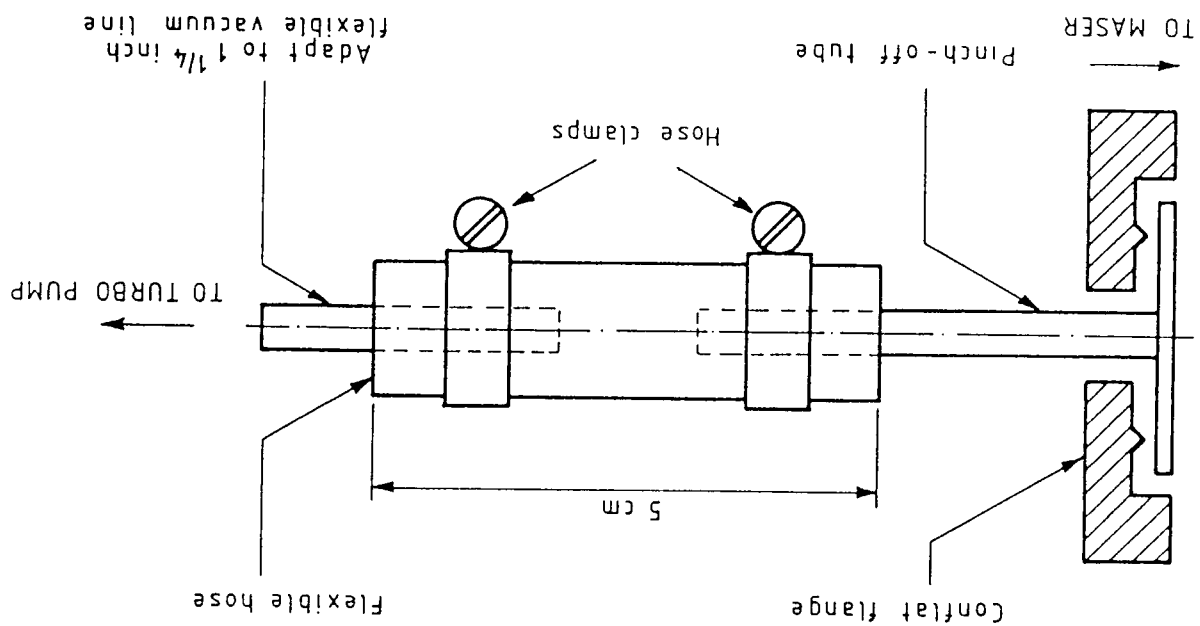


FIG. 3.4. : PINCH-OFF ASSEMBLY

3.7. HYDROGEN DISSOCIATOR PRESSURE SETTING - START-UP

Normal dissociator pressure setting for maser start-up is 0 (\$ 3.2.). 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 by switch "RF OSC", fig. 1.3.1. With no hydrogen present in the dissociator, the oscillator draws full load-limit current from its power supply (about 1.2 A). It should be turned off when H-pressure is zero.

When hydrogen pressure rises to the value necessary for the dissociation to take place, oscillator current drops to a value between 0.5 and 1.0 A. A rich pink light is seen on the light pipe located on vacuum manifold compartment rear panel (2), fig. 1.1. At the same time, pressure will momentarily rise in the maser internal vacuum system. Proceed as follows :

- set monitor "ADDRESS" to 05 : H-PRESSURE SET
- turn pressure setting potentiometer (7), fig. 1.3. to obtain monitor readout as indicated in the maser logbook
- monitor "ADDRESS" 07 : PRESSURE MEASURE. This value will increase until the set value and measured value correspond closely (± 2 monitor unit)

3.8. 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, and the hydrogen dissociator is functioning properly.

3.9. MASER OSCILLATION START-UP

- After establishing operating conditions of \$ 3.6., 3.7. and 3.8., initial maser oscillation tests can be carried out.
- set C-field to nominal value according to \$ 3.1.1.
 - 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 \$ 3.10.
 - if no output at 5.7 KHZ is obtained, check all maser operating values on the monitor (table 3.4.) to assure normal operation of vacuum and electronics systems. Compare with monitor reading in the maser logbook. Proceed to \$ 3.9.1.

3.9.1. Maser output signal check

Set C-field current to 10 mA according to § 3.10. 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 § 3.12. and then proceed to threshold measurements § 3.10.
- if no oscillation is obtained, large magnetic inhomogeneities may be present or some other malfunction may prevent oscillations. Demagnetize according to § 3.12.
- if oscillation is not obtained after this demagnetization, consult troubleshooting guide in the maintenance manual. After oscillations are obtained, proceed to threshold tests (§ 3.10.)

"ADDRESS"	MEASURED PARAMETER	READOUT
0 0	U } BATTERY A	100
0 1	I }	15
0 2	U } BATTERY B	100
0 3	I }	15
0 4	SET	73*
0 5	MEASURE	72*
0 6		
0 7	PIRANI	
1 0	LO	55
1 1	UO	33
1 2	DA	27
1 3	LI	37
1 4	UI	29
1 5	CAV	58
1 6	T - CAV	± 01
1 7	T - AMB (000 reading = +25°C)	000 ± 100
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 }	20 to 40
2 6	-U } VAC ION EXT	100
2 7	I }	20 to 0
3 0	U } RF SOURCE	115
3 1	I }	50 - 100*
3 2	+24 V	100
3 3	+15 V	100
3 4	-15 V	-100
3 5	+5 V	100
3 6	+15 V	100
3 7	-15 V	-100

* Consult master logbook for nominal operating value

TABLE 3.4. : MONITOR NOMINAL START-UP VALUES

3.10. MASER SIGNAL VS C-FIELD

Signal vs C-field tests are made to evaluate magnetic homogeneity of the maser. They also indicate the oscillating threshold thus giving an indication of hydrogen flux available for maser operation. The threshold measurements plus the maser rise-time (§ 3.11.) are practical evaluations of the dissociator.

For signal vs C-field measurements, proceed as follows :

- Set the C-field current control (15) , fig. 1.3. to zero current : full counter clockwise rotation. Check monitor ADDRESS 23 for 0 reading.
- Connect a DC voltage supply through a DC milliammeter and a series resistance (current limit to 10 mA) to the control panel C-field connector (4) , fig. 1.3.

C A U T I O N

The C-field winding resistance is about 14 ohms. A series resistance to limit current from the external power supply must be used, otherwise, the maser could be magnetized by an excessive C-field current

- Connect a high impedance voltmeter to the 5.7 kHz coax output (14) , fig. 1.3.

- Record signal output for values of C-field current from +10 mA to -10 mA (reserve connections on power supply). Near threshold, the current will be normally 5 - 20 μ A.

- Reduce C-field current slowly or in small steps (e.g. 5 μ A) until maser output signal rapidly drops to zero. Note C-field current.
- Increase the C-field in small increments, and wait several minutes 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 μ A. If the threshold is greater than 50 μ A, a demagnetization cycle should be accomplished according to § 3.12. or the source should be evaluated (§ 3.11.)

- Refer to the maser logbook for the normal signal/C-field characteristics. If the general response vs C-field is the same, but signal level is low, check dissociator (§ 3.11.). If the response vs current differs significantly, the maser should be demagnetized (§ 3.12.) See § 7.2.1. maintenance and repair manual for further information on C-field evaluation.

3.11. MASER RISE-TIME

The maser rise-time is independent of the absolute amplitude of the maser oscillating signal. This is so because the rise-time will be determined by the flux of atoms available from the dissociator for maser oscillation whereas signal output level will depend on other factors such as receiver gain parameters, etc.

The rise-time measurement is made practically independent of magnetic field homogeneity by using a high value of C-field. Proceed as follows :

- Set C-field current to 10 mA (\$ 3.10)
- Connect a chart recorder capable of a chart speed of one or more cm/sec. to the 5.7 KHz output on the control panel (14), fig. 1.3. Set chart scale factor such the maser output from zero to maximum is conveniently presented.

- Turn off or disconnect C-field external supply. Maser output will go to zero if there is no residual C-field. If maser oscillations do not cease, consult logbook for signal/C-field characteristics to ascertain if a residual is normal. If not, demagnetize the maser according to \$ 3.12. If residual is normal, see fourth paragraph below.

- Turn on recorder and connect external C-field. Record maser signal from zero to a stable output level. Measure time & rise from 10% of maximum to 90% of maximum.

- Check reading on monitor ADDRESS 21 : XTAL-VAR and compare with logbook reading to assure that maser PLL is functioning normally.
- Rise time should be about 3 seconds. If longer, see source evaluation and pressure setting procedures \$ 3.9.

- If a residual field is normal, proceed as follows :
 - set C-field potentiometer (1), fig. 1.3. to maximum clockwise
 - adjust amplitude and polarity of external power supply to null the internal C-field causing the maser to stop oscillating
 - make rise-time measurements by disconnecting the external C-field supply

3.12. DEMAGNETIZING PROCEDURE

3.12.1. General

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 constructed 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 realized with OSA model 3098 A demagnetizing unit.

The connection of a low resistance current path between the maser demagnetizing electrodes (as is necessary for demagnetizing) allows a thermoelectric current to flow through the maser which creates a residual magnetic field in the maser after the demagnetizing cycle. The model 3098 A demagnetizer is designed to counteract this current. No other demagnetizing equipment should be used with the EFOS maser.

The first demagnetizing cycle is used to set current level and adjust the demagnetizer 3098 A. The subsequent demagnetizing cycle is accomplished by passing a high (30 A) current through 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 maser. If oscillation is not obtained after this demagnetization, consult troubleshooting guide in the maintenance manual. After oscillations are obtained, proceed to threshold test § 3.10. (see low current cycle below).

3.12.2. Demagnetizing procedure

- Prepare the maser for connection of the demagnetizing system by removing the internal electrodes insulated plug (4), fig. 3.5. and inserting the external demagnetizing electrodes (2), fig. 3.5. to engage the internal demagnetizing electrode. Travel of this engagement is about 20 mm. This is accomplished by inserting the external electrode through the access opening (1), fig. 3.5.

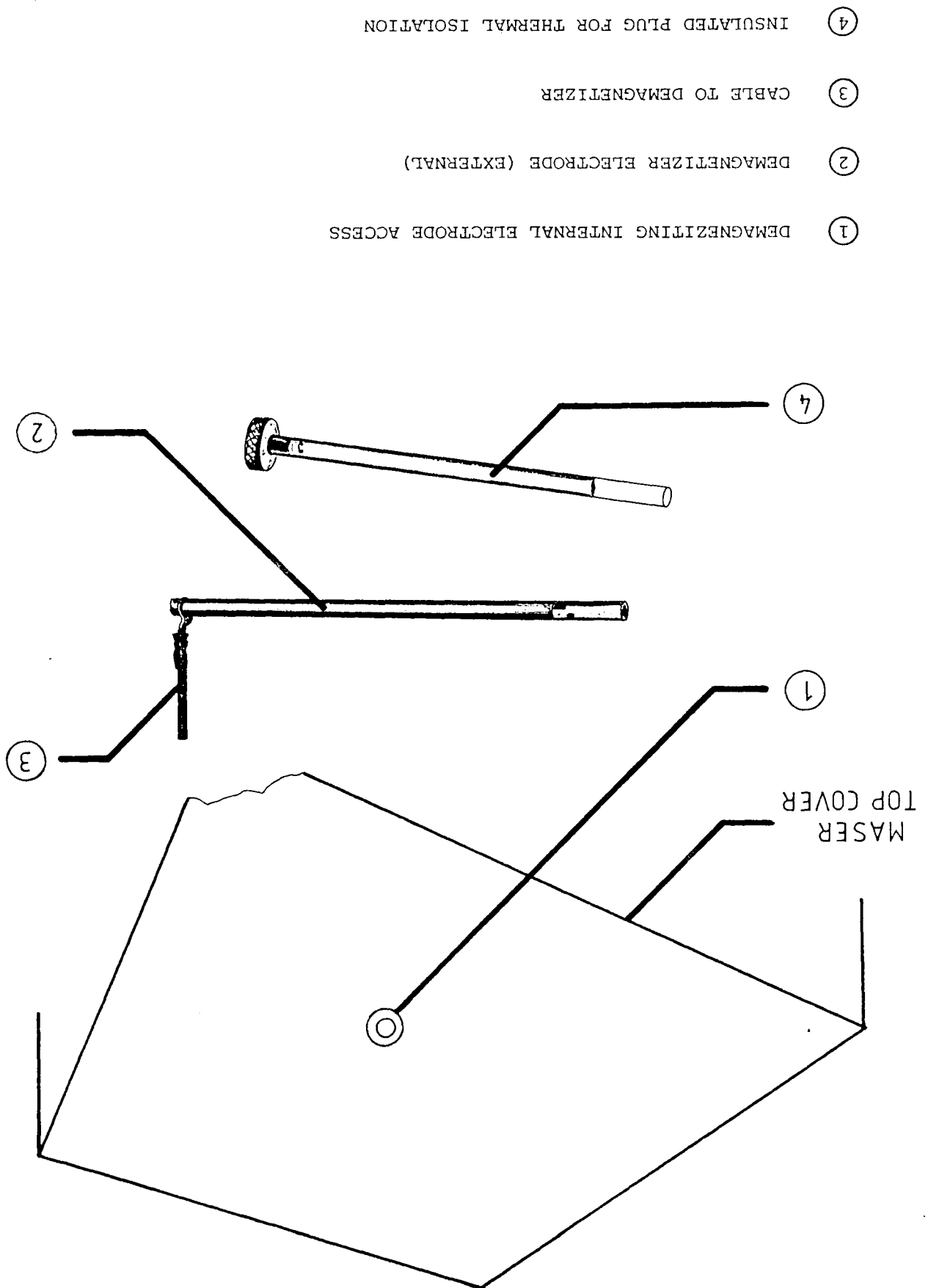
- Energize the 3098 A demagnetizer according to procedures outlined in the 3098 A operating manual. This must be carried out before connecting the demagnetizer ground return to the maser.

- Remove the demagnetizer connection access panel (8), fig. 7.15. 1.1. Pull out the maser ground return cable, (7) fig. 7.15.

- After demagnetizer warm-up, connect the return cable to the demagnetizer.

- Proceed with demagnetizing cycle according to 3098 A instruction book

FIG. 3.5. : DEMAGNETIZER CONNECTIONS TO MASER



3.13. 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

3.13.1. 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 μ A of C-field current. Thus full scale output voltage is 5 V for the C-field current maximum of 250 μ A. One digital unit or the external monitor readout is 2 μ A (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 nOersteds

3.13.2. 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 frequency, 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 (1), fig. 1.3. Response is more easily seen, is more rapid, and has greater resolution than the digital readout on the monitor receiver.

Proceed as follows :

- determine the expected Zeeman frequency from formulas given in fig. 3.6.
- 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 maser 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 variation 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. 3.6., at the Zeeman frequency

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

3.13.3. Dissociator pressure setting

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. 3.7.). The nominal pressure range used in the EFOS 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.

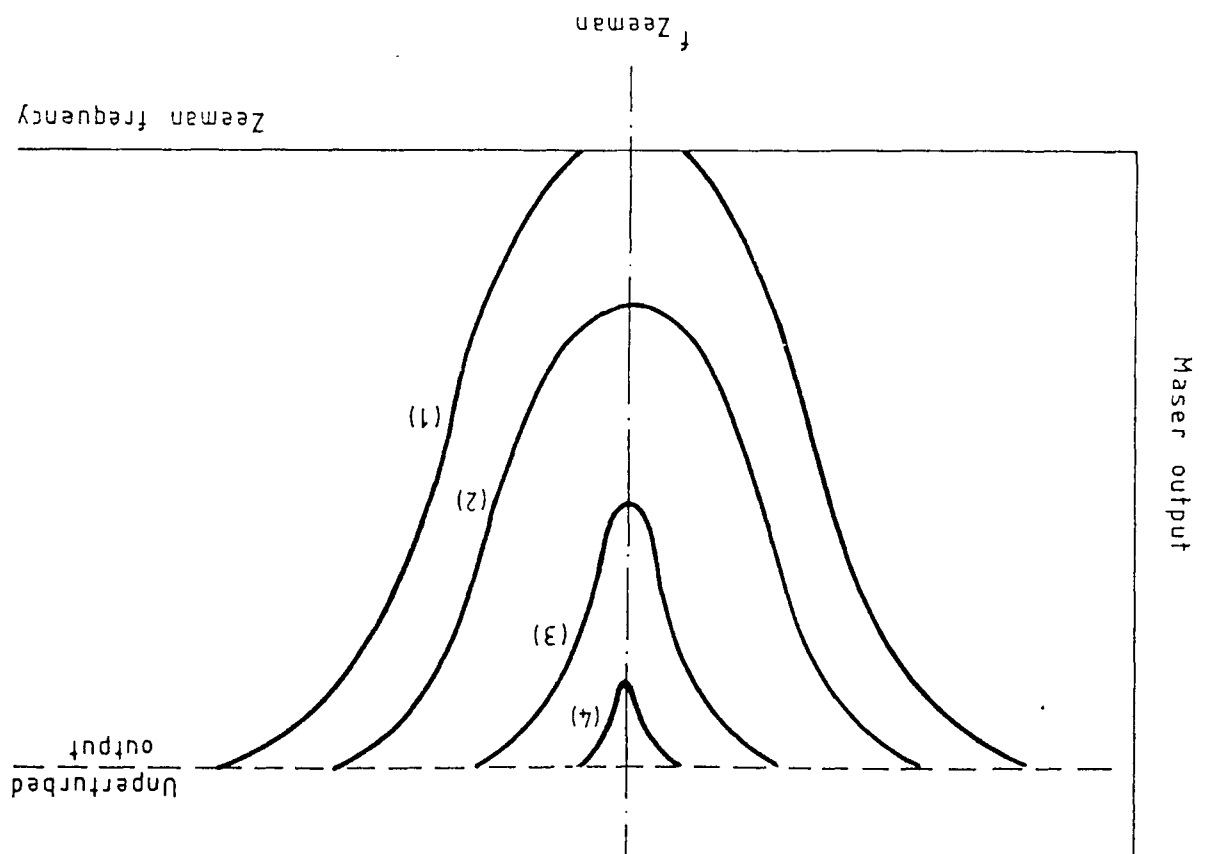
- set C-field to 50 μ A reference value before the following steps are undertaken

- set monitor "ADDRESS" to 05 - H-PRESSURE SET and set the value given in logbook 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. 3.7. 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) for a signal between 9.0 and 10 V (90 to 100 monitor units). Record this setting in the logbook.



C-field calibration :

$$H = 8.2 \text{ } \mu\text{Oersted}/\mu\text{A}$$

$$F_{\text{Zeeman}} = 1.4 \text{ Hz}/\mu\text{Oersted}$$

Voltage reading on H.P. 3325A synthesizer :

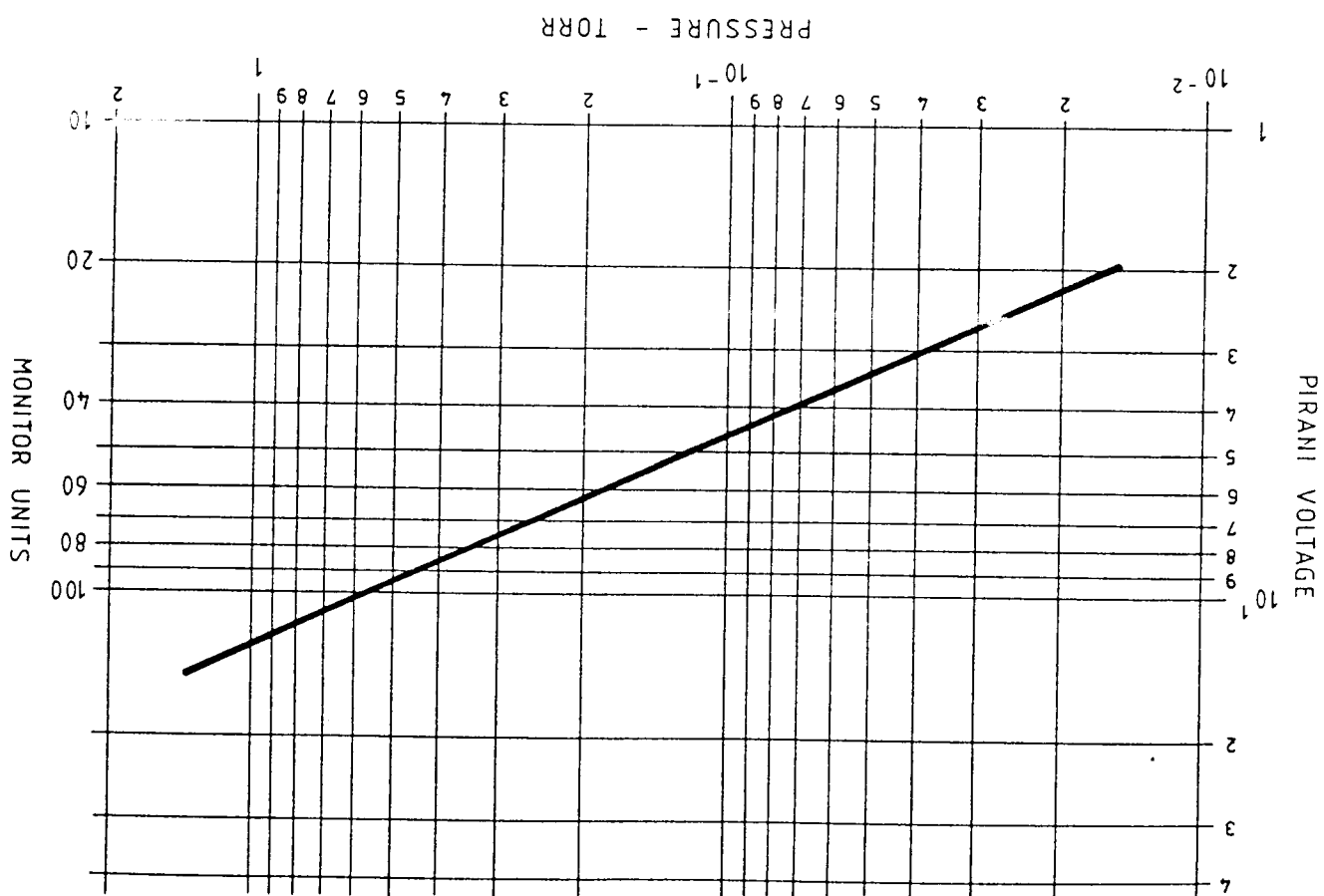
$$(1) = 1 \text{ Vrms}$$

$$(4) = 0.2 \text{ Vrms (approx. depending on Zeeman frequency)}$$

FIG. 3.6. : C-FIELD CALIBRATION (Zeeman frequency measurement)

FIG. 3.7. : PIRANI PRESSURE-VOLTAGE CHARACTERISTICS

0.1-0.5 Torr



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.

3.13.4. 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.

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.

Typical varactor frequency voltage characteristics are shown in fig. 3.8. The frequency voltage calibration to be used in the spin-exchange tuning is recorded in the maser logbook.

3.13.5. 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 reference 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. 3.9. (example) for maser frequency measurement. Any measurement system of suitable resolution may be used.

2) Set cavity varactor voltage to 1 V, (12) , fig. 1.3., § 3.13.4.

Determine cavity frequency (f_0) from the locked calibration (typical fig. 3.8.) and record V_1 , f_{c1} (fig. 3.10.)

3) Set dissociator pressure to 7 V (typical) (§3.13.3.) and record P_1 , fig. 3.10.

4) Record maser frequency by obtaining an average of 3-5 measures using 100 sec. intervals after the frequency is stabilized (f_{m1}), fig. 3.10.

5) Set dissociator pressure to 8 V (typical) and record P_2 , fig. 3.10.

6) Measure maser frequency and record f_{m2} , fig. 3.10.

7) Set varactor voltage to 6 V and record V_2 , f_{c2} , fig. 3.10.

8) Measure maser frequency and record f_{m4} , fig. 3.10.

9) Set dissociator pressure to 7 V and record P_1 , fig. 3.10.

10) Measure frequency and record f_{m3} , fig. 3.10.

11) From the recorded data plot Δf_{m1} and Δf_{m2} for corresponding cavity frequencies f_{c1} and f_{c2} . Where the line connecting the two points crosses the Δf_m axis at zero determines the spin exchange cavity tuning point, f_{co} .

12) From the cavity varactor tuning curve and the f_{co} (fig. 3.10.) determine the varactor tuning voltage. Set this voltage on the cavity varactor (§ 3.13.4.)

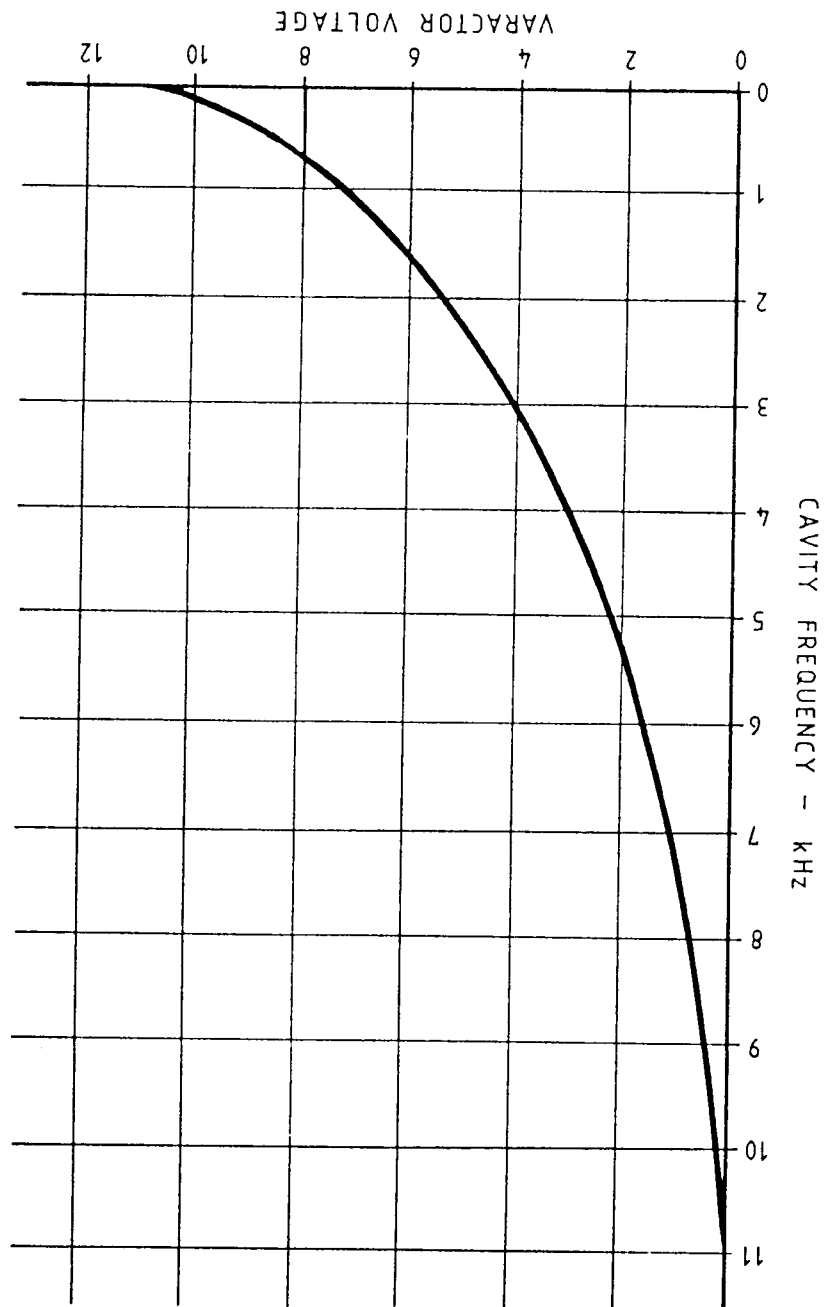
3.13.6. Phase lock-loop synthesizer setting

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. 3.11. for the detailed frequency setting information

3.13.7. Receiver

No operational adjustment 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 logbook (a typical plot is shown in fig. 3.12.).

FIG. 3.8. : CAVITY VARACTOR TUNING (TYPICAL)



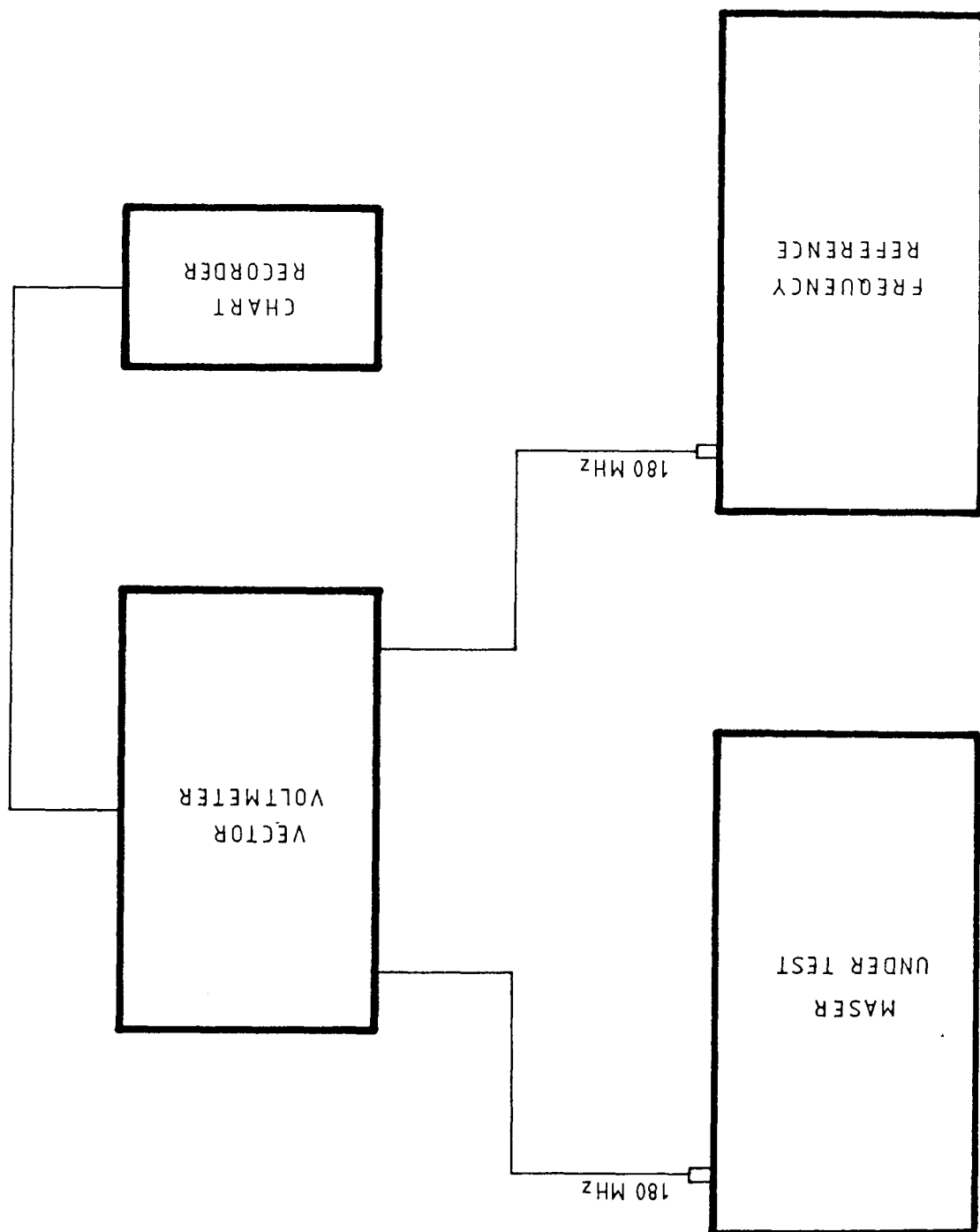


FIG. 3.9. : FREQUENCY MEASURING SET-UP FOR SPIN - EXCHANGE TUNING

PARAGR.	3.11.5.2 .3	V1	f _{c1}	P1	f _{m1}	Δ f _{m1}	Δ f _{m2}
VARAC. VOLT.	5 .6	V1	f _{c1}	P2	f _{m2}		
CAVITY FREQ.	9 .10	V2	f _{c2}	P1	f _{m3}		
DISSOC. PRESS.	5 .8	V2	f _{c2}	P2	f _{m4}		
MASER FREQ.							
Δf MASER							

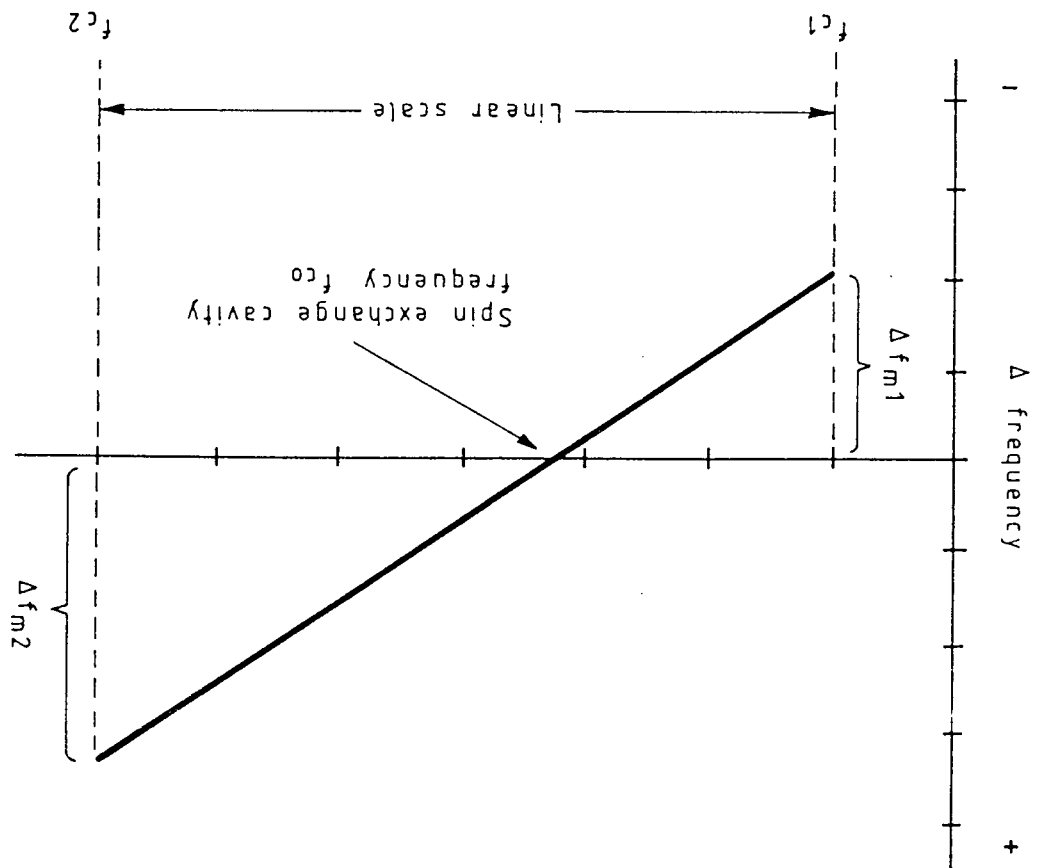
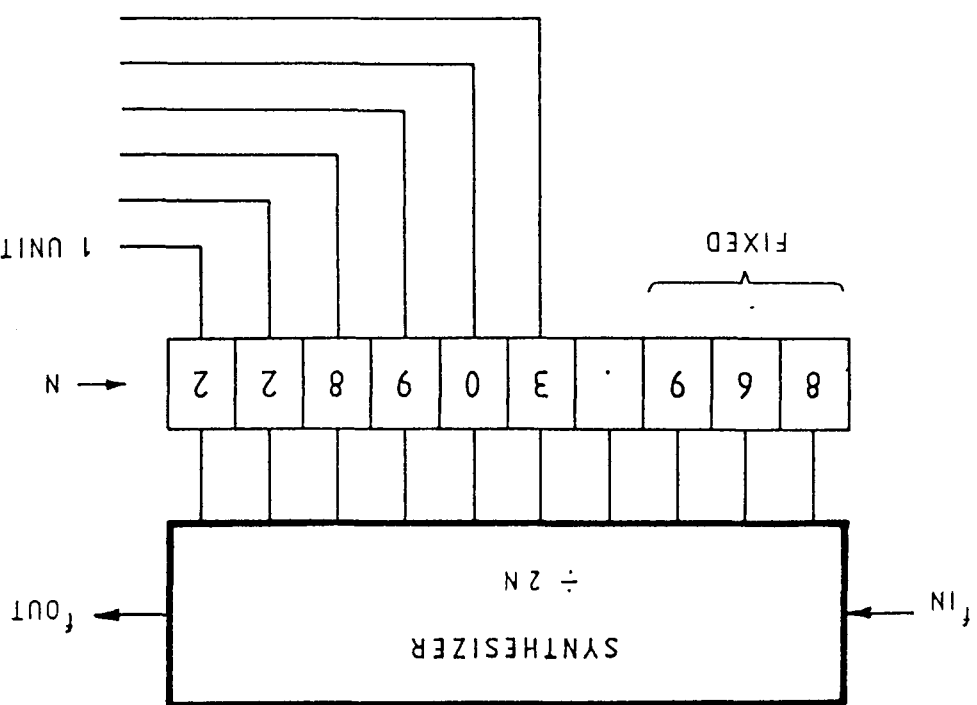


FIG. 3.10. : SPIN-EXCHANGE TUNING



$$\text{Synthesizer } f_{out} = \frac{f_{in}}{2N}$$

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

$$\Delta f_{out} = + \frac{f_{in}}{2N} \times \Delta N \times (1)$$

$$f_H = \text{hydrogen maser frequency} = 1420405751, 6893 \text{ Hz}$$

$$f_{in} = 10^7 \text{ Hz}$$

$$N = 869.309822$$

$$\Delta N = 10^{-6} \text{ (last digit)}$$

$$\frac{\Delta f_H}{f_H} = +4.658 \times 10^{-15} \text{ for one unit in last digit}$$

* The change of sign in equation (1) is due to the frequency trans-
lation in the receiver. See fig. 4.4-1.

FIG. 3.11. : SYNTHESIZER DIGITAL SWITCH SETTING

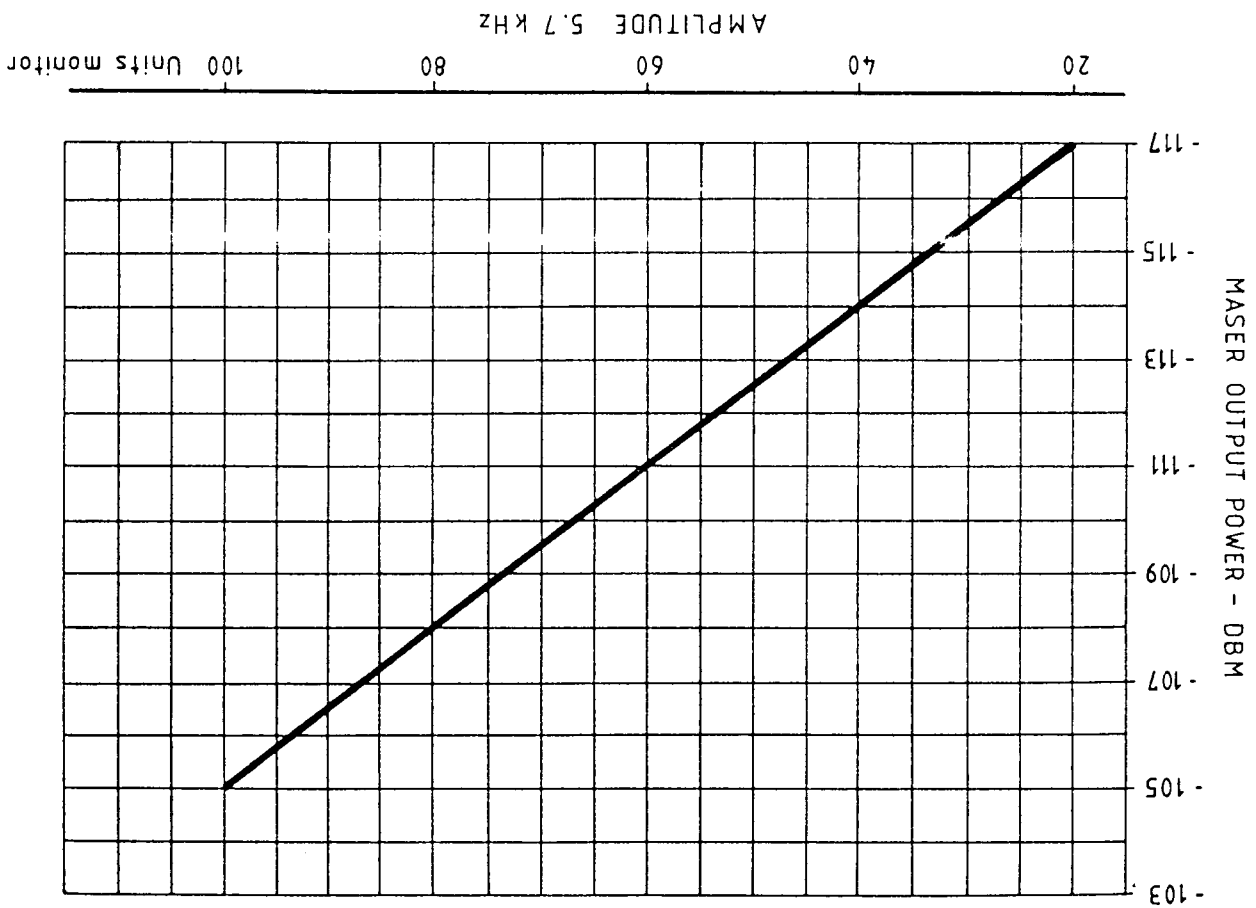


FIG. 3.12. : 5.7 KHZ AMPLITUDE VS MASER OUTPUT POWER